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AgriGate

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An International Multidisciplinary Monthly e-Magazine

"If you fail, never give up because FAIL means
"First Attempt in Learning"



15 OCTOBER

BIRTH ANNIVERSARY OF

Dr. A.P.J ABDUL KALAM

MISSILE MAN OF INDIA

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From the Desk of Editor-in-chief



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I would like to introduce the launch of **"AgriGate - An International Multidisciplinary Monthly e-Magazine Volume 05 Issue No. 10 – October 2025"** with immense pleasure our team is privileged to dedicate this issue to **former president of India, Bharat Ratna Dr. A.P.J. Abdul Kalam**. **World Students' Day** is observed on 15 October annually to mark the **birth anniversary of A.P.J. Abdul Kalam**. The day celebrates education as such, asking students to innovate and be leaders and confronting the challenges education systems face in both India and the world at large. This day honours and pays respect to him and his efforts in the field of science and technology and also the role of the teacher that he played throughout his scientific and political careers.

The main objective of the magazine is to provide a publishing platform to young researchers and scientists as well as an information hub for the enthusiast, progressive farmer and also common readers. We envisage providing an online platform that appreciates illuminating articles on various topics related to agriculture and allied sciences monthly that will appraise and update the students, farming community and the whole society at large on the updates in agriculture.

Last but not the least, I wholeheartedly thank the editorial team, authors as well as anonymous reviewers for contributing to the release of this issue.

Our team welcomes your constructive feedback and suggestions to improve delivering fruitful content to hungry minds.



Dr R Shiv Ramakrishnan
Editor-in-chief
AgriGate Magazine

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contents

ASSESSMENT OF NUTRIENT POLLUTION IN FRESHWATER AND MARINE ECOSYSTEM – Divya Dewangan., *et al.* 01

PRECISION AGRICULTURE: TRANSFORMING FARMING WITH TECHNOLOGY - Adhithya Prasad 10

THE SCIENCE OF RESILIENCE: EXPLORING ADAPTOGENS AND ACTOPROTECTORS - Saraswathy Balajinathan and Loganathan M 17

CULTIVATION AND MEDICINAL PROPERTIES OF CYCLOCYBE AEGERITA - P. Ahila devi and K.Subhrahmaniyan 26

REARING OF MULBERRY SILKWORM - Pavithra.N., *et al.* 32

ARSENIC CONTAMINATED SOILS AND THEIR REMEDIATION - Shruthi G S 38

POPULAR BRINJAL VARIETIES SUITABLE FOR CULTIVATION IN TAMIL NADU - S. Ranjith Raja Ram 41

OSCILLATING MAGNETIC FIELD PROCESSING OF FOODS - Ganjahalli Vani., *et al.* 46

POLLINATOR MANAGEMENT IN ONION SEED PRODUCTION - Karuppaiah V., *et al.* 53

NAGATENGA – AN UNDERVALUED FRUIT OF NORTH EASTERN INDIA - Soumendra Nath Das 56

contents





GERMPLASM CONSERVATION IN TOMATO
-Krishnan, V., *et al.* 61

SEX SORTED SEMEN (SSS): A REVOLUTIONARY TECHNOLOGY IN THE INDIAN DAIRY SECTOR - V.Ramakrishna and L.Vimalendran 66

NEONATAL CARE IN ANIMALS
- N. Gurunathan and G. Shalini 73

ENSURING GENETIC PURITY OF SEEDS: CONVENTIONAL VS MOLECULAR METHODS - R. Vigneshwari and K. Malarkodi 77

REVOLUTIONIZING RURAL FARMING: HOW ARTIFICIAL INTELLIGENCE IS TRANSFORMING INDIAN AGRICULTURE - Badal K. Koyani., *et al.* 82

REVIEW ON EUTROPHICATION IN AQUATIC ECOSYSTEMS
- Dr.Supriya D Meshre and Panchakarla Sedyaaw 88

GENE PYRAMIDING: A SINGLE LINE OF GENES
- Dr. R. N. Dhawale., *et al.* 92

MEDICAL TERMINATION OF PREGNANCY IN BITCHES: PHARMACOLOGICAL STRATEGIES AND CLINICAL PROTOCOLS - A. Thangamani., *et al.* 100

SEAHORSES AS BIOINDICATORS OF COASTAL ENVIRONMENTAL HEALTH
- S. Sakthi., *et al.* 106

FUNGAL DISEASES IN SILKWORM (*Bombyx mori* L.)
- M. Parasuramudu 112

contents





WEED MANAGEMENT: SYNERGISTIC USE OF MECHANICAL, BIOLOGICAL AND CHEMICAL CONTROLS IN VEGETABLE CROPS - M. Karal marks 120

REVIEW ON CAUSES, EFFECTS AND CONTROL MEASURES OF ACID RAIN - Dr.Supriya D Meshre and Panchakarla Sedyaaw 126

ADDRESSING GENDER ISSUES FOR EMPOWERING RURAL WOMEN IN INDIAN AGRICULTURE THROUGH DIGITAL TECHNOLOGY - Dr. Vasupriya Parashar and Dr. Seema Tyagi 131

VERTICAL FARMING: A SUSTAINABLE SOLUTION TO URBAN AGRICULTURAL CHALLENGES - Pavisana V 141

SAVING OUR LAKES: HOW ALGAE CAN PREVENT EUTROPHICATION - S. Keerthivarshini and N. Arunkumar 148

GREEN GOLD: HOW MICROALGAE ARE REVOLUTIONIZING WASTEWATER TREATMENT - M. Keshavendra and N. Arunkumar 151

WATERLOGGING & SALINITY: SILENT KILLERS OF FARMLAND – AND HOW TO FIGHT THEM - Sadineni Avinash and Prasanth R 155

DROUGHT TOLERANCE IMPROVEMENT IN PEARL MILLET: STATUS AND PROSPECTS - Chandan Kapoor and Anamika 161

AFRICAN TULIP TREE (*SPATHODEA CAMPANULATA*) IN THE NILGIRIS: ORNAMENTAL BEAUTY OR ECOLOGICAL CATASTROPHE?- P. Jaisridhar., *et al.* 174

SYSTEM OF MATING IN CROP IMPROVEMENT - S.Saravanan and K. Gowtham 192





CONTENTS

KEY INSECT PESTS AFFECTING WHEAT CULTIVATION IN KOSI REGION OF BIHAR - Pankaj Kumar., *et al.* 196

INSECT PESTS OF GARLIC AND THEIR MANAGEMENT - V. Karuppaiah and P.S. Soumia 199

ANALYSING WORLD MARINE FISHERIES AND AQUACULTURE TRENDS (2012-2022) - J. Sam Rejin and B. Asvitha 203

BOTANICA OF BRINJAL - Kanthaswamy, V., *et al.* 210

EXPLOITING UNDERUTILIZED VEGETABLES - Bavithra, B., *et al.* 217

CLASSIFICATION OF CULTIVATED BRINJAL - Krishnan, V., *et al.* 222

COMMERCIAL APPLICATION OF BIOACTIVE COMPOUNDS FROM MARINE ALGAE - Dr. M. Jeya Bharathi 228

THE PERFORMANCE OF INDIGENOUS AZOSPIRILLUM OF THE PLANT GROWTH UNDER POT CULTURE FROM MADURAI DISTRICT - Dr. M. Jeya Bharathi 245

META ANALYSIS OF YIELD IN INTEGRATED NUTRIENT MANAGEMENT ON MAIZE CULTIVATION - K.Maruthupandi., *et al.* 254

POTENTIAL BIOPRODUCTS FROM OIL PALM RESIDUES - P. Vijayakumary., *et al.* 260

contents





PREPARATION AND NUTRIENT ANALYSIS OF LABORATORY-MADE RAW UNCOOKED FISH-PASTA FOR HEALTH BENEFITS - Farhan Fahim., *et al.* 264

FROM EVERY KITCHEN TO NOWHERE - THE RISE AND FALL OF DALDA: AN ENTREPRENEURIAL LENS - Sarath M., *et al.* 274

KITCHEN GARDENS FOR NUTRITION AND WOMEN'S EMPOWERMENT IN SOUTHERN ODISHA - Smaranika Mohanty., *et al.* 281

SMART HARVESTING SOLUTIONS: ADVANCING PADDY FARMING PRACTICES - Adithya B ., et al. 290

ADVANCES IN THRESHING MECHANIZATION: EFFICIENCY GAINS, TECHNOLOGICAL INNOVATIONS, AND AGRICULTURAL PRODUCTIVITY - Nithiya Prakash. R. R ., *et al.* 297

VEGETABLE GRAFTING - A TOOL TO MITIGATE PESTS AND DISEASES IN SOLANACEOUS CROPS - A Reshma and Syed Sadarunnisa 307

USE OF ARTIFICIAL INTELLIGENCE IN HORTICULTURE - A Reshma and Syed Sadarunnisa 311

ALTERNATIVE PROTEINS AND PRECISION FERMENTATION: ADDRESSING GLOBAL PROTEIN DEMAND WITH SUSTAINABLE INNOVATION - Baranidharan S and Loganathan M 316

BALANCING GROWTH AND SUSTAINABILITY: THE ROLE OF NOVEL FERTILIZERS IN CLIMATE-SMART AGRICULTURE - V. Arunkumar., *et al.* 324

COMPONENTS AND INDICATORS OF SUSTAINABILITY IN FISHERIES - Mary Helena.S 331





contents

WHY SOLAR ENERGY IS BLOOMING AS FASTEST SOURCE IN TAMIL NADU?
- Karnika E — 336

BUNCH NUTRITION AND SPRAYS FOR SUPERIOR BANANAS
- K. Venkata Ramudu — 342

EMERGING BIOTECHNOLOGICAL APPLICATIONS OF BIOACTIVE COMPOUNDS FROM MICROALGAE AND SEAWEEDS- B. Deepika and P. Ganesan — 347

SMART AGRICULTURE: LEVERAGING SENSORS FOR EFFICIENT WEED MANAGEMENT - Revathipriya P., *et al.* — 351

FROM FARM WASTE TO SUPERFOOD: HOW INDIA'S NEW "MUSHROOM REVOLUTION" IS TAKING ROOT - S. Dugyala., *et al.* — 358

GRAFTING A NOVEL TECHNIQUE FOR THE MANAGEMENT OF PEST AND DISEASES IN VEGETABLE CROPS - M. Shanmuga Priya., *et al.* — 366

IMPORT RISK ANALYSIS OF FISH AND FISHERIES PRODUCTS
- Harita Krishnan — 372

NEURO-LINGUISTIC PROGRAMMING (NLP) FOR EFFECTIVE COMMUNICATION
- Rashmita and Seema Naberia — 381

ENHANCING THE LIVELIHOODS OF SMALL AND MARGINAL FARMERS THROUGH CUSTOM HIRING CENTERS - Pushpa P., *et al.* — 387

RECENT ADVANCES IN HEAVY METAL REMEDIATION
- T.L.S.Samuel Moses and Naveen Dhatchanamoorthi — 390

CONTENTS





UREA: A POISONED CHALICE
- Maddela Tejaswini., *et al.* 394

BIO CONTROL METHODS FOR LEAF SPOT DISEASE OF MULBERRY
– Mavilashaw. V.P 400

SAFE ROUTE WITH A CHART PLOTTER IN NAVIGATION SYSTEM
Semina Yasmin., *et al.* 403

NANO-SELENIUM: A TINY NUTRIENT WITH BIG POTENTIAL IN MITIGATING ABIOTIC STRESS – Bekkam Rakesh 410

MOLECULAR SHIELDS: HARNESSING BIOTECHNOLOGY FOR PEST RESILIENT FARMING -Lipsa Dash and Niranjan Mandi 414

POWER OPERATED SPRAYER
- R. Ganika., *et al.* 419

FUNGICIDE RESISTANCE (MECHANISMS, MONITORING AND MANAGEMENT)
– Rithik P 424

ARTIFICIAL WETLANDS: NATURE-INSPIRED SOLUTIONS FOR WASTEWATER TREATMENT- *S.* Kanmani 428

DISEASE MANAGEMENT OF PET BIRDS
- S. Vinothraj., *et al.* 435

AI-POWERED DRIP IRRIGATION IN PRECISION FARMING
- Sowndharya K., *et al.* 443





CONTENTS

MECHANIZATION OF INTERCULTURAL OPERATION USING POWER WEEDER FOR ENHANCED CROP PRODUTIVITY - Mohanapriya S., *et al.* 448

EXPLORING DIFFERENT TYPES OF HAND SPRAYER – Anushree V., *et al.* 455

HETEROTIC GROUPING IN MAIZE: UNLOCKING THE POWER OF HYBRID BREEDING - Dr. G. Anusha and Dr. P. Jhansi rani 462

AUTOMATION MEETS AGRICULTURE: THE RISE OF THE INTELLIGENT PADDY THRESHER - Arun. R., *et al.* 468

JOURNEY OF STRAW-IMPLEMENT FOR CROP RESIDUE MANAGEMENT - P. Ezhilarasi., *et al.* 473

MISSION FOR AATMANIRBHARTA IN PULSES - Adhithya Prasad 483

INNOVATION IN FOOD PACKAGING: THE EMERGENCE OF SMART MATERIALSTHAT ARE STARCH-BASED AND NANOTECHNOLOGY-BASED - Yazhini. S P 488

COMMON DISEASES OF ONION AND THEIR MANAGEMENT - Sanjeev Kumar 492

AI ASSISTED IN HARVESTING CROPS - Hemadharshini.V., *et al.* 499

PERFORMANCE EVALUATION OF KNAPSACK SPRAYER - Dharani G., *et al.* 503





Contents

LIDAR IN AGRICULTURE: TRANSFORMING FARMING THROUGH PRECISION TECHNOLOGY - Dhanasekaran SK., *et al.* 507

PAH IN SMOKED FISH: SOURCE, OCCURRENCE AND HEALTH RISKS – Ulaganathan Arisekar., *et al.* 511

TURNING WEEDS INTO WEALTH: THE HIDDEN TREASURE OF HERBAL REMEDIES - Vanitha K., *et al.* 517

SALTMARSH ECOSYSTEM - A. Yamini., *et al.* 522

TRICLOSAN IN FISH: SOURCE, TOXICITY, AND HUMAN HEALTH RISKS - Ulaganathan Arisekar., *et al.* 527

SMART AQUATIC MANAGEMENT: ROLE OF AI, DRONES, AND GIS IN WATER QUALITY MONITORING - S. Kumaaraguru., *et al.* 534

PROMOTION OF IMPROVED MUNG BEAN VARIETIES THROUGH SEED HUB - Hari Ram Choudhary., *et al.* 539

ROLE OF EDNA IN THE CONSERVATION OF THREATENED AND ENDANGERED FISH SPECIES - Priya Yadav 545

TOWARD SEAMLESS SENSING: AN OVERVIEW OF WEARABLE TECHNOLOGIES - Dr. Radhika Damuluri 551

A CARBON NEGATIVE REVOLUTION IN YOUR BACKYARD – BIOCHAR AN EMERGING REMEDY FOR CLIMATE CHANGE - V.Sowmiya., *et al.* 562





Contents

MULCHING IN ORGANIC AGRICULTURE
- Dr. P. Thukkaiyannan and Dr. P. Ayyadurai — 571

INNOVATIVE NUTRITIONAL AND FEEDING STRATEGIES FOR PRODUCING DESIGNER EGGS FROM POULTRY: IMPROVE HUMAN HEALTH AND WELFARE
– Anand Kumar Pathak — 576

OCEAN-CLIMATE NEXUS: INSIGHTS INTO CARBON STORAGE AND SEQUESTRATION - --
Dr. Gokila. B and Dr. Pramila. P — 584

SCIENTIFIC APPROACHES TO WHEAT SEED PRODUCTION IN THE PENINSULAR ZONE OF INDIA - Yamina Karade and Rajendra Lokhande — 591

SCOPE FOR ROBOTICS IN AQUACULTURE
- Rohit Kumar., *et al.* — 597

ANTIDEPRESSANT AS AN EMERGING CONTAMINANT IN AQUATIC ECOSYSTEMS
- Shalini.R., *et al.* — 604

SMART HARVESTING SOLUTIONS: ADVANCING COTTON FARMING PRACTICES
- Manikandan G., *et al.* — 611

PRECISION WEED MANAGEMENT USING ARTIFICIAL INTELLIGENCE
- Adhithyan K G., *et al.* — 616

NATURE'S PHARMACY: THE ROLE OF FISH IN TRADITIONAL INDIAN MEDICINE - Anusuya Pandiyan and Dr. J Jaculine Pereira — 622

FUNCTIONAL FEED: THE NEW FUEL FOR HEALTHY SHRIMP FARMING
- Mariammal Senthilvel and Jaculine Pereira J — 630





contents

"THE BAOBAB TREE – A HIDDEN MYSTERY IN ITS TRUNK" - Hema R., *et al.* 635

CARBON SMART FARMING: THE FUTURE OF AGRICULTURE – Prasanth R and Sadineni Avinash 643

EPIGENETIC EFFECTS OF NUTRITION ON GENE EXPRESSION - Dr. Sonika Choudhary., *et al.* 649

INSECT MEAL AS A SUSTAINABLE PROTEIN SOURCE:EMERGING TREND AND FUTURE PROSPECTS IN AQUAFEED - Amit Kumar 657

THE BLACK SOLDIER FLY: THE TINY INSECT POWERING THE FUTURE OF FOOD AND FUEL - J. Sandeep Kumar., *et al.* 669

AI AND REMOTE SENSING: THE NEW EYES OF INDIAN AGRICULTURE - Shail Bala and S. I. Harlapur 676

BIOCHAR IN THE CIRCULAR ECONOMY: TURNING WASTE INTO VALUE - T. Tarun Kshatriya ans R. Thamizh Vendan 684

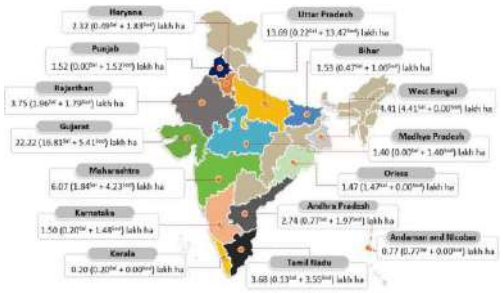
BIODIVERSITY OF WESTERN GHATS - Harini SubaLaxmi. B ., *et al.* 690

GERMPLASM CONSERVATION IN BRINJAL - Marichamy, M. S., *et al.* 695

POPULAR AND PROMISING VARIETIES OF GROUNDNUT FOR CULTIVATION IN INDIA - Shivada. A., *et al.* 703

CONTENTS





BLOCKCHAIN TECHNOLOGY AS A BREAKTHROUGH IN THE FOOD SUPPLY CHAIN: KNOW THE JOURNEY OF YOUR FOOD - Anjana K and Ravindra Naik **711**

BANANA PSEUDOSTEM SAP: NOVEL UNDERUTILIZED RESOURCE – Aswathy T., *et al.* **718**

INNOVATIVE APPROACH TO TREE CUTTING USING ELECTRIC DRIVE MECHANISM - Boomika.K., *et al.* **723**

FROM SALINE TO BARREN: INDIA'S GROWING SOIL EMERGENCY - Sujal Sanjay Bachhav., *et al.* **730**

GAS SENSING FILMS IN INTELLIGENT PACKAGING FOR SPOILAGE DETECTION P. - Sudha., *et al.* **735**

SPEED BREEDING AND REDUCING BREEDING CYCLE TIMES IN INDIA - P. Catherine **740**

PALMYRA TREE: A FORGOTTEN TREASURE - Dhanasekaran SK., *et al.* **745**

SCIENTIFIC PREPARATION OF VERMICOMPOST AND ITS ENRICHMENT - Kamble Anand Shankar and Venkannagouda R. **749**

SWEET FLAG- A TRADITIONAL MEDICINAL PLANT - Sherly. J., *et al.* **757**

INTEGRATING NANOTECHNOLOGY WITH NEMATOLOGY:ADVANCES AND FUTURE PROSPECTS - Shaikh Massarrat Shaikh Ameer **762**





contents

POPULAR AND PROMISING HYBRIDS AND VARIETIES OF BRINJAL FOR CULTIVATION IN INDIA - N. Bavya., *et al.* 766

SUSTAINABLE ORGANIC AGRICULTURE PRACTICES FOR ENHANCING SMALL MILLETS PRODUCTION – K. Sivagamy., *et al.* 773

CLIMATE-RESILIENT CROPS: BUILDING FUTURE FOOD SECURITY IN A WARMING WORLD - Ashika. D. C., *et al.* 779

CAPTIVE BREEDING AND REINTRODUCTION:SUCCESS STORIES AND CHALLENGES FOR THE RED-CROWNED ROOFED TURTLE - Lashega S., *et al.* 785

GROWTH AND PERFORMANCE OF CROP INSURANCE SCHEME IN INDIA (2016 – 2024) - Dhivya Dharsini S and Raj Adhithiya D P 789

CLIMATE CHANGE'S NEGATIVE IMPACT ON BIODIVERSITY - Hari Priya R., *et al.* 795

ARTIFICIAL INTELLIGENCE IN PLANT GENETIC RESOURCES - Kalaimathi R., *et al.* 798

INTEGRATING ARTIFICIAL INTELLIGENCE IN PLANT GENETIC RESOURCE MANAGEMENT - Padmavathi. *K., et al.* 803

IMPACT OF NATIONAL CANCER AWARENESS DAY - Geeta Channal and Bhavyashree. V 807

CENTRAL PIVOT IRRIGATION SYSTEM - NEED OF SUSTAINABLE AGRICULTURE - C. Sangeetha 813





contents

MACADAMIA NUT THE QUEEN OF NUTS-A BUTTERY TREASURE
- Uma Rani. K and Dinesh M.S — 816

PROCESSING OF PULSES
– M. Marimuthu — 826

TOMATO GRADING USING ARTIFICIAL INTELLIGENCE – A REVIEW
- Dr. P. Prema — 829

CRISPR-CAS9: A GENE EDITING TOOL
- Harini, R., *et al.* — 833

THE ECOLOGICAL ROLE OF SEA COWS: NATURE'S GENTLE GARDENERS
- Lathiga. S., *et al.* — 843

ROLE OF GENE BANK IN CROP IMPROVEMENT
- Monisha. V., *et al.* — 848

MAIZE FALL ARMYWORM, *SPODOPTERA FRUGIPERDA* (J.E.SMITH) THREATENING TO MAIZE FARMERS - Reedhu Shifani.C.S., *et al.* — 853

IMPROVED WHEAT VARIETIES FOR FARMERS OF MAHARASHTRA: USEFUL FOR UPCOMING *RABI* SEASON - Rajendra Lokhande and Mayur Kale — 858

SUNFLOWER – WHERE PROSPERITY BLOOMS
- Sindhu P — 863

FLAVR SAVR TOMATO: A MILESTONE IN PLANT GENETIC ENGINEERING
- K. Pavithra., *et al.* — 867





contents

THE EMERGENCE OF WINGED TERMITES AFTER RAIN: OVERVIEW
- Dr. M. Devi — 873

ROTARY DISC SPRAYER
– M. R. Mohammed Muhaideen., *et al.* — 878

INTEGRATED PEST MANAGEMENT OF RICE INSECT PESTS
- K. Vasanta Bhanu — 882

BIOFORTIFICATION OF FOOD CROPS AND ARTIFICIAL INTELLIGENCE IN AGRICULTURE IS FUTURE INDIA FOOD SECURITY - Priyadharsan. D. S., *et al.* — 891

IPR RELATED TO PLANT GENETIC RESOURCES AND TRADITIONAL KNOWLEDGE - Malini. M., *et al.* — 899

ROLE OF ARTIFICIAL INTELLIGENCE AND DIGITALIZATION IN DISASTER MANAGEMENT IN AGRICULTURE - Baranidharan. S., *et al.* — 906

DEVELOPMENT OF IOT AND DATA DRIVEN MODELS FOR ESTIMATION OF CROP EVAPOTRANSPIRATION A CASE STUDY OF OKRA (LADIES FINGER)
- S.Jeevasakthiyan. S., *et al.* — 910

GRAVITY FED MICRO IRRIGATION A WATER SAVING SOLUTION
- Anushree V. S., *et al.* — 917

SWOT ANALYSIS: VERTICAL FARMING
- Prabakaran. S — 923

SMART FERTIGATION TECHNOLOGY FOR EFFICIENT NUTRIENT AND WATER MANAGEMENT - Joshika S. S., *et al.* — 928





CONTENTS

ADVANCEMENTS IN AGRICULTURAL SPRAYER TECHNOLOGY FOR PRECISION PESTICIDE APPLICATION - Deepika. S. M., *et al.* 933

WORLD'S FIRST CRISPR-EDITED SPIDER PRODUCES GLOWING RED SILK FROM ITS SPINNERET – Jesima, M., *et al.* 939

HUMAN-WILDLIFE CONFLICT - Beeresh, K . and Dr. Venkatesh L 942

ADAPTING AGRICULTURE: MANAGING PESTS IN A WARMING WORLD - Poorvasandhya R and Ram Kumar P 946

FUCOIDAN FROM MARINE MACROALGAE: A MULTIFUNCTIONAL BIOPOLYMER FOR BIOMEDICAL AND INDUSTRIAL APPLICATIONS - B. Deepika and P. Ganesan 948

CLIMATE CHANGE -INDUCED FLOOD RISK AND ITS IMPACT ASSESSMENT ON AGRICULTURE IN ASSAM : A CASE STUDY - Mriganka Barman., *et al.* 951

FARM BUND RECONSTRUCTION AND SOIL EROSION CONTROL MEASURES - Dr. Suyog Khose., *et al.* 960

SAMBA SEASON TRADITIONAL RICE VARIETIES AND AROMA RICE VARIETIES – A GLANCE - C. Sivaranjani., *et al.* 964

TURMERIC PROCESSING: STAGES, QUALITY CONTROL AND CHALLENGES - Shubham Namdev Dhawale 972

RESILIENT FODDER SYSTEM FOR WATERLOGGED, DROUGHT, SALINE AND ACID SOILS - P.Aruna and B.V.Subramanyam 981





CONTENTS

NAVIGATING THE NANO-FRONTIER: A REVIEW OF PROMISE AND PERIL - Dr. T. Abarna 984

COFFEE LEAF RUST DISEASE: SYMPTOMS, ETIOLOGY AND MANAGEMENT – Dr. M. Kabilan 989

SCOPE OF CHATBOTS IN FISHERIES EXTENSION - Shweta Biswas and Lloyd Chrispin C 994

WATER BUDGETING AND MANAGEMENT IN INDIA - Dr. A. Mani 1002

INDIGENOUS FISH PROCESSING AND PRESERVATION PRACTICES AMONGST WOMEN IN NORTH EASTERN STATES OF INDIA - Hridam Saha., *et al.* 1008

PRECISION BREEDING: REVOLUTIONIZING CROP IMPROVEMENT FOR A SUSTAINABLE FUTURE - Dr Rahul Kaldate., *et al.* 1017

NANOTECHNOLOGY MEETS SOIL SCIENCE: INNOVATIONS FOR A SUSTAINABLE PLANET - Sumit Gahlot., *et al.* 1022

SUCCESSFUL CONTAINMENT OF COFFEE BERRY BORER (*HYPOTHENEMUS HAMPEI*) IN ANDHRA PRADESH BY DR. YSR HORTICULTURAL UNIVERSITY IN ASSOCIATION WITH DEPARTMENT OF HORTICULTURE AND COFFEE BOARD– A TEAM EFFORT TO PROTECT ORGANIC COFFEE - Dr N.B.V. Chalapathi Rao., *et al.* 1030

BREWING THE PERFECT PLANT: HOW SCIENTISTS USE MAGIC TO CREATE BETTER CROPS - Rajesh Ramasandra Venkataraja., *et al.* 1038

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ASSESSMENT OF NUTRIENT POLLUTION IN FRESHWATER AND MARINE ECOSYSTEM

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Abstract

Nutrient pollution, mainly cause from excess nitrogen (N) and phosphorus (P) is a major problem for water systems (freshwater and marine ecosystem) around the world. Nature usually helps move and spread nutrients through rocks weathering, plants decaying, and runoff. Human activities such as agriculture, aquaculture, waste discharge and industrial effluent, cause more nutrient input. Excess nutrient leads to eutrophication, algal blooms, oxygen depletion, coral reef degradation etc. These also affect fish diversity carbon storage, and ecosystem services. The amount of nutrients in water changes with the seasons with freshwater systems serving as nutrient transport pathways to coastal areas, experiencing the greatest risks of accumulation. Nutrient dynamics are further shaped by seasonal and spatial variations, Assessment relies on biological (phytoplankton, macrophytes, fish communities), chemical (DIN, phosphate, N:P ratio, DO, BOD, COD), and physical (water clarity, temperature, stratification) indicators to evaluate ecosystem health. For mitigation of these problems need effective management requires integrated strategies, including source reduction, advanced wastewater treatment, ecosystem restoration, strong policy frameworks, and community participation. These efforts are important to reduce nutrient pollution, protect water life, and keep water systems and the economy healthy for the future.

Introduction

Nutrient pollution refers to the over-enrichment of nutrients in aquatic ecosystem, primarily nitrogen (N) and phosphorus (P), beyond their optimal limits. While these elements are essentially supporting plant and algal growth and their excessive presence disturb the ecological balance of both freshwater and marine environments. In natural ecosystems nutrient pollution, primarily resulting from human activities—such as heavy fertilizer use in agriculture. The global production of agricultural fertilizers alone released <10 million metric tonnes of nitrogen in 1950, but may exceed 135 million metric tonnes of N by the year 2030. The wastewater discharged from domestic premises like residences, institutions and commercial level. It comprises of 99.9% water and 0.1% solids and is organic because it consists of carbon compounds like human waste, paper, vegetable matter etc. Besides community wastewater/sewage, there is industrial wastewater in the region. Many industrial wastes are also organic in composition and can be treated physico-chemically and/or by micro-organisms in the same way as sewage and also from the other sources such as soil erosion, decomposition of organic matter, and atmospheric deposition are generally absorbed and recycled within food webs. It is a significant environmental concern that deteriorates water quality and contributes to greenhouse gases emissions. Freshwater and marine ecosystems play a vital role in nutrient pollution, they functioning simultaneously as regulators of excess nitrogen

(N) and phosphorus (P) originating from human activities. Freshwater systems include - rivers, lakes, and wetlands act as key channel transporting nutrient loads from agriculture, wastewater, and industrial sources to coastal zones, while also providing natural buffering capacity through processes such as sedimentation, plant assimilation, and microbial denitrification. When nutrient inputs exceed in freshwater systems, they become highly susceptible to eutrophication, affected through harmful algal blooms, oxygen depletion, and declines in biodiversity. The nutrients carried downstream into marine environments cause ecological imbalances, leading to coastal eutrophication, the expansion of harmful algal blooms (HABs) and coral reef degradation. (Diaz & Rosenberg, 2008). These are the major issues for the freshwater and marine ecosystem in all over the world caused by nutrients.

Sources of Nutrient Pollution

Natural sources – Natural sources such as rock weathering and soil is a source of phosphorus. Over time, this phosphorus is released as phosphate into rivers and lakes through the breakdown

of minerals (Maher et al., 2016). Nutrient pollution isn't just from human activities but also from the natural sources. Natural processes also play a big role in how nitrogen and phosphorus cycle which move in aquatic environments. When rocks and soil break down, they release phosphorus in a soluble form, which ends up in rivers and lakes through mineral dissolution (Maher et al., 2016). Decomposition of organic matter from aquatic vegetation, and dead organisms releases ammonium, nitrate, and phosphate, forming part of the natural nutrient recycling within ecosystems. Moreover, natural water flow from forests, wetlands, and grasslands carries nutrients, especially during rain or seasonal flooding, delivering both dissolved and solid nutrients to fresh and saltwater systems. These natural sources maintain nutrient levels stable and support primary productivity.



Fig: Rock weathering



Fig: Natural runoff

Anthropogenic sources:

Nutrient pollution mainly caused by the human activities such as agricultural runoff mainly through the excess use of chemical pesticides, fertilizers, insecticides, and herbicides, which mainly contains phosphorus, nitrogen and potassium, helps in plant growth. In aquaculture intensive fish and shrimp farming release excess nitrogen (N) and phosphorus (P) into surrounding waters through uneaten feed, fish waste, and organic matter decomposition contributing in nutrient pollution. The sewage and wastewater discharged from domestic and industries consists of carbon compounds like human waste, paper, vegetable matter etc. affect the aquatic ecosystem. Atmospheric precipitation serves as a primary source of various chemical components for many ecosystems. Composition of precipitation is significantly affected by anthropogenic activity. Rainwater composition plays an important role in the absorption of

soluble components from the atmosphere. Urban areas are especially vulnerable due to dense traffic and industrial activity (Fornaro and Gutz, 2006). Rising emissions of SO_2, NO_x, VOCs, and aerosols are largely linked to urban population growth and increased vehicle use.

Mechanism of Nutrient Enrichment

Nutrient cycling in aquatic ecosystems:

Nutrient cycling in aquatic ecosystems involves the movement and recycling of key elements like nitrogen (N) and phosphorus (P) between biotic and abiotic components. Phytoplankton and aquatic plants are primary producer absorb dissolved nutrients through their roots and pass in the food web, and are eventually released back into the water or sediments through decomposition for reuse. Microbial processes— including nitrification, denitrification, mineralization, and sedimentary phosphorus release— are vital in controlling nutrient availability and maintaining ecosystem productivity (Dodds & Smith, 2016). Although natural nutrient cycling sustains ecological balance, excessive inputs from human activities can disrupt these processes, causing eutrophication and deterioration of water quality.

Seasonal and spatial variations:

Nutrient pollution in aquatic ecosystems varies seasonally and spatially, driven by climate, hydrology, and human activities. During rainy seasons, runoff, erosion, and fertilizer leaching increase nutrient loads, while in dry periods, reduced flow often concentrates pollutants in stagnant waters. Temperature also regulates biological processes such as algal growth and microbial nutrient transformations, intensifying eutrophication in warmer months. Spatial variation in nutrient loads depends on land use, watershed features, and proximity to pollution sources, with agricultural and urban areas contributing higher nitrogen (N) and phosphorus (P) than forested or less disturbed regions. Similarly, coastal zones and semi-enclosed seas are more prone to nutrient accumulation than open oceans due to restricted water exchange (Conley et al., 2009).

Ecological Impacts

Freshwater ecosystems:

Excess nutrient enrichment in aquatic ecosystems leads to eutrophication, characterized by higher number of algal blooms that reduce and block sunlight penetration, reduce water transparency, depletion of dissolved oxygen in aquatic ecosystem, resulting in hypoxia and make it hard for many aquatic plants and animals to survive (Diaz & Rosenberg, 2008). When oxygen

in water gets very low and toxic algae are present, they make it hard for many aquatic plants and animals to survive, also resulting the imbalance ecosystem.

Marine ecosystems:

Marine ecosystems play a central role in nutrient pollution impacts. Excess nitrogen (N) and phosphorus (P) lead to **dead zones** (low-oxygen areas where aquatic life cannot survive) and **harmful algal blooms (HABs)**. The largest U.S. dead zone, about 6,500 square miles, occurs each summer in the Gulf of Mexico due to nutrient runoff from the Mississippi River Basin. HABs, often caused by cyanobacteria (blue-green algae), release toxins harmful to humans and marine life. Coral reefs are among the most biologically rich and economically valuable ecosystems on Earth (Haider et al., 2023). Often described as the "rainforests of the sea," they support a wide diversity of marine life and provide essential ecosystem services, including shoreline protection, food security through fisheries, and economic benefits from tourism and recreation. Excess nitrogen (N) and phosphorus (P) from runoff, sewage, and coastal development upset the coral–algae balance, causing macroalgae and phytoplankton overgrowth that smothers corals. This leads to higher bleaching risk, greater disease susceptibility, and reduced water clarity, making nutrient pollution a major driver of coral reef degradation. (Fabricius, 2005). Seagrasses are submerged flowering plants that form productive underwater meadows in shallow coastal waters. Seagrass ecosystems are also recognized for their capacity to sequester and store organic carbon.

They store as much as 8.3– 23.1 Pg organic carbon (Corg) in biomass and underlying soil (known as "blue carbon") (Krause et al, 2025). Seagrass loss lowers water quality, damages fish and wildlife habitats, releases stored carbon, and reduces coastal protection and fisheries, which hurts biodiversity and brings economic problems to coastal areas.



Fig: Harmful Algal Blooms (HABs)



Fig: Coral Reef Degradation

Indicators and Assessment Methods

Biological indicators:

Biological indicators are effectively used to assess nutrient pollution, as aquatic organisms respond quickly to water quality changes. Phytoplankton and periphyton are important indicators because excess nutrients often cause their communities to shift from diverse species to fast-growing, nutrient-tolerant ones, including harmful algal bloom (HAB) producers. Macrophytes and benthic invertebrates also reflect nutrient stress—macrophytes decline with reduced water clarity, while invertebrates indicate long-term oxygen and nutrient conditions in sediments (Carvalho et al., 2019). Likewise, fish community structure serves as an integrator of ecosystem health, with tolerant species prevailing as oxygen-sensitive ones diminish under nutrient loading.

Chemical indicators:

Chemical parameters form the core of nutrient pollution assessment. Dissolved inorganic nitrogen (DIN), phosphate, and silicate are directly linked to eutrophication and harmful algal blooms, with elevated concentrations signaling anthropogenic nutrient loading (Howarth et al., 2011). The nitrogen-to-phosphorus (N:P) ratio is critical for understanding nutrient limitation, as deviations from the Redfield ratio (16:1) can favor certain algal groups, particularly cyanobacteria (Guildford & Hecky, 2000). Oxygen-related parameters such as dissolved oxygen (DO), biochemical oxygen demand (BOD), and chemical oxygen demand (COD) provide insights into the balance between oxygen supply and consumption. High BOD and COD alongside low DO are clear indicators of organic and nutrient pollution, often leading to hypoxic or anoxic conditions in aquatic systems (Diaz & Rosenberg, 2008).

Physical indicators:

Physical parameters strongly influence how nutrients affect aquatic ecosystems. Water clarity, measured through Secchi depth and turbidity, declines with nutrient enrichment due to phytoplankton blooms and suspended particles, which reduce light penetration and impair submerged vegetation growth. Temperature and stratification effects also play a crucial role; warmer conditions enhance metabolic and decomposition rates, while stratification limits oxygen exchange between surface and bottom waters, exacerbating hypoxia in nutrient-rich systems. Thus, physical indicators complement biological and chemical measures in evaluating the ecological impacts of nutrient pollution.

Management and Mitigation Strategies: There are several strategies for nutrient pollution

Source Control

- Reduce fertilizer use through precision farming, controlled application timing, and use of slow-release fertilizers.
- Proper storage and treatment of manure to minimize nutrient runoff.
- Implement green infrastructure (rain gardens, permeable pavements, vegetated swales) to reduce nutrient-rich stormwater flows.

Wastewater Treatment Improvements

- Use advanced technologies (e.g., biological nutrient removal, membrane filtration) to reduce nitrogen (N) and phosphorus (P) discharge.
- For rural or small communities, promote septic system upgrades and constructed wetlands.

Ecosystem-Based Approaches

- These act as natural nutrient filters, trapping sediments and absorbing excess nitrogen and phosphorus.
- Improve watershed health and reduce nutrient runoff into water bodies.
- Bivalves like oysters can remove excess nutrients by filtering water.

Policy and Regulation

- Enforce water quality standards for N and P concentrations.
- Allow industries or farmers to trade credits for reducing nutrient pollution, encouraging cost-effective solutions.
- Regular water quality assessments to track nutrient levels and enforce mitigation measures.

Public Awareness and Engagement

- Educating farmers, industries, and communities about the impacts of nutrient pollution.
- Encouraging sustainable household practices, such as reducing lawn fertilizer use and avoiding disposal of waste into drains.

Conclusion

Nutrient pollution, driven mainly by excessive nitrogen (N) and phosphorus (P), has become a critical global threat to freshwater and marine ecosystems. Although natural processes contribute to nutrient cycling, human activities such as intensive agriculture,

aquaculture, industrial discharges, and wastewater release have elevated nutrient inputs far beyond ecosystems' natural capacity to regulate them. This over-enrichment disrupts ecological balance, leading to eutrophication, harmful algal b looms (HABs), oxygen depletion, coral reef decline, and seagrass loss—ultimately harming biodiversity, fisheries, carbon storage, and human well-being. The use of biological, chemical, and physical indicators is essential for assessing nutrient dynamics and ecosystem health, underscoring the need for immediate management actions. Effective mitigation requires a combination of source reduction, advanced wastewater treatment, ecosystem restoration, robust policy measures, and active community participation. By adopting these integrated strategies, nutrient pollution can be controlled, safeguarding aquatic ecosystems, sustaining biodiversity, and ensuring the long-term health of water resources vital to both nature and society.

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PRECISION AGRICULTURE: TRANSFORMING FARMING WITH TECHNOLOGY

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Introduction

Agriculture, the backbone of human civilization, has always evolved with the integration of new tools and methods. From traditional practices of subsistence farming to the Green Revolution's scientific advancements, each step has brought us closer to more efficient and productive systems. Today, as the world faces challenges of population growth, climate change, shrinking natural resources, and environmental degradation, a new era of farming has emerged: **Precision Agriculture (PA)**.

Precision agriculture is revolutionizing the way we farm, using cutting-edge tech and data analysis to grow crops more efficiently and sustainably. It is not just about producing more but producing more with fewer inputs, greater efficiency, and sustainability. Often described as "smart farming," precision agriculture leverages cutting-edge technologies such as sensors, satellites, GPS, Geographic Information Systems (GIS), drones, and artificial intelligence to monitor, analyze, and manage agricultural activities with unparalleled accuracy. This approach provides farmers with valuable insights into soil conditions, crop health, water needs, and weather patterns, allowing them to make informed decisions that improve productivity, protect resources, and reduce costs.



What is Precision Agriculture?

Precision agriculture (PA) can be defined as a management strategy that uses advanced technologies and information systems to gather, process, and analyze agricultural data for optimizing decision-making. It takes into account the spatial and temporal variability within farms and provides tailored solutions to specific sites instead of adopting a "one-size-fits-all" approach.



This method involves identifying and measuring variations in soil fertility, moisture content, pest incidence, and crop growth across different fields or even within the same field. Based on this data, customized agronomic treatments—such as the application of fertilizers, pesticides, irrigation, and crop rotation—can be planned to match the needs of specific zones.

In essence, precision agriculture is about doing the right thing, in the right way, at the right time, in the right place, and in the right amount. This holistic approach extends beyond just crop management, incorporating financial planning, marketing strategies, and personnel management, all guided by technology-driven insights.

The Goals of Precision Agriculture

The adoption of precision agriculture is driven by multiple objectives:

1. **Enhancing Productivity** – By identifying the specific needs of crops and applying targeted interventions, PA helps in achieving higher yields.
2. **Improving Efficiency** – Inputs like fertilizers, herbicides, pesticides, and water are used in the exact quantities needed, reducing waste.
3. **Protecting the Environment** – Precision use of chemicals minimizes runoff, groundwater contamination, and soil degradation, thus contributing to environmental sustainability.
4. **Energy and Resource Savings** – Efficient input use translates into lower energy consumption and operational costs.
5. **Climate Resilience** – By integrating predictive models and early warning systems, PA prepares farmers to adapt to unpredictable weather events, pests, and diseases.
6. **Ensuring Quality Production** – Tailored nutrient and water management improve crop quality, making produce more competitive in markets.

Key Components of Precision Agriculture

Precision farming integrates several elements that work together to create a comprehensive management system. These can be broadly categorized into three pillars:

1. **Management** – Refers to decision-making processes that integrate field data, technological tools, and farm management practices.
2. **Information & Data** – Includes collecting and analyzing data from multiple sources such as sensors, satellites, drones, and remote sensing technologies.
3. **Technology & Application** – Involves the use of IT tools, GPS, GIS, automated machinery, and variable rate technology (VRT) to apply inputs precisely.

The 5 R's of Precision Agriculture

A central principle of precision agriculture is the **"5 R's"** concept, which ensures efficiency and sustainability in farming operations:

1. **Right Input** – Selecting the appropriate input, whether it is seed, fertilizer, pesticide, or water.
2. **Right Amount** – Applying the exact quantity required, avoiding both under-application and overuse.
3. **Right Place** – Ensuring the input is delivered exactly where it is needed, targeting specific zones within a field.
4. **Right Time** – Timing interventions according to the growth stage of the crop or the prevailing environmental conditions.
5. **Right Manner** – Using the most effective method of application, whether through drip irrigation, drone spraying, or precision seeding.

By following these 5 R's, precision agriculture not only optimizes productivity but also safeguards the environment.

Core Technologies in Precision Agriculture

Precision farming relies heavily on advanced tools and systems. These technologies can be grouped into five main categories:

1. **Computers and Data Processing Systems**
    - Provide platforms for storing, analyzing, and interpreting large volumes of data.
    - Software applications enable decision-support systems for farmers.

2. **Global Positioning System (GPS)**
    - Allows accurate mapping of fields and real-time tracking of farm machinery.
    - Facilitates site-specific management practices.
3. **Geographic Information System (GIS)**
    - Helps in creating detailed maps of soil types, crop yields, pest infestations, and irrigation needs.
    - Provides spatial analysis to guide input application.
4. **Sensors**
    - Soil sensors measure moisture, pH, and nutrient levels.
    - Crop sensors assess health, growth, and pest stress.
    - Weather sensors monitor local climatic conditions.
5. **Application Control Technologies**
    - Variable Rate Technology (VRT) enables site-specific input applications.
    - Automated machinery ensures precise and uniform field operations.

In addition, recent advancements such as the **Internet of Things (IoT), Big Data analytics, Artificial Intelligence (AI), and Machine Learning (ML)** have revolutionized PA. These technologies allow predictive forecasting, real-time monitoring, and automated decision-making.

Applications of Precision Agriculture

The versatility of precision farming technologies makes them applicable across several areas of farm management:

- **Soil and Nutrient Management** – By mapping soil variability, farmers can apply fertilizers only where needed, improving nutrient use efficiency.
- **Water Management** – Precision irrigation systems, such as drip irrigation connected to sensors, ensure optimal use of water.
- **Crop Health Monitoring** – Drones and remote sensing can detect early signs of diseases, nutrient deficiencies, or pest infestations.
- **Pest and Weed Control** – Site-specific spraying reduces chemical use while improving effectiveness.
- **Yield Prediction** – Data-driven models allow accurate forecasting of crop yield, aiding marketing and storage decisions.

- **Harvest Management** – Precision tools help determine the best harvest time, ensuring high-quality produce.

Advantages of Precision Agriculture



Compared to traditional farming practices, precision agriculture offers a range of advantages:

1. **Economic Benefits** – Reduced input costs and increased yields improve profitability.
2. **Environmental Sustainability** – Less chemical runoff and reduced soil degradation protect ecosystems.
3. **Resource Efficiency** – Saves water, energy, and time by optimizing field operations.
4. **Risk Mitigation** – Predictive analytics provide early warnings of adverse weather or pest outbreaks.
5. **Improved Food Quality and Safety** – Better nutrient management results in healthier crops.

Challenges in Adopting Precision Agriculture

Despite its many benefits, precision agriculture is not without challenges:

1. **High Initial Investment** – Advanced technologies, machinery, and sensors can be expensive, limiting accessibility for smallholder farmers.
2. **Technical Knowledge** – Farmers require training to operate and maintain precision tools effectively.
3. **Infrastructure Limitations** – Rural areas often lack reliable internet connectivity, electricity, and digital infrastructure.
4. **Data Management Issues** – Large datasets require sophisticated processing systems and data security measures.
5. **Scalability** – While large farms can easily adopt PA, small-scale farms may struggle due to fragmented land holdings.

The Future of Precision Agriculture

The future of precision agriculture lies in the **integration of emerging technologies**. With continuous advancements in artificial intelligence, machine learning, and cloud-based data systems, PA will become more accessible, accurate, and cost-effective.

- **IoT in Farming** – Smart sensors connected through IoT networks will monitor crops and soils continuously, sending real-time alerts to farmers' mobile devices.
- **Big Data Analytics** – Analysis of global agricultural datasets will provide insights into long-term climate trends and global food security planning.
- **Artificial Intelligence and Robotics** – AI-driven robots could autonomously plant, weed, and harvest crops.
- **Satellite and Drone Imagery** – High-resolution images will provide more detailed monitoring and forecasting capabilities.
- **Sustainable Farming Integration** – PA will become central to climate-smart agriculture, reducing the sector's carbon footprint while enhancing resilience to climate change.

Governments and institutions are also beginning to recognize the role of PA in addressing global food security challenges. Support in the form of subsidies, training programs, and infrastructure development will be essential for wider adoption, particularly in developing countries.

Conclusion

Precision agriculture is much more than a technological upgrade—it represents a revolution in the way farming is approached. By combining modern technologies with traditional farming knowledge, PA provides a pathway toward sustainable, resilient, and profitable agriculture.It ensures that every drop of water, every granule of fertilizer, and every unit of energy is used efficiently and responsibly. For a world grappling with limited natural resources and rising food demands, precision agriculture offers hope for balancing productivity with sustainability.

The **5 R's of precision agriculture—Right Input, Right Amount, Right Place, Right Time, and Right Manner—capture its essence perfectly**. They highlight its ability to integrate science, technology, and management for smarter farming.

As technologies evolve and become more affordable, the widespread adoption of precision agriculture could play a defining role in shaping the future of global food systems, ensuring not only higher yields but also environmental protection and improved livelihoods for farmers worldwide.

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THE SCIENCE OF RESILIENCE: EXPLORING ADAPTOGENS AND ACTOPROTECTORS

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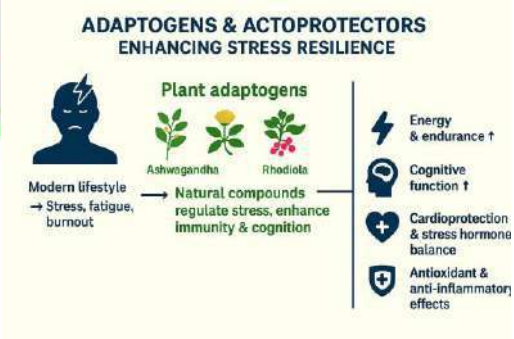
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Abstract

Adaptogens improve the body's ability to handle physical, mental, and environmental stressors. Plant adaptogens like *Panax ginseng*, *Withania somnifera*, and *Rhodiola rosea* are known for their ability to enhance immune function, regulate stress reactions, and boost cognitive and physical performance, usually without noticeable side effects. Conversely, synthetic actoprotectors such as bemethyl and bromantane offer benefits for performance and neuroprotection, but their use in sports is restricted due to concerns about providing an unfair advantage. Although these agents are increasingly incorporated into nutraceuticals and functional foods, challenges remain regarding regulatory inconsistencies, ambiguous dosing, possible interactions, and potential side effects. The article emphasises the necessity for standardised protocols and evidence-based approaches to ensure the safe and effective adoption of adaptogens and actoprotectors for health and resilience.



Introduction

In this fast-paced world, stress, fatigue, and burnout have become common issues. Whereas caffeine and energy drinks provide quick relief, they often lead to health issues like crashes and heartburn in excessive consumption (1). Adaptogens are a group of compounds

which are either synthetic or derived from a variety of natural plant sources. Dr. Israel Itskovich Brekhman, a Russian pharmacologist, coined the term "Adaptogen". The substances found within these diverse plant species are known for their ability to help the body adapt to external stress, regularise body functions, boost energy, naturally combat stress, and restore balance and well-being. Their origins may vary, encompassing both laboratory-created formulations and those extracted from the rich variety of the plant kingdom. The classification is based on their source, and it is divided into two categories; Plant adaptogens and Actoprotectors (Morozov et al., 2001).

Plant adaptogens like Ashwagandha, Ginseng, and Reishi are naturally available. The extracts from *Panax ginseng, Eleutherococcus senticosus, Rhaponticum carthamoides, Rhodiola rosea*, and *Schisandra chinensis* are considered to be naturally occurring adaptogens (3), whereas the actoprotectors are synthetically derived compounds like levamisole, bromantane, aphobazole, and bemethyl (4). These compounds not only enhance the body's function but also maintain the normal body metabolic processes. The use of adaptogens as medicinal compounds and ingredients in human and animal food has a long history. According to Dr. Brekhman, adaptogens have 4 general properties: i) these compounds are harmless to the host, ii) they rather have a general, non-specific effect, iii) they act as a general stabiliser, iv) they enhance the recipient's ability to withstand various physical, chemical or biological stressors (5).

Adaptogens enhance cognitive function, regulate stress hormones, modulate neurotransmitters, promote Nerve Growth Factor (NGF) production, reduce inflammation, and improve blood flow rather than merely helping the body adapt to stress. The mechanism of adaptogens includes effects on different stages of metabolism, humoral-hormonal regulation, neurogenic regulation, lipid peroxide processes, the structure and function of cell membranes, etc (Morozov et al., 2001). Adaptogens can be classified into both nutraceuticals and functional foods. The extracts obtained from plant extracts and actoprotectors are categorised as nutraceuticals as they are the concentrated bioactive compounds consumed in supplement form. On the other hand, the adaptogens incorporated into food and beverages (mushroom-infused coffee, Licorice root tea and energy bars made with maca root) fall under functional foods, known to provide health benefits beyond basic nutrition (4,5). The consumption of adaptogens significantly influences blood glucose levels, cortisol levels, nitric oxide levels, and hepatic enzymes (7).

Plant Adaptogens

The most common type of adaptogen that people recognise is the extracts of plant adaptogens, consumed to enhance the body's resistance to disease and strengthen the immune system without causing any side effects to the host. The well-recognised plant adaptogens are: *P. ginseng* (Asian/Korean ginseng), *Hericium erinaceus* (*Lion's Mane mushroom*), *E. senticosus roots*, *Withania somnifera* (Ashwagandha), *Ocimum tenuiflorum* (Holy basil), and *Asparagus racemosus* (Shatavari). These substances have origins in historical use that date back to the medieval era, during which they were important in Ayurvedic medicine for improving human health. The bioactive compounds, like triterpenoid saponins, polysaccharides, phytosterols, and lignans, influence the adrenal axis and stress mediators (8,9).

P. ginseng is a medicinal plant that has been used since ancient times and continues to be utilised in modern times for its adaptogenic properties, which enhance calmness, mood, mental health, deep sleep, and reduce fatigue (10). The extracts from *P. ginseng* are known to have ergogenic properties and enhance muscle strength. If this is included in athletes' diets, it's known to improve their performance. Inclusion of 200mg of this extract in their daily regimen improves cognitive performance, mood, and psychomotor function, enhancing psychological function, boosting immune response, and managing diabetes (11).

R. carthamoides, also known as Leuzea, is known to provide enhanced physical endurance and performance, anabolic effect, hypocholesterolemic effects, neuroprotective effect, anti-diabetic properties, anti-oxidative, and increased immunity (Kokoska & Janovska, 2009; Timofeev, 2006). It includes biostimulants and phytoecdysteroids, and it stands out among other adaptogens for its capacity to prevent numerous illnesses and efficiently treat a wide range of pathologies. Leuzea is known to help in decreasing the body weight of an individual and increase disease resistance, physical, and mental endurance (8).

R. rosea L is a traditional medicine, used in the past in Asia to treat flu and cold, and in Europe to improve physical endurance (14). The extract of *R. rosea* helps in overcoming fatigue, and if included in the diet of cardiovascular patients, it’s shown to improve the health of the heart rate and muscle contractions (15). The extracts are known to have a hepatoprotective effect, which will help in improving the health of liver failure patients, fatty liver diseases, and the extracts are recommended for sleep disorders and anxiety.

Table 1. Adaptogens and its uses

S. No.	Scientific Name	Uses	Reference
1.	*P. ginseng*	Used to support immune function, improve psychomotor skills, and enhance physical performance, managing stress, fatigue, and conditions associated with diabetes.	(16)
2.	*R. rosea*	Traditionally used to alleviate stress, fatigue, depression, enhance mental and physical performance, reduce burnout. Studied for its anti-ageing, anti-inflammatory, and neuroprotective properties.	(14,15)
3.	*E. senticosus*	Also known as Siberian ginseng, it's used to increase vital energy, improve fatigue resistance, and enhance immune system function. It's often used during periods of physical and mental stress.	(17)
4.	*W. somnifera*	Important herb in Ayurvedic medicine used to alleviate stress, anxiety, and fatigue. It improves sleep quality and enhances cognitive function and memory Also possessing antioxidant and anti-inflammatory properties.	(18)
5.	*S. chinensis*	Important herb in Traditional Chinese Medicine, known for nourishing the lungs and kidneys, reducing fatigue, and enhancing stamina. Its active components are also researched for liver-protecting and neuroprotective benefits.	(19,20)

Actoprotectors

Actoprotectors are formulations which are known to enhance the body's stability and physical endurance without raising the oxygen consumption and heat production. They are known as non-exhaustive agents; the main reason to differentiate actoprotectors from psychostimulants and nootropic agents (Shabanov & Vinogradov, 2024). These are known as synthetic adaptogens, which enhance physical health as well as mental health by producing a relaxing feeling in the body(Morozov et al., 2001). Their work principle includes stimulating protein synthesis, increasing work capacity, and exerting antihypoxic and antioxidant effects. By

modulating physiological receptors without causing excessive stimulation, actoprotectors can protect the organs from heavy loads like hypoxia and heavy physical loads (22). Based on their chemical composition, actoprotectors are classified into three categories: i) benzimidazole derivatives (bimitil), ii) Adamantine derivatives (bromantane, chlodantan) and iii) compounds which belong to other chemical classes (ginseng, nicotinic acid derivatives).

The common actoprotectors cover the Bimitil (bemethyl), and bromantane, an adamantine derivative. Bimitil is used by athletic personnel to prevent decreased working capacity without compromising the organism's energy resources and has been proven to give recovery in extreme conditions like high temperature, low oxygen and high physical exertion (Morozov et al., 2001). Bromantane is used for treating asthenic and restless conditions, has a unique dual activity stimulant and anxiolytic (anxiety-reducer), and Adamantine derivatives that show promising results as an antiparkinsonian drug, helping to prevent neuronal dysfunction and loss in different pathological states of the brain (22,23).

While actoprotectors demonstrate a positive impact on the host body, it's banned in competitive sports and military use because of performance enhancement, lack of long-term safety data and potential abuse. The World Anti-Doping Agency (WADA) bans substances like Bemethyl and Bromantane under the Stimulants or Glucocorticoids categories because they can unfairly enhance athletic performance. These compounds boost energy, improve focus, and aid recovery, giving athletes an unearned advantage. The regulations ensure fair competition and protect athlete health by preventing the misuse of performance-altering substances (24).

Table 2: Actoprotectors and it's uses

S. No.	Substance	Chemical origin / class	Use of the substance	Reference
1.	Bemethyl (Metaprot)	Benzimidazole derivative	Enhances physical and mental endurance, especially under extreme conditions like low oxygen and high temperatures, by optimizing energy metabolism and stimulating protein synthesis.	(22)
2.	Ethomersol	A relative benzimidazole derivative	Primarily used as a protective agent against cerebral hypoxia and post-ischemic damage,	(6)

			particularly for conditions involving transient cerebral ischemia.	
3.	Bromantane (Ladasten)	Adamantane derivative	Used to enhance physical and mental performance by providing both a stimulating and anxiety-reducing effect, improving work capacity without causing an exhaustive crash.	(6,22)
4.	Chlodantan	Adamantane derivative	Based on animal and cell culture studies, it is said to improve physical performance and has immunostimulant effects.	(Morozov et al., 2001)
5.	Emoxypine succinate (Mexidol)	3-Hydroxypyridine derivatives	Used for its powerful antioxidant, antihypoxic, and neuroprotective effects to treat conditions such as anxiety, stress, and certain neurological and cardiovascular disorders.	(22)

Challenges

The problem in the consumption of adaptogens is the lack of regulation and standards for the manufacturing and marketing of these compounds. In most countries, including the U.S., adaptogens are sold as dietary supplements and are not regulated by the FDA for safety and effectiveness. Inconsistent dosage remains a significant concern, as individuals often lack clarity regarding the appropriate daily amount of the compound to be taken. While adaptogens are recognised for their health advantages, certain individuals may not be able to handle the chemical components or effects associated with their consumption. Common side effects may include nausea, diarrhoea, sleep disturbances, fatigue, headaches or drowsiness. Adaptogens can reduce or counteract the effects of prescription medications and other supplements like Reishi mushroom, which has a blood-thinning effect when taken with anticoagulants they raising the concern of bleeding and bruising, and certain groups of people should avoid the consumption or use them with greatest heed, for example it can harm the hormone level of pregnant and breast-feeding woman because it concerns with miscarriage and difficulty during labour.

Conclusion

Adaptogens and actoprotectors represent a unique category of both natural and synthetic substances that support the body's ability to cope with physical, mental, and environmental stressors. Their diverse benefits, which encompass enhancement of cognitive performance and immune function, as well as improvements in endurance and recovery, have been recognised in both traditional medicine and modern research. However, despite their potential as functional foods and nutraceuticals, their safe and effective use requires well-defined regulatory frameworks, standardised dosing guidelines, and heightened consumer awareness. Achieving a balance between innovation and evidence-based practices will ensure responsible usage of these substances to promote overall health, resilience, and well-being.

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CULTIVATION AND MEDICINAL PROPERTIES OF CYCLOCYBE AEGERITA

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Introduction

Cyclocybe aegerita, also called *Agrocybe cylindracea*, *Agrocybe aegerita* or *Pholiota aegerita*, is a mushroom in the genus *Cyclocybe* which is commonly known as the poplar fieldcap or poplar mushroom, or velvet pioppini . 'Tea Tree Mushroom'). In Japan, it is called *Yanagi-matsutake*

Description

It belongs to the white rot fungi and is a medium-sized agaric having a very open and convex cap, almost flat, with a diameter of 3–10 centimetres (1–4 inches). Underneath, it has numerous whitish radial plates adherent to the foot, later turning to a brownish-grey colour, and light elliptic spores of 8–11 by 5–7 micrometres. The white fibre foot is generally curved, having a membranous ring on the top part which promptly turns to tobacco colour due to the falling spores. .



When very young, its colour may be reddish-brown and later turn to a light brown colour, more ochre towards the centre, whiter around its border. It grows in tufts on logs and holes in poplars, and other large-leaved trees

Morphology of Cyclocybe aegerita

Uses

It is cultivated and sold in the United States, Chile, Japan, Korea, Italy, Australia and China. The cultivation in the Mediterranean region is very old, e.g. it is described in the book *Naturalis Historia* by Pliny the ElderIn traditional Chinese medicine, it is often used as a diuretic.

The mushroom is a typical ingredient found in both Southern European and Chinese cuisine. In East Asia, it is used fresh and rehydrated in various dishes, including stir-fry, soup, stew, and hot pot. It has a soft cap and a harder stem. Picking specimens from the wild is not recommended due to the difficulty of identification.Along with *Mycetinis alliaceus* and *Chondrostereum purpureum*, it is suitable for counteracting olive-mill wastewater plant toxicity.

Edible:

A. aegerita is a well-known edible mushroom with a pleasant taste and aroma, making it a popular ingredient in various dishes.

Cultivated:

It is cultivated and sold in numerous countries, including the United States, Chile, Japan, Korea, Italy, Australia, and China.

Traditional Use:

In East Asia, it is used both fresh and rehydrated in dishes like stir-fries, soups, and hot pots.

Medicinal/Bioactive Properties:

Anti-tumor:

Studies suggest A. aegerita possesses anti-tumor properties and can inhibit the growth of certain cancer cell lines.

Anti-inflammatory:

It has been shown to have anti-inflammatory effects, potentially alleviating inflammatory conditions.

Anti-oxidant:

A. aegerita is a source of antioxidants, which can help protect the body against damage from free radicals.

Anti-aging:

Research indicates that A. aegerita polysaccharides (AAPS) may have anti-aging effects, potentially by reducing oxidative stress and regulating gut microbiota.

Hypouricemic:

Extracts of A. aegerita have been shown to have hypouricemic effects, potentially reducing uric acid levels.

Enzyme Activity:

It contains enzymes like peroxidase and unspecific peroxygenase, which can be used in various industrial applications.

Prebiotic:

A. aegerita polysaccharides have been shown to be a suitable prebiotic, potentially beneficial when combined with certain bacteria like Lactobacillus rhamnosus GG.

Other Potential Uses:

- **Hydrolyzing Agricultural Waste:** A. aegerita has been reported to hydrolyze agricultural waste efficiently.
- **Antiviral Activity:** Some studies suggest it may have antiviral activity against certain viruses.
- **Counteracting Toxicity:** It has been identified as a suitable mushroom for counteracting the toxicity of olive-mill wastewate

Cultivating Agrocybe aegerita, also known as Pioppino or Black Poplar mushroom, involves several key steps. It requires a hardwood sawdust or Master's Mix (a mixture of hardwood sawdust and bran) as a substrate, which should be pasteurized to eliminate competing organisms. The spawn is then introduced, and the substrate is incubated at room temperature (21-24°C) for 3-4 weeks, or until fully colonized. After incubation, the temperature is lowered to 15-18°C to initiate pinning (primordia formation). Maintaining high humidity (80-85%) and proper ventilation are crucial during fruiting.

Cultivation of Agrocybe aegerita :

1. Substrate Preparation:

- **Hardwood sawdust (e.g., beech, birch, or alder) or Masters Mix:** These are common choices.

- **Pasteurization:** The substrate needs to be pasteurized to eliminate unwanted microorganisms. This can be done by heating the substrate to a specific temperature for a set time.
- **Supplementation:** Adding supplements like wheat bran or black tea pomace can enhance yields.



Fig 2. Emerging buds of *Agrocybe aegerita*

2. Spawn Run (Incubation):

- **Spawn:** Use a grain-based spawn of Agrocybe aegerita.
- **Inoculation:** Introduce the spawn to the prepared substrate at a rate of 2-4% on a dry weight basis.
- **Incubation:** Maintain room temperature (21-24°C) and high humidity (80-85%).
- **Duration:** The incubation period typically lasts 3-4 weeks, until the substrate is fully colonized by mycelium.

3. Fruiting:

- **Lowering Temperature:** Reduce the temperature to 15-18°C to initiate primordia formation (pinning).
- **Humidity:** Maintain high humidity (80-85%) and proper ventilation.
- **Light:** Provide indirect light.
- **Harvesting:** Once the fruiting bodies (mushrooms) are fully developed, they can be harvested.

4. Additional Tips:

Hygiene:

Maintain strict hygiene throughout the process to prevent contamination.

Watering:

Ensure adequate moisture in the substrate throughout the fruiting phase, using a spray bottle if needed.

Air Exchange:

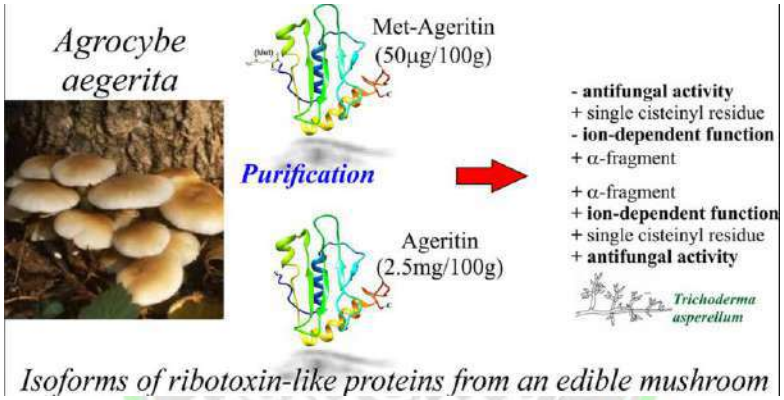
Ensure proper air exchange to prevent the buildup of CO2, which can inhibit fruiting.

pH:

Agrocybe aegerita prefers a slightly acidic environment, with a pH between 6.0 and 7.0.

By following these steps, you can successfully cultivate Agrocybe aegerita mushrooms and enjoy their unique flavor and texture.

Medicinal properties of *Agrocybe aegerita*



Agrocybe aegerita, also known as the black poplar mushroom, offers significant value addition potential through its edible and medicinal properties. It can be used to create flavorful food products, potentially contributing to the development of novel umami agents and prebiotic formulations. Furthermore, its bioactive compounds, including polysaccharides and ceramide, exhibit antioxidant, anti-cancer, and anti-inflammatory properties, suggesting its potential in pharmaceuticals and nutraceuticals.

Value Addition through Food Applications:

Flavor Enhancement:

A. aegerita is known for its delicious aroma and flavor. Applying flavor extraction techniques can enhance its umami taste, making it a valuable ingredient in food products.

Prebiotic Properties:

The A. aegerita polysaccharide (AAPS) has been shown to act as a prebiotic, potentially benefiting gut health and mitigating aging damage.

Nutritional Value:

It is a good source of protein, and enzymatic hydrolysis can be used to extract amino acids and peptides, further increasing its nutritional value and flavor.

Novel Food Products:

Fermented beverages like soy drink can be enhanced with A. aegerita, potentially leading to new food products with unique flavor profiles, like the aroma of Parmesan and Emmental cheeses.

Value Addition through Medicinal Applications:

Anticancer Properties:

A. aegerita contains compounds like cylindan, ceramide, and a lectin that have shown anti-cancer activity against various cancer cell lines.

Antioxidant and Anti-aging Effects:

AAPS has demonstrated potent antioxidant and anti-aging activity in vitro and in vivo, potentially offering benefits in combating oxidative stress and promoting longevity.

Anti-inflammatory Properties:

A. aegerita lectin has shown inhibitory activity against inflammatory conditions, and ceramide has been found to inhibit cyclooxygenase enzymes, which play a role in inflammation.

Bioavailability Enhancement:

Polysaccharide-polyphenolic complexes derived from A. aegerita can enhance the bioavailability and biological activity of polyphenols, potentially leading to more effective health products.

Other Value-Added Products:

Mycoprotein:

A. aegerita can be used to produce mycoprotein, a meat substitute with high protein content, which can address the growing demand for sustainable protein sources.

Functional Foods:

The combination of A. aegerita with other ingredients like Lactobacillus rhamnousus GG can create functional foods with synergistic health benefits.

Pharmaceutical and Nutraceutical Applications:

The bioactive compounds found in A. aegerita, including polysaccharides and polyphenols, can be utilized in the development of pharmaceuticals and nutraceuticals targeting various health conditions.

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REARING OF MULBERRY SILKWORM

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Abstract

Mulberry silkworm rearing, or sericulture, is the labor-intensive process of raising silkworms (Bombyx mori) on mulberry leaves to produce silk cocoons. This age-old practice is a vital economic activity and a cornerstone of the silk industry, providing income and employment, particularly in rural Asian communities. Successful rearing requires careful control of environmental conditions like temperature and humidity, proper mulberry cultivation and feeding, and hygienic management of rearing facilities to ensure the production of high-quality silk.

Introduction

Cultivation of mulberry plants is called moriculture. There are over 20 species of mulberry, of which four are common: Morus alba, M. indica, M. serrata and M latifolia. Mulberry is propagated either by seeds, root- grafts or stem cuttings, the last one being most common. Cuttings, 22-23 cm long with 3- 4 buds each and pencil thick, are obtained from mature stem. These are planted directly in the field or first in nurseries to be transplanted later. After the plants have grown, pruning is carried out routinely which serves two purposes, induction of growth and sprouting of new shoots.

Harvesting of leaves for feeding larva is done in three ways: leaf picking, branch cutting and top shoot harvesting. In leaf picking, individual leaves are handpicked. In branch cutting method, entire branch with leaves are cut and offered to 3rd instar larva. In top shoot harvesting,

the tops of shoots are clipped and given to the 4th & 5th instars. The yield and quality of leaf depend upon the agronomic practices for cultivation of mulberry trees, namely irrigation, application of fertilizers etc. It is estimated that 20,000 to 25,000 kg of leaves can be harvested per hectare per year under optimum conditions. It has also been estimated that to rear one box of 20,000 eggs, 600-650 kg of leaves are required for spring rearing and 500-550 kg for autumn rearing in Japan. In India, to rear 20,000 eggs the quantity of leaves required is about 350-400 kg.

Rearing Equipments:

- Rearing house
- Rearing stand
- Ant well
- Rearing tray
- Paraffin paper
- Foam rubber strips
- Chopsticks
- Feathers
- Chopping board and Knife
- Leaf chambers
- Cleaning net
- Mountages
- Hygrometers and Thermometers
- Feeding stands

Rearing Practices:

Silkworms must be reared with utmost care since they are susceptible to diseases. Therefore, to prevent diseases, good sanitation methods and hygienic rearing techniques must be followed. The appliances and the rearing room should be thoroughly cleaned and disinfected with 2-4% formaldehyde solution. Room temperature should be maintained around 250 C.

Procurement of quality seeds:

The most important step in silkworm rearing is the procurement of quality seeds free from diseases. Seeds are obtained from grainages, which are the centers for production of disease

free seeds of pure and hybrid races in large quantities. These centers purchase cocoons from the certified seed cocoon producers. These cocoons are placed in well-ventilated rooms with proper temperature (23-25o C) and humidity (70-80 %), and emergence of moth is allowed. Grainage rooms may be kept dark, and light may be supplied suddenly on the expected day of emergence to bring uniform emergence. Emerging moths are sexed and used for breeding purposes to produce seed eggs. Three hours of mating secures maximum fertilized eggs. The females are then made to lay eggs on paper sheets or cardboard coated with a gummy substance. Egg sheets are disinfected with 2% formalin, and then washed with water to remove traces of formalin and then dried up in shades. The eggs are transported in the form of egg sheet. However, it is easy to transport loose eggs. To loosen the eggs, the sheets are soaked in water. The loose eggs are washed in salt solution of 1.06-1.10 specific gravity to separate out unfertilized eggs and dead eggs floating on surface. Prior to the final washing, the eggs are disinfected with 2% formalin solution. Eggs are dried, weighed to the required standard and packed in small flat boxes with muslin covers and dispatched to buyers.

Brushing:

The process of transferring the silkworm to rearing trays is called brushing. Suitable time for brushing is about 10.00 am. Eggs at the blue egg stage are kept in black boxes on the days prior to hatching. The next day they are exposed to diffused light so that the larvae hatch uniformly in response to photic stimuli. About 90% hatching can be obtained in one day by this method. In case of eggs prepared on egg cards, the cards with the newly hatched worms are placed in the rearing trays or boxes and tender mulberry leaves are chopped into pieces and sprinkled over egg cards. In case of loose eggs a net with small holes is spread over the box containing the hatched larvae and mulberry leaves cut into small pieces are scattered over the net. Worms start crawling over the leaves on the net; the net with worms is transferred to rearing tray**.**

Preparation of feed bed and feeding:

After brushing, the bed is prepared by collecting the worms and the mulberry leaves together by using a feather. The bed is spread uniformly using chopsticks. The first feeding is given after two hours of brushing. Feed bed is a layer of chopped leaves spread on a tray or over a large area. The first and second instar larvae are commonly known as chawki worms. For chawki worms, paraffin paper sheet is spread on the rearing tray. Chopped mulberry leaves are

sprinkled on the sheet and hatched larvae are brushed on to the leaves. A second paraffin paper sheet is spread over the first bed. In between two sheets water- soaked foam rubber strips are placed to maintain humidity.

The 4th and 5th instars are reared in wooden or bamboo trays by any of the three methods: viz., shelf-rearing, floor-rearing and shoot-rearing. In shelf rearing, the rearing trays are arranged one above the other in tiers on a rearing stand which can accommodate 10 -11 trays. This method provides enough space for rearing, but it is uneconomical as it requires large number of laborers to handle the trays. Chopped leaves are given as feed in this method. In floor rearing, fixed rearing sheets of 5-7x1-1.5m size are constructed out of wooden or bamboo strips in two tiers one meter apart. These sheets are used for rearing. Chopped leaves are given as feed. This method is economical than the first one because it does not involve much labour in handling of trays. Shoot-rearing is most economical of the three methods. The rearing sheet used is one meter wide and any length long in single tier and the larvae are offered fresh shoot or twigs bearing leaves. This method can be practiced both outdoors and indoors depending upon the weather.

Each age of the silk worms could be conveniently divided into seven stages. First feeding stage, sparse eating stage, moderate eating stage, active eating stage, pre-moulting stage, last feeding stage, moulting stage. The larvae have good appetite at first feeding stage and comparatively little appetite at sparse and moderate eating stages. They eat voraciously during active stage to last feeding stage after which they stop feeding.

Bed Cleaning:

Periodical removal of left over leaves and worms' excreta may be undertaken and is referred to as bed cleaning. It is necessary for proper growth and proper hygiene. Four methods are adopted: conventional method, husk method, net method, and combined husk and net method**.**

Spacing :

Provision of adequate space is of great importance for vigorous growth of silkworms. As the worms grow in size, the density in the rearing bed increases and conditions of over-crowding are faced. Normally it is necessary to double or triple the space by the time of moult from one to other instar stage, with the result that from the first to third instar the rearing space increases eight fold. In 4th instar, it is necessary to increase the space by two to three times and in 5th

instar again twice. Thus, the rearing space increases up to hundred folds from the time of brushing till the time of maturation of worms.

Mounting:

Transferring mature fifth instar larvae to mountages is called mounting. When larvae are fully mature, they become translucent, their body shrinks, and they stop feeding and start searching for suitable place to attach themselves for cocoon spinning and pupation. They are picked up and put on mountages. The worms attach themselves to the spirals of the mountages and start spinning the cocoon. By continuous movement of head, silk fluid is released in minute quantity which hardens to form a long continuous filament. The silkworm at first lays the foundation for the cocoon structure by weaving a preliminary web providing the necessary foot hold for the larva to spin the compact shell of cocoon. Owing to characteristic movements of the head, the silk filament is deposited in a series of short waves forming the figure of eight. This way layers are built and added to form the compact cocoon shell. After the compact shell of the cocoon is formed, the shrinking larva wraps itself and detaches from the shell and becomes pupa or chrysalis. The spinning completes within 2-3 days in multivoltine varieties and 3-4 days in uni and bivoltine.

Harvesting of Cocoons:

The larva undergoes metamorphosis inside the cocoon and becomes pupa. In early days, pupal skin is tender and ruptures easily. Thus, early harvest may result in injury of pupa, and this may damage the silk thread. Late harvest has a risk of threads being broken by the emerging moth. It is, therefore, crucial to harvest cocoons at proper time. Cocoons are harvested by hand. After harvesting the cocoons are sorted out. The good cocoons are cleaned by removing silk wool and faecal matter and are then marketed.

The cocoons are sold by farmers to filature units through Cooperative or State Govt. Agencies. The cocoons are priced on the basis Rendita and reeling parameters. Rendita may be defined as number of kg of cocoon producing 1 kg of raw silk.

Conclusion

Sustainable and Profitable: Mulberry silkworm rearing offers a reliable source of income, as mulberry can withstand adverse agricultural conditions and consistently provide leaves for silkworm feeding.

Critical Factors: Proper timing, environmental control (temperature 24–28°C, humidity 70–85%), and disease management are vital for healthy larval growth and optimal cocoon development.

Socio-economic Impact: The practice not only fosters economic opportunities in rural areas but also empowers self-employment and supports livelihoods, underpinning the rural economy in many regions

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ARSENIC CONTAMINATED SOILS AND THEIR REMEDIATION

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Introduction

The toxic element arsenic (As) discovered by Albertus Magnus in 1250 A.D. Arsenic is found in the natural environment in abundance in the Earth's crust and in small quantities in rock, soil, water and air About one third of the arsenic in the atmosphere comes from natural sources. Volcanic action is the most important natural source of arsenic. The next most important natural source is the arsenic-containing vapour that is generated from solid or liquid forms of arsenic salts at low temperatures. The rest two third comes from man-made sources such as mining, metal smelting, burning of fossil *etc.*

Remediation technologies for arsenic contaminated soils

a) Electrokinetic system

In situ electrokinetic treatment of arsenic uses the natural conductivity of the soil (created by pore water and dissolved salts) to affect movement of water, ions, and particulates through the soil. Water and/or chemical solutions can also be added to enhance the recovery of metals by electrokinetics. Positively charged metal or metalloid cations, such as As (V) and As (III) migrate to the negatively-charged electrode (cathode), while metal or metalloid anions migrate to the positively charged electrode (anode). Extraction may occur at the electrodes or in an external fluid cycling/extraction system. Alternately, the metals can be stabilized in situ by injecting stabilizing agents that react with and immobilize the contaminants. Arsenic has been removed from soils treated by electrokinetics using an external fluid cycling/extraction system.

b) Soil washing/acid extraction

Soil washing is an ex situ technology that takes advantage of the behaviour of some contaminants to preferentially adsorb onto the fines fraction. The soil is suspended in a wash solution and the fines are separated from the suspension, thereby reducing the contaminant concentration in the remaining soil. The choice of chemicals used for extractant and high cost have often restricted the usage of soil washing into a smaller-scale operations as it is the disadvantages of using soil washing method.

c) Phytoremediation

Phytoremediation is an emerging technology generally applicable only to shallow contamination that can be reached by plant roots. The mechanisms of phytoremediation include phytoextraction, enhanced rhizosphere biodegradation, phytodegradation and phytostabilization. Hyperaccumulating fern (*Pteris vittata)* has been used in the remediation of arsenic-contaminated soil, waste, and water. This fern can tolerate as much as 1,500 ppm of arsenic in soil (Mandal *et al*, 2012).

d) Vitrification for arsenic

Vitrification is a high temperature treatment aimed at reducing the mobility of metals by incorporating them into a chemically durable, leach resistant, vitreous mass. This process also may cause contaminants to volatilize or undergo thermal destruction, thereby reducing their concentration in the soil or waste. Vitrification occurs at temperatures from 2,000 to 3,600^{0}F (Mandal and Suzuki., 2002).

e) Biological treatment for arsenic

Biological treatment of arsenic is based on the theory that microorganisms that act directly on arsenic species or create ambient conditions that cause arsenic to precipitate/ co-precipitate from water and leach from soil and waste. *Corynebacterium glutamicum, Bacillus sphaericus, Rhodococcus, Arthrobacter, Acinetobacter, Agrobacterium, etc* are used to remediate cadmium contaminated soils.

f) In situ soil flushing for arsenic

In situ soil flushing techniques may employ water or a mixture of water and additives as the flushing solution. Additives may include acids (sulfuric, hydrochloric, nitric, phosphoric, or carbonic acid), bases (for example, sodium hydroxide), chelating or complexing agents (such as

EDTA), reducing agents, or surfactant to aid in the desorption and dissolution of the target contaminants

g) Solidification and stabilization (S/S)

The stabilization process involves mixing a soil or waste with binders such as Portland cement, lime, fly ash, cement kiln dust, or polymers to create a slurry, paste, or other semi-liquid state, which is allowed time to cure into a solid form. When free liquids are present the S/S process may involve a pretreatment step (solidification) in which the waste is encapsulated or absorbed, forming a solid material. Pozzolanic binders such as cement and fly ash are used most frequently for the S/S of arsenic.

Volume: 05 Issue No: 10

POPULAR BRINJAL VARIETIES SUITABLE FOR CULTIVATION IN TAMIL NADU

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Introduction

Brinjal is a diploid species with chromosome number 2n=2x=24, One of the most important tropical vegetable crops grown in India. A large number of cultivars differing in size, shape and colour of fruits are grown in India. Brinjal is originated in Indo-Burma region. Crop is distributed in south and south East Asia, southern Europe, China and Japan. Genus Solanum comprises approximately 2000 species, which include both tuber bearing and non-tuber bearing forms. Important edible species tuber bearing forms are S. melongena, S. torvum, S. nigrum, S. macrocarpom, S. ferox and S. aethiopicum, S. torvum-used for its small clustered fruits for curry purpose and for drying. It is grown as a wild plant in backyards and roadsides. Due to its resistance to Fusarium wilt and bacterial wilt, S. torvum can be a resistant root stock for grafting cultivated S. melongena. S. macrocarpom and S.aethiopicum-grown for edible fruits. Studies on inter-specific hybridization revealed incompatibility between cultivated S. melongena with other species, except with S. incanum.

Brinjal a self-pollinated crop, cross pollination to varying degree has been reported in brinjal. Cross pollination is due to its heteromorphic flower structure and is mainly by honey bees and bumble bees. Depending on length of style in relation to position of anthers, four types of flowers-heterostyly are available. Long styled-stigma well above the anthers, Medium styled-stigma and anthers at same level, Short styled-style short, Pseudoshort styled-style rudimentary.Fruit set in long styled flowers ranges from 60 to 70% whereas in medium styled flowers it is 12.5 to55.6%, Short styled and pseudoshort styled flowers act as male flowers and there is no fruit.

Opening of flower and dehiscence of anthers are almost simultaneous and it takes place at 6-7.30 am during summer and is delayed up to 11 am during winter Flowering depends on climatic factors and high temperature and humidity in the morning hasten flower opening and dehiscence of anthers. In addition to climatic factors, fertility level of the soil also influences flower initiation and development.

A long and warm growing season with a temperature range of 21-270C is ideal for its production. Crop is adversely affected by chilling temperature of winter in North India. Generally late cultivars can withstand low temperature than early ones. Plants grown luxuriantly and yield heavily during rainy season under warm humid climatic condition of Kerala.

India is the second largest producer of brinjal in the world next to China.. Immature fruits are used in curries and a variety of dishes are prepared out of brinjal. It is known by different names like Kathiri (Tamil), Ringna (Gujarathi), Baingan (Hindi), Vashuthana (Malayalam), venkaya .Fruits are good sources of vitamins and minerals like phosphorous, calcium and iron. Brinjal has got decholestrolizing property primarily due to presence of poly-unsaturated fatty acids (linoleic and lenolenic). Presence of magnesium and potassium salt in fruits also impart de-cholestrolizing action. Medicinal properties like treatment of liver diseases, cough due to allergy, rheumatism, colilithiasis, leucorrhea and treating intestinal worms.

Popular Varieties

Fruits of some local cultivars exhibit bitterness due to presence of glycolalkaloids like solanin. Generally glycol-alkaloid content varies from 0.37 to 4.83 mg/100g in most of cultivars. High glycol-alkaloids (20 mg/100g fresh weight) produces bitter taste and off flavour.

A large number of cultivars and improved varieties differing in size, shape and colour of fruits are grown in India. Since consumer preference varies from region to region and from district to district, judicious selection of varieties plays an important role in success of brinjal cultivation.

The important features of improved brinjal varieties developed in India are furnished below.

Popular varieties developed by Tamil Nadu Agricultural University

1. CO 1-

- ✓ It was developed from the vegetable section of the then agricultural college and Research Institute, Coimbatore.
- ✓ It is a pureline selection.

- ✓ The plants are compact and bushy.
- ✓ It has a yield potential of 20-25 tones/ha.
- ✓ The fruits are Oblong, pale green fruits and soft seeded even at full maturity with pale green shade under white background.

It is preferred in the markets of Tirunelveli, Ramananthapuram district and also Karnataka State.

2. CO 2-

- ✓ This variety was developed at the Department of Vegetable crops, College of Horticulture, Tamil Nadu Agricultural University, and Coimbatore.
- ✓ It is a pure line selection from local vanety called varikkathiri in the village Negamam of Pollachi taluk, Coimbatore district.
- ✓ Oblong fruits having dark purple streaks under pale back ground
- ✓ The plants are compact with slightly oblong fruits having dark purple streaks.
- ✓ It has a great preference in Coimbatore and Erode districts of Tamil Nadu.
- ✓ It yields about 35 tones/ha in crop duration of 150 days.

3. PKM 1-

- ✓ It was evolved at the then Horticultural Research Station, Periyakulam of Tamil Nadu Agricultural University.
- ✓ Developed from a local type called Puzhuthi Kathiri through mutation breeding.
- ✓ Small ovate fruits with green stripes
- ✓ It is adapted to rainfed cultivation in Madurai and Anna Districts.

4. PLR 1-

- ✓ Small to medium sized egg shaped fruits with purple colour
- ✓ Developed at the vegetable Research station, Palur of TNAU in cuddalore district of Tamil Nadu.
- ✓ The fruits are small to medium in size, sometimes borne in clusters, egg shaped and with bright glossy purple colour
- ✓ It fetches premium price in the markets of Cuddalore, Chengalpattu and chennai
- ✓ It has got a shelf life of 8-10 days under ambient temperature
- ✓ It yields on an average 25 tones/ha

5. MDU 1-

- ✓ It is a pure line selection from a local type called kallampatti developed at the Department of Horticulture, Agricultural College and Research Institute, Madurai
- ✓ The fruits are Large, round and purple colour size each weighing about 200-250g.
- ✓ As the fruit matures, the purple color fades to pale pink.
- ✓ It has got a yield potential of 30 tones ha.
- ✓ Duration 135-140 days.
- ✓ Preferred in Madurai and Trichy districts people and also in Kerala State.

6. KKM 1-Small, white coloured and egg shaped fruits borne in clusters of 2-4

Annamalai variety

1. Annamalai brinjal

- ✓ Aphid resistant variety developed at the department of Horticulture, Faculty of Agriculture, Annamalai University.
- ✓ The fruits are oblong, deep purple in colour with a characteristic yellowish mark along the calyx border and a few thorns on the calyx surface
- ✓ This is preferred in Cuddalore, Villupuram, Vellore, Thiruvannamalai and chengalpattu districts people and Chennai market.
- ✓ It has a yield potential of 20-22 tones/ha.

Soil Type

Rich organic matter with fertilesoil and Well drained soil is suitable with pH of 6.5-7.5.

Season of Sowing

December – January

May – June season higly suitable for brinjal cultivation

Nursery

Thirty days old seedlings are transplanting from nursery to main field.

Main Field

Apply FYM @ 25 t / ha, Follow Ridges and Furrows system at a spacing of 60 cm.

Apply 2 kg / ha of Azospirillum and 2 kg / ha of Phosphobacteria by mixing with 50 kg of FYM.

Irrigate the field and transplant 30-35 days old seedlings.

Spacing

Varieties: Ridges to Ridges spacing 60 cm, Plant to plant spacing 60 cm

Hybrids: Ridges to Ridges spacing 90 cm, Plant to plant spacing 60 cm

Weed control

Weed control is one of the important operation in brinjal cultivation Apply Pendimethalin or Fluchloralin 1.0 kg a.i / ha as pre-emergence herbicide, followed by hand weeding once at 30 days after planting.

Harvest

Harvesting can starts from 55 – 60 days old crop. Fruits are harvested at tender stage at 4 – 5 days intervals.

Yield

Varieties : 25 to 30 t/ha

Hybrids : 60 - 80 t/ha

Volume: 05 Issue No: 10

OSCILLATING MAGNETIC FIELD PROCESSING OF FOODS

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Introduction

As global demand for safe, high-quality, and minimally processed foods continues to grow, the food industry faces increasing pressure to adopt innovative preservation techniques that can ensure microbial safety without compromising nutritional and sensory attributes. Traditional food processing techniques are effectively inactivating microorganisms and enzymes, these techniques often lead to undesirable changes in texture, flavor, color, and nutritional content. This has spurred a wave of interest in non-thermal food processing technologies that can deliver similar levels of safety while preserving the fresh-like quality of foods. The nutritional and sensory qualities of food may be compromised by traditional thermal treatments. In response, non-thermal technologies, which are environmentally friendly, safe, and sustainable, are becoming increasingly necessary. One such emerging technology is the use of oscillating magnetic fields (OMFs).

Oscillating magnetic fields are time-varying magnetic forces generated through alternating current. These fields have the unique ability to penetrate food materials without causing significant temperature increases, making them a promising candidate for non-thermal food preservation. The principle behind OMF technology is based on the interaction between magnetic fields and biological molecules, leading to the disruption of microbial cells and the inactivation of enzymes. Unlike conventional thermal treatments, this process does not rely on heat, thus maintaining the integrity of the food's original characteristics. The interest in magnetic field applications in food preservation is not entirely new. Static magnetic fields have been studied for their effects on biological systems for decades. However, it is the oscillating or

alternating magnetic fields that have shown greater potential in food processing due to their dynamic nature and ability to influence molecular-level activities. These fields can be tailored in terms of frequency, intensity, and exposure time, offering a versatile and controllable means to achieve desired food safety outcomes.

Recent scientific research has demonstrated the effectiveness of OMFs in reducing microbial populations in a variety of food matrices, including liquids like milk and juice, and solid foods such as meats and fresh produce. Moreover, OMFs have shown potential in deactivating spoilage enzymes that are responsible for quality deterioration, such as browning in fruits and vegetables. These benefits not only extend the shelf life of perishable foods but also reduce food waste and support sustainability goals in the food sector. In this article, we delve into the fundamentals of oscillating magnetic fields, explore their mechanism of action in microbial and enzyme inactivation, examine the methods used for their generation, and discussed the applications in the food industry. With growing evidence supporting its efficacy, OMF technology may soon become a cornerstone of modern, non-thermal food processing.

2. Mechanisms of Microbial Inactivation

Oscillation shows promise in potentially deactivating microorganisms present in food. Various theories have been proposed to explain the impact of magnetic fields on biological systems. Two primary models are commonly used for microbial inactivation: the Ion Cyclotron Resonance (ICR) model and the Ion Parametric Resonance (IPR) model. In the ICR model, the ions within the cell, including the interaction site of the Oscillating Magnetic Field (OMF), play a role in transmitting the effects of magnetic fields to components such as the cytoskeleton, organelles, nuclear membrane, chromosomes, and protein molecules. The response to the magnetic field's intensity is diffused and delayed in tissues other than the interaction site. On the other hand, the IPR model focuses on how an ion cofactor in a crucial molecular complex, such as an enzyme binding site, can alter the conformational states of that complex. Changes in the interactions between ions and molecules, particularly proteins, lead to cellular-level changes. This model predicts the ion's response based on variations in the magnetic flux densities of AC and DC magnetic fields, AC frequency, and charge-to-mass ratio (Barbosa-Cánovas, G.V., 1998).

3. Generation of High Intensity Magnetic Fields

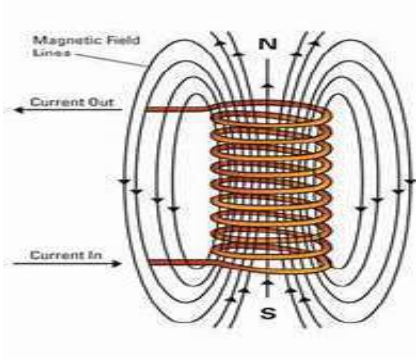
In high magnetic field applications, superconducting coils are employed. These coils

carry an electric current of up to 40kA. To initiate the process, a high-voltage DC power supply charges the capacitor. Upon closing the switch, this action generates oscillating current within the capacitor. Consequently, an oscillating magnetic field is induced in the food material placed within the magnetic coil. To effectively deactivate microorganisms, a flux density ranging from 5 to 20 T (Tesla) is required, representing a high-intensity condition. This level of oscillating magnetic field (OMF) density can be generated using the method proposed by Gersdorf et al in 1983:

- Superconducting coils
- Coils with produce dc fields
- Coils energized by the discharge of energy stored in a capacitor.

When the core is inserted into the coil, made of paramagnetic or ferromagnetic material, it enhances the production of magnetic fields, making them more intense (fig 1.a). To generate magnetic fields of up to 20 T, superconducting coils are required. To maintain the superconductor filaments below their critical temperature of 4.2K, liquid helium serves as the coolant for superconducting materials, while liquid nitrogen is utilized for higher temperatures (fig.1.b.). It is possible to create magnetic fields stronger than 30 T with this combination. As a result, the system uses a capacitor bank to store energy that is then released by creating an oscillating electrical current, which in turn creates an oscillating magnetic field (OMF).

The capacitance of the capacitor, along with the resistance and inductance of the coil, dictate the frequency and intensity of the magnetic field. Compared to resistive electromagnets, superconducting magnets provide a number of advantages. Usually, they keep the field more steady, which results in readings that are less noisy.



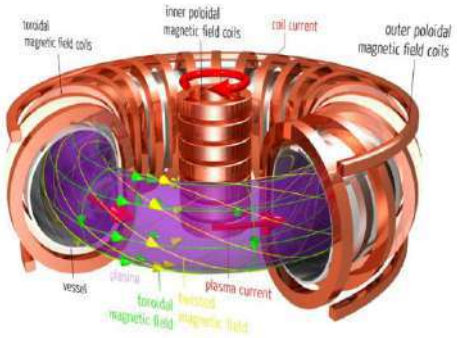


Fig 1.a Coils that produce DC fields Fig 1.b Superconducting coils

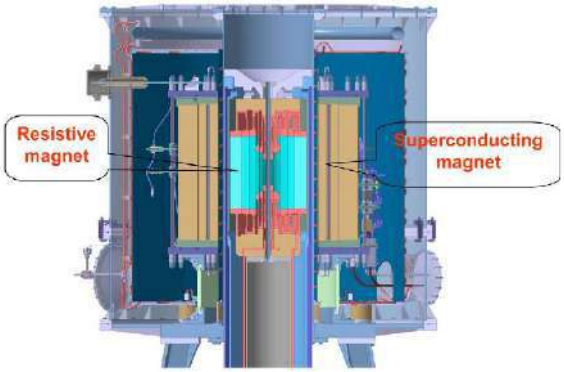


Fig 1.c Hybrid magnets

Additionally, superconducting magnets can be smaller, giving designers additional options for how to arrange the device's other parts. Furthermore, they use a great deal less energy, with their steady-state power consumption being minimal. However, cooled resistive and hybrid magnets can reach higher fields because, at high fields, superconducting coils change into a normal, nonsuperconducting state, which causes Joule heating phenomenon.

4. Critical process factors:

Critical process variables such as magnetic field properties, electrical resistivity, microbiological kind, microbial development stage, treatment duration, and treatment temperature largely determine how well magnetic field treatments work on microbial populations.

1. **Magnetic Field:** Exposure to a magnetic field has the potential to either stimulate or inhibit the growth and reproduction of microorganisms. Typically, a single pulse with an intensity ranging from 5 to 50 T and a frequency between 5 to 500 kHz leads to a reduction in the microbial population by at least 2-log cycles (Hoffman 1985). Highintensity magnetic fields can influence the fluidity of cell membranes and other cellular properties. Nevertheless, the inconsistent results observed in various inactivation studies prevent making definitive statements about the microbial inactivation efficiency of magnetic fields or making predictions about their effects on microbial populations. In the case of OMF specifically, exposure induces an electrical current in the treated product.

2. **Electrical Resistivity:** Electrical resistivity quantifies a material's resistance to the flow of electrically charged particles. High electrical resistivity typically more than 10 to 25 ohms-cm is required for foods to deactivate microbes when exposed to OMF. The electrical resistance and

thickness of the food being magnetized determine how strong the applied magnetic field should be. Products with higher resistivity and thickness are treated with larger magnetic field strengths.

3**. Microbial Growth Stage:** Tsuchiya et al., (1996) conducted research involving both homogeneous (7 T) and inhomogeneous (ranging from 5.2 to 6.1 T and 3.2 to 6.7 T) magnetic fields, revealing a growth stage-dependent response in Escherichia coli bacterial cultures. Initially, the ratio of cells exposed to a magnetic field compared to those under the geomagnetic field was less than 1 during the initial 6-hour treatment period but exceeded 1 after 24 hours. Additionally, these authors observed that cellsurvival rates were higher in inhomogeneous fields when compared to homogeneous fields. They postulated that magnetic fields might function as a source of stress. In order to study this, cells that were obtained during the stationary phase following a protracted magnetic field treatment or after 30 minutes of incubation under magnetic field treatment (lag or early lag phase) were heated to 54ºC. Remarkably, there were no appreciable variations found between the control and treatment samples. On the other hand, nothing is still known about how the stage of microbial growth affects a cell's sensitivity to magnetic fields.

4. **Temperature:** Our understanding of the relationship between microorganism inactivation and temperature remains limited. In a study by Berk and colleagues (1997), the impact of 71 and 106 mT magnetic fields on three potentially pathogenic amoebae was assessed. Their findings indicated that, following a 72-hour exposure to magnetic fields at temperatures of 20ºC or higher, there was a significant reduction in the number of amoebae across all three species. The final counts of amoebae exposed to the magnetic field ranged from 9% to 72% lower than counts in samples that were not exposed to the magnetic field.

5. Applications in Food Processing Industry:

Oscillating magnetic fields (OMFs) have emerged as a promising non-thermal technology in food processing, particularly for extending shelf life and preserving quality. Recent studies have highlighted their role in supercooling and freezing applications: Lee et al. (2024) demonstrated that OMF treatment, in combination with pulsed electric fields, suppressed ice crystal formation and maintained the quality of Atlantic salmon fillets during storage, while Kang et al. (2021) showed that OMFs effectively inhibited ice nucleation in water and fresh-cut mango, thereby reducing freezing damage. Similarly, Otero et al. (2023) found that OMFs enhanced supercooling stability and altered ice nucleation kinetics in model food systems, suggesting

potential for improving frozen storage. Beyond freezing, OMFs have also been reported to influence enzyme activity and microbial safety, offering avenues for controlling spoilage reactions and enhancing food preservation. A comprehensive review by Miñano et al. (2020) further emphasized that OMFs can serve as an energy-efficient, non-invasive approach to improving food quality, safety, and storage stability, making them an attractive tool for future food processing applications.

Conclusion

Oscillating magnetic field (OMF) technology represents a promising non-thermal approach for food preservation, offering the ability to inactivate microorganisms and enzymes while maintaining the nutritional and sensory qualities of foods. By influencing microbial cell structures, enzyme conformations, and ice nucleation processes, OMFs have demonstrated potential in enhancing microbial safety, controlling spoilage, and improving freezing and supercooling stability. Critical factors such as field strength, frequency, exposure time, electrical resistivity of food, and microbial growth stage significantly influence treatment efficacy. Although challenges remain in terms of process standardization and scalability, current evidence highlights OMFs as an energy-efficient, sustainable, and versatile tool that could complement or replace conventional thermal methods in the food industry. Further research on optimizing process parameters and validating large-scale applications will be essential to fully realize the potential of OMFs in modern food processing.

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POLLINATOR MANAGEMENT IN ONION SEED PRODUCTION

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Introduction

Pollinators play a critical role in the success of onion seed production, with bees especially Apis species as well as non-Apis being the primary pollinators. Effective pollinator management not only ensures high-quality seed yield but also promotes biodiversity within the agro-ecosystem. Here's a comprehensive guide to managing pollinators efficiently while balancing pest control in onion crops.



Fig 1. Onion seed production field

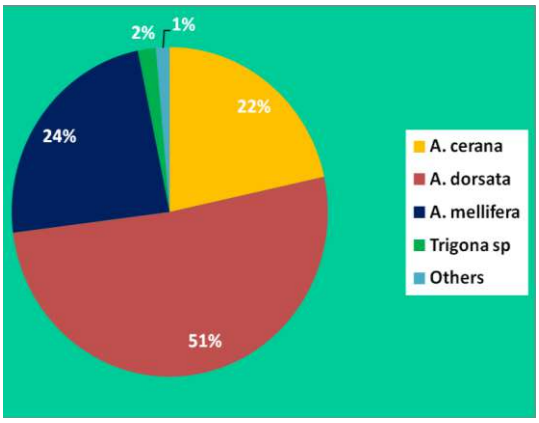


Fig 2. Abundance of insect pollinators in onion



Fig 3. Rock bee foraging in onion umbel

Chemical control with bee safe practices

Onion thrips (*Thrips tabaci*) are a major pest concern, but controlling them must not come at the cost of pollinator health. Since bees are highly sensitive to insecticides, the following best practices are advised. Follow window strategies for pesticide application. Use neem based formulations 2-3 mi/litre and entomopathogenic fungus Lecanicillium lecanii @ 5 g/litre for controlling onion thrips. Whenever the thrips infestation is severe apply insecticides like Profenophos @ 1 ml/litre, Fipronil @ 1 ml/litre, Carbosulfan @ 2 ml/litre. Apply these only until umbel initiation, and strictly and completely avoid spraying after flowering begins to prevent harm to visiting bees. Prefer late evening applications when bee foraging activity is minimal, reducing their exposure to toxic chemicals.

Crop planning to support pollinator activity

To enhance bee visitation, plant attractant crops such as mustard, fennel, or coriander around or within the onion field. For best results, sow mustard as a border or intercrop two weeks after onion transplanting. Ensure these attractant crops are removed before umbel initiation to focus bee activity on the onion flowers. The selection of surrounding crops significantly influences pollinator behavior and efficiency. Avoid planting bee attractive crops near onion seed fields during flowering. Instead, use non-attractive crops like grains and tomatoes as border crops.

Optimize nectar production through good agronomic practices

Healthy nectar production is essential for attracting and sustaining pollinator visits.

Maintain balanced fertilizer application and proper irrigation. Avoid overly dry or waterlogged conditions, as both reduce nectar secretion. Ideal irrigation is every 10-12 days, depending on soil type and weather conditions.

Strategic hive placement

Introducing managed bee colonies can significantly boost pollination rates, especially in open-pollinated onion varieties. Deploy *Apis mellifera* or *Apis cerana* hives at a rate of 4-6 hives per acre or *Tetragonula* sp hives @ 8-10 per acre to enhance the pollination. Place hives in and around the field with sufficient shade. Always orient the hive entrance towards the interior of the field to encourage foraging within the crop. Maintaining hive health and foraging behavior as healthy bee colonies are key to sustained pollination. Use colonies that are disease, pests and mite-free, with good foraging strength. Inspect hives regularly to monitor colony health.

Enhance bee visitation using commercial bee attractants like Bee-Q @ 15 g/litre 5% sugar syrup or 10% molasses spray around the crop

Conclusion

Bees-both *Apis* and non-*Apis* species are vital pollinators in onion seed production. The frequency, timing, and type of their floral visits directly influence seed set and yield. However, threats such as indiscriminate pesticide use, declining pollinator diversity, and anthropogenic pressures like urbanization can hinder pollination efficiency. To ensure sustainable seed production, it is imperative to protect, attract, and conserve these natural pollinators. Adopting pollinator-friendly practices not only supports high yields but also contributes to a healthier agro-ecosystem.

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NAGATENGA – AN UNDERVALUED FRUIT OF NORTH EASTERN INDIA

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Introduction

The north-eastern region of India is endowed with a large number of rich genetic diversity of underutilized indigenous lesser known fruits. These fruits are being used by the local people since long. Being rich in plant food elements like vitamins, minerals, antioxidants they are serving as protective food. A few of them have good flavour, colour, juice and pulp content for which they can be used for preparation of different value added fruit based products. Nagatenga(Rhus chinensis) is one of them.

Origin and Distribution

Nagatenga: (Rhus Chinensis) is a sub-temperate to subtropical deciduous small fruit tree, native to East Asia including China and Japan. It is distributed from foot hills to the lowland forest areas of India. Nagatenga is extensively grown in China, Japan and other Asian countries. In India it is predominantly grown in the state Nagaland, Meghalaya, Sikkim, Assam and Mizoram. The largest area belongs to Mizoram State. Nagatenga flourishes in environments including foot hills, low lands, forest, sunny slopes, valleys, streams and roadsides. It's name varies from region to region including 'Sohma' in Khasi, 'Tangmo' in Naga, 'Khimta' in Garo and 'Khahmha' in Mizo.

Plant Morphology

Nagatenga is a large shrub or small deciduous tree that grows to a height of 6-8 meters with open sprading crown. The leaves are ovate to oblong in shape and pinnately compound comprising 7 to 10 leaflets. Leaflets are toothed along the margin and look bright green in colour

above and pubescent beneath with densely rusty velvet hair. The petioles are often winged. The leaves turn red in autumn before falling on the ground. Creamy white flowers in large round panicles are produced at the terminal end of the shoots. The panicles are 15 to 20 cm long. Being diocious in nature male and female flowers are produced in separate plants. Blooming time of this fruit plant is August and September. Only the pollinated flowers can bear the fruits. The fruits are small and round in shape. They turn orange and red in colour during the time of maturity containing only a single seed inside.





Nutritional properties

Nagatenga fruits are richer sources of different nutrients and health protective compound like vitamins, minerals, antioxidants and other phytochemicals which have high nutritional value. The pulp of ripe fruits are loaded with protein, fat, dietary fibre, vitamins (Vitamin C, B-6 and B-9), minerals like iron, phosphorus, magnesium, and zinc, antioxidants (Lycopene, bête-carotene and quercetin), polyphenols, flavonoids, galic acid, linoleic acid and oleic acid. The fruits are also rich in organic acid like malic, citric and ascorbic acids. 100g of edible ripe fruit pulp contains 50-60g. carbohydrates. 4.25g. protein, 11.32g. moisture, 4.0g. ash, 95 mg. Vitamin C, 220mg phosphorus, 20mg. iron, 15mg. magnesium, and 2.4mg. zinc.

Health Benefits

Consumption of ripe fruits help to reduce ageing, cancer and cardiovascular disease. The fruits are wonderful source of different types of nutrients which will be very effective for controlling the hidden hunger among the under privilege rural people of north eastern region.

The fruits are used for curing different ailments like diarrhoea, dysentery, cold and cough and urine bleeding. The fruits have also anti-virus, antibacterial, anti-inflammatory and anticancer properties. Fruit juice is used by the local people traditionally for curing various intestinal disorders.

The concentrated food extract is locality called “Bhakim-lo-ko-cuk” in Nepali language which has long been used in sikkim himalaya for the treatment of gastro intestinal disorder, dysentery and respiratory troubles. The fruits are also used to cure jaundice, alcoholism and hepatitis. The seeds are used traditionally for the treatment of cough, dysentery, fever, malaria, rheumatism and jaundice. Different parts of this plant like leaves, steam, roots, fruits and seeds are used for that treatment of gastro intestinal disorders. The leaves can stimulate blood circulation and help to cure stomach ache, snake bite, diarrhoea and hepatitis.



Uses

The acidic fruits of nagatenga are used in east asian cuisines for their tangy flavour and high nutrient content. They are used as often raw, ripe, dried and powdered and added so savory and sweet dishes, fermented product and beverages. The ripe fruits are commonly used as appetizer, beverage and natural vinegar by the local people. They are also suitable for making different value added products like pickle, chutney and sauces for future use. The fresh fruits are sour and delicious in taste. They are sold in local village market or hat. Due to high tanin content, the fruits can be served as a natural thickening agent in certain recipes. A very refreshing drink is also prepared from freshly harvested fruits for quenching thirst during hot summer. Delicious sour pickle can be prepared by perfect blending of mustard oil and spices with fresh fruits. The tangy and citrus like flavour of it is used to enhance the taste of meats, salads and other dishes. It can also be added to the marinade, rub and spice blends for a distinct taste. The fruit oil has been approved as a nobel food ingredient for daily consumption in China

due to its nutritional and health benefits.

Soil and Climate

Nagatenga can easily be grown in dry to medium moist well- drained soil. Full sunlight to partial shady condition is ideal for its growth and development. It commonly grows in sub-tropical climate in an altitude of 1300 to 2000 metre.

Propagation

This indigenous fruit can be propagated by seeds, semi hard wood stem and root cuttings. This plant can also be multiplied naturally by root suckers. Pre-soaking of seeds for 24 hours in hot water (72^0-80^0C) is done to break the dormancy by cracking the hard seed coat and leaching germination inhibitors. Sowing pre-treated seeds on seedbed should be done in a cold frame. Seedling can be moved into individual pots before being planted in the field in late spring or early summer.

Semi hard wood stem cutting of 10 cm each should be planted in a rooting medium in July and August month for root and shoot formation. There after they are placed in a frame. 4cm long root cutting are placed in rooting medium in a greenhouse during December for raising saplings. New shoots that are arising from the roots should be collected as suckers in late autumn or winter for final planting in the beds.

Harvesting

The ripe fruit clusters are collected by hand or with a sharp knife when their green leaves begin to turn brown indicating their ripening stage. The ideal time of harvesting of fruits is from November to December. Some fruits are allowed to remain on mother plants for natural propagation.

Post-Harvest Handling

The harvested fruits should be thoroughly cleaned to remove the debris and maintain the quality and sanitation standards. For long-term storage the fruits are often dried under sunlight for 7 days to minimise water content which is crucial for preventing the spoilage and facilitating further processing. Modern method of drying of fruits may involve oven drying at temperature around 55^0 - 60^0C for 3-4 hours. After drying, the fruits are often pulverized or crushed into a fine powder or pulse. It should be done immediately after drying so as to retain the distinct flavour and taste of fruits.

Storage

The dry fruits should be stored in airtight containers at low temperature of 4^0C for preserving the fruits and their bioactive components for later formulation and analysis. Store food can be used to prepare different value added products. Storage structure may also be constructed for proper storing of harvested fruits for making available in the market throughout the year and also to minimise the post-harvest losses.

Value addition

Self-life can be extended by processing of the fruits in to different value added products. Different value added products like juice, jam, tea, tablets and candy can be prepared from the fruit pulp to enhance it's nutritional and medicinal properties such as high fibre, minerals and antioxidant content. The fruits are also used in condiments, beverage and vinegar. Additionally the oil from its fruits is considered as novel edible oil with having potential benefits for reducing fatigue and also fermented extracts are used to create antioxidant and skin whitening cosmetic products.

Fruit Processing Industries

Food processing industries may be established with good transportation facility near the area of production for ensuring proper utilization of entire quantity of fruits produced.

Potentiality

Nagatenga has great potential for commercial exploitation which yet to be achieved. As it is well adapted to marginal land and local climatic condition needs less care and management. It may thus be of benefit for the survival of the poor people, their employment generation, restoration of its natural habitat and sustainability of existing agricultural ecosystem.

Constraint

Nagatenga is a crop that holds great potential for use in technical foods and medicines. However, due to its wild origin and lack of standardized research work the crops variability in plant materials posses challenges. To fully realize this fruits crops potential, these challenges must be address by establishing consistent cultivation practices and scientific protocols.

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GERMPLASM CONSERVATION IN TOMATO

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1. INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is a highly valued vegetable crop within the solanaceous group, adaptable to both open fields and greenhouse cultivation. Tomato is vernacularly called Tomator (in hindi), Takkaali (in kannada, Tamil and Malayalam), Khamrn Asinba (in Manipuri), Golabhenda (in napali), Bilahi Beguna and Tomyato (in Bengali). Tomato is a fruited vegetable largely cultivated all over the world as well as in India. In India it is used in almost all dishes of curries as well as a salad. Tomato plays a major role in the vegetable economy of India. It holds significant commercial importance in human nutrition, featuring over 3,000 species among solanaceous vegetables. Tomato cultivation includes two main types: cultivated and wild forms, with wild types exhibiting remarkable genetic diversity, especially in self-incompatible species like *S. chilense* and *S. peruvianum*. This crop thrives across tropical and subtropical regions globally and is considered a protective food, rich in nutrients such as beta-carotene, lycopene, vitamin C, and flavonoids. Lycopene, known for its antioxidative and anti-cancer properties, has boosted the tomato's popularity, particularly in recent years.

2. TAXONOMY OF TOMATO

Rank	Classification
Kingdom	Plantae
Subkingdom	Tracheobionta
Division	Magnoliophyta

Rank	Classification
Class	Magnoliopsida
Order	Solanales
Family	Solanaceae (Nightshade family)
Genus	*Solanum*
Species	*Solanum lycopersicum* L.

The tomato *(Solanum lycopersicum*) belongs to the Solanaceae family and has a chromosome number of 2n = 2x = 24 (Jenkins, 1948; Peralta et al., 2008). Initially classified under the genus Lycopersicon, it was later reintegrated into Solanum based on molecular phylogenetic studies (Peralta et al., 2008; Asamizu and Ezura, 2009). Advances in DNA sequencing during the 1990s led to a revision of the Solanaceae family's classification, confirming that tomatoes share closer genetic ties with other Solanum species, such as potatoes and eggplants.

Taxonomic studies by Müller (1940) and Luckwill (1943) classified tomatoes into two subgenera:

1. Eulycopersicon: This included cultivated tomatoes (*L. esculentum*) and *L. pimpinellifolium*, characterized by smooth red to yellow fruits, bractless inflorescences, and self-fertility.

2. Eriopersicon: This includes wild species like *L. peruvianum*, *L. hirsutum*, *L. glandulosum*, and *L. cheesmanii*, which had pubescent green or striped fruits, bracteate inflorescences, and were mostly self-incompatible.

3. WILD RELATIVES OF TOMATO

A variety of Solanum species exhibit distinct fruit colors and habitats. For example:

- ***S. lycopersicoides***: This produces green-yellow fruits that turn black when ripe and grows on dry, rocky slopes in Peru and Chile.
- ***S. pennellii***: This bears green fruits and is found in arid regions from Peru to Chile.
- ***S. chilense***: This species has green or purple-striped fruits and thrives in hyper-arid environments
- ***S. cheesmaniae***: This produce yellow to orange fruits and are endemic to the Galápagos Islands.

Further revisions by Warnock (1988) recognized nine species within Lycopersicon. Jenkins (1948) suggested that the likely ancestor of cultivated tomatoes was *L. esculentum* var. *cerasiforme*, widely found across tropical and subtropical America. While cultivated tomatoes are largely self-fertile, certain wild species remain self-incompatible, necessitating cross-pollination.

The taxonomy of tomatoes (*Solanum lycopersicum*) is based on morphological traits, phylogenetic relationships, and geographic distribution. Among the species, *S. galapagense* and *S. cheesmaniae* are endemic to the Galápagos Islands, while the cultivated tomato and its weedy forms are distributed worldwide.

Peralta *et al.* (2005) identified and illustrated two new wild tomato species, *Solanum arcanum* and *S. huaylasense*, which were separated from *Solanum peruvianum* sensu lato. These species were categorized alongside other segregates of *S. peruvianum* sensu lato, *including S. peruvianum* sensu stricto and *S. corneliomulleri*, as well as the morphologically similar *S. chilense*. Additionally, Peralta (2007) described two species in Solanum section Juglandifolia (*S. juglandifolium* and *S. ochranthum*), which are closely related to wild tomatoes and are found in Colombia, Ecuador, and Peru. Two other species, *S. lycopersicoides* and *S. sitiens*, belong to Solanum section *Lycopersicoides* and are distributed in southern Peru and northern Chile

Table 1. The crossability nature of different species of *lycopersicum*

Species	**Common Name**	**2n No.**	**Reproductive Feature**
L. esculentum	Common tomato	24	SP
L. pimpinellifolium	Currant tomato	24	SP + CP
L. cheesmanii	Wild species	24	CP
L. peruvianum	Wild species	24	SI
L. chilense	Wild species	24	SI
L. hirsutum	Wild species	24	SF, SI
L. pennellii	Wild species	24	SF, SI
L. chmielewskii	Wild species	24	SP
L. parviflorum	Wild species	24	SP

SP-Self-pollinated; CP-Cross-pollinated; SF-Self-fertile; and SI-Self-incompatible (**Ram, 2006)**

Later, Rick and Lamm (1955) emphasized the distinctiveness of *L. chilense*, while Thompson and Kelly (1957) classified tomatoes into two main species (L. *esculentum* and L. *pimpinellifolium*) with several botanical varieties.

Peralta *et al*. (2008) classified tomato species into four informal groups within Solanum section Lycopersicon:

1. Lycopersicon group: Includes *S. lycopersicum, S. cheesmaniae*, *S. galapagense*, and *S. pimpinellifolium*, known for their red or orange fruits.

2. Arcanum group: Comprising S. arcanum, *S. chmielewskii*, and *S. neorickii*, characterized by green fruits.

3.'Eriopersicon group' with *Solanum huaylasense, Solanum chilense, Solanum corneliomulleri, Solanum peruvianum,* and *Solanum habrochaites.*

4. **'Neolycopersicon group'** containing only *Solanum pennellii*, which was considered to be sister to the rest of the section by (Peralta et al., 2008) based on its lack of the sterile anther appendage that occurs as a morphological synapomorphy in *S. habrochaites* and the rest of the core tomatoes.

4. CONSERVATION OF TOMATO GERMPLASM

Worldwide about 83,000 accessions of the wild and cultivated species of Tomato are maintained in germplasm banks located in over 120 countries, ranking first among vegetable species. The most important germplasm conservation centre involved in maintain Tomato germplasm includes the following.

1. C. M. Rick Tomato Genetics Resources Centre (TGRC), University of California, Davis, USA
2. USDA Plant Genetic Resource Unit (PGRU), Geneva, USA
3. International Board for Plant Genetic Resources, Rome Italy
4. The Universidade Estadul do Norte Fluminense, Rio de Janerio, Brazil
5. National Genetic Resource Centre (CNRG), Mexico
6. The World Vegetable Centre (WVC), Tainan, Taiwan
7. Botanical and Experimental Garden, Radboud University, Netherlands
8. Vavilov All-Russian Institute of Plant Genetic Resources (VIR), Saint Petersburg, Russia.

9. National Institute of Agrobiological Sciences (NIAS), Kannondai, Tsukuba, Ibaraki, Japan

10. Instituto Nacional de Innovación Agraria (INIA), Directorate of Genetic Resources and Biotechnology, La Molina, Lima, Peru

11. El Instituto de Investigaciones Fundamentales en Agricultura Tropical "Alejandro de Humboldt" (INIFAT), Pai's, Cuba

12. Svalbard Global Seed Vault, Island of Spitsbergen, Arctic Svalbard archipelago, Norway

13. National Bureau of Plant Genetic Resources, New Delhi, India

5. INSTITUTIONS INVOLVED IN TOMATO IMPROVEMENT

a. International Institute

- World Vegetable Centre, Tainan, Taiwan

b. National Institutions

- ICAR-Indian Institute of Vegetable Research (IIVR), Varanasi, Uttar Pradesh
- ICAR-Indian Agricultural Research Institute (IARI), New Delhi
- ICAR-Indian Institute of Horticultural Research (IIHR), Bengaluru, Karnataka
- Tamil Nadu Agricultural University (TNAU), Coimbatore-641003, Tamil Nadu
- G. B. Pant University of Agriculture and Technology (GBPUAT), Pantnagar, antnagar Udham Singh Nagar-263 145 Uttarakhand
- Dr. YSR Horticultural University (DYSRHU), Venkataramannagudem West Godavari Distt, Andhra Pradesh
- Punjab Agricultural University (PAU), Ludhiana, Punjab
- Kerala Agricultural University (KAU), Thrissur, Kerala
- University of Agricultural Sciences (UAS), Bengaluru, Karnataka
- University of Agricultural Sciences (UAS), Dharwad, Karnataka

c. Tamil Nadu State level institutes

- Vegetable Research Station, Palur, Cuddalore District, TNAU, Tamil Nadu
- Horticultural College and Research Institute, Coimbatore, TNAU, Tamil Nadu
- Horticultural College and Research Institute, Periyakulam, TNAU, Tamil Nadu
- Horticultural College for Women, Navalur Kuttapattu, Trichirapalli, TNAU, Tamil Nadu

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SEX SORTED SEMEN (SSS): A REVOLUTIONARY TECHNOLOGY IN THE INDIAN DAIRY SECTOR

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Abstract

Sex Sorted Semen (SSS) is transforming the way dairy farmers plan their herds and secure their livelihoods. Unlike conventional artificial insemination, where the sex of the calf is purely a matter of chance, SSS enables farmers to produce up to 90% female progenies. This shift carries enormous implications for India's dairy economy, as female calves grow into future milk producers, directly enhancing productivity and profitability. The technology also helps reduce the burden of unproductive male calves, thereby addressing issues such as stray cattle menace, road accidents, and unnecessary feeding costs.This article provides an in-depth discussion of the principles behind SSS, its development in India, practical applications in dairy farming, and the socio-economic benefits for rural communities. It also explores the challenges of cost, conception rate, and awareness, while presenting future prospects under government schemes like the Rashtriya Gokul Mission. With proper farmer training, financial support, and wider adoption, SSS can become a cornerstone technology in achieving sustainable dairy production, improved food security, and socio-economic progress in rural India.

Keywords: Sex Sorted Semen, Artificial Insemination, Dairy Farming, Sustainable Livelihood, Female Calves

Introduction

India is rightly called the "milk bowl of the world." Contributing more than 23% of global milk production, the country's dairy sector is not only a source of nutrition but also a backbone of rural livelihoods. Millions of smallholder farmers, especially women, depend on

dairy animals for daily income, food security, and employment. However, this success story faces persistent challenges. Productivity of indigenous breeds remains low, reproductive efficiency is suboptimal, and the growing population of unproductive male calves adds economic and social burdens.

Traditionally, dairy farmers relied on conventional artificial insemination (AI). While AI helped improve breed quality and reduce dependence on natural service, it offered no control over the sex of the calf. This meant that every insemination was a 50:50 gamble between male and female calves. For a dairy farmer, however, female calves are infinitely more valuable: they grow into cows or buffaloes that produce milk, reproduce, and sustain the farming cycle. Male calves, on the other hand, contribute little to the dairy economy and often end up as stray animals, creating problems ranging from crop damage to road accidents.

It is in this context that Sex Sorted Semen (SSS) has emerged as a revolutionary reproductive technology. By making it possible to predetermine the sex of offspring with up to 90% accuracy, SSS empowers farmers to build female-dominant herds. This not only strengthens household income and milk production but also contributes to broader goals like environmental sustainability, animal welfare, and social harmony. The adoption of SSS is gradually expanding in India through both government initiatives and private sector investments. While challenges such as cost, conception rate, and limited awareness persist, the technology's potential to reshape the dairy sector is undeniable. As India marches toward its vision of Viksit Bharat @2047, SSS could play a pivotal role in ensuring food security, rural prosperity, and sustainable livestock development.

Development of Sex Sorted Semen (SSS) in India

The concept of sperm sexing originated internationally, with the USDA patenting the Beltsville Sperm Sexing Technology in 1991, allowing researchers to separate X- and Y-bearing sperm with high precision. This technology gradually spread across countries, with refinements improving efficiency and practical applicability. India, recognizing the potential impact on its vast dairy sector, adopted this technology over the past decade, blending advanced scientific methods with local dairy development needs.

In India, the first dedicated bovine semen sexing laboratory was established at Brahma Genetics Facility, Pune in 2017, deploying Genus IntelliGen™ Technology. This marked a significant milestone, providing Indian farmers access to high-quality sexed semen doses for the

first time. Following this, the government-supported Rashtriya Gokul Mission (RGM) facilitated the establishment of a laboratory in Rishikesh, Uttarakhand (2019), while ABS Genus set up a facility at Deep Frozen Semen Production Centre, Babugarh, Hapur, Uttar Pradesh (2019). These laboratories are capable of producing thousands of frozen semen doses (FSD) monthly, with the technology carefully optimized for Indian breeds including CBHF, HF, Gir, Sahiwal, Tharparkar, Murrah, Mehsana, and Jaffrabadi.The Indian adaptation of SSS also accounts for local realities: elite bulls with high genetic merit are selected, and semen is carefully processed to ensure high viability despite lower sperm concentration compared to conventional semen. Importantly, these facilities have reduced the cost barrier to farmers, with a single sexed semen straw priced at approximately ₹100, making this technology accessible to smallholder dairy operators.



Applications in Dairy Farming

The practical applications of SSS are numerous and directly benefit both farmers and the broader dairy ecosystem. First and foremost, the technology allows for a higher proportion of female progenies. By increasing the number of heifers in the herd, farmers can systematically improve milk production, genetic potential, and herd replacement rates. For example, if a farmer aims to expand a herd of high-yield cows, SSS ensures that the majority of new calves will be productive females rather than surplus males.Another major application is the reduction of unproductive male calves, which has social, economic, and environmental benefits. Fewer male calves reduce the incidence of stray cattle roaming public roads, minimizing accidents, crop damage, and local conflicts. This also lowers the costs associated with feeding and housing unproductive animals.

SSS also contributes to better herd health and fertility management. Female calves generally face fewer calving complications than males, reducing the risk of dystocia and associated veterinary costs. By combining SSS with regular monitoring and skilled artificial insemination practices, dairy farmers can achieve improved conception rates, better reproductive efficiency, and healthier herds.Furthermore, SSS enables targeted genetic improvement. By selecting elite sires and dams, farmers can enhance the overall genetic quality of their herd, ensuring higher milk yield, improved fat content, and disease resistance. This aligns with national goals of increasing productivity in indigenous breeds while preserving their genetic integrity.

Case Studies and Farmer Experiences

Sex Sorted Semen technology has been extensively tested and applied worldwide, and India is gradually catching up with field-level adoption. International studies, such as those by Norman et al. (2010), reported a consistent 90% female progeny in Holstein cattle using sexed semen, demonstrating both feasibility and economic benefit. These studies also highlighted improved herd fertility and reduced calving complications in first-calf heifers, proving the health benefits for both cows and calves.In India, private and government initiatives have led to successful field applications. ABS India, using its IntelliGen™ technology at Brahma Genetics Facility and Deep Frozen Semen Production Centres, has reported encouraging results among farmers in Maharashtra and Uttar Pradesh. Dairy farmers observed increased numbers of female calves, which translated into higher milk production and improved herd quality. For instance, a smallholder farmer in Uttar Pradesh, after using SSS for two breeding cycles, reported 20–30% higher income per lactation due to more productive heifers joining the milking herd.

Similarly, cooperative-based trials under the Rashtriya Gokul Mission in Uttarakhand demonstrated that SSS could be efficiently applied in indigenous breeds like Gir, Sahiwal, and Murrah buffaloes, maintaining genetic diversity while improving productivity. Farmers emphasized the reduced burden of male calves, fewer veterinary interventions, and the confidence of producing genetically superior female offspring for sustainable herd growth.These case studies collectively suggest that when combined with skilled AI technicians, proper heat detection, and pre-rectal examinations, SSS can provide tangible benefits to both smallholder and medium-scale dairy farmers. The experiences also underline the importance of farmer training and awareness to maximize the potential of this technology.

Advantages for Farmers and Society

Sex Sorted Semen technology offers multiple advantages that extend beyond individual farms to the wider society:

1. Economic Gains: By producing more female calves, farmers can expand their milking herd efficiently. This results in higher milk output, increased milk sales, and improved household income. Additionally, the generation of genetically superior heifers enhances herd value over the long term.

2. Reduced Calving Risks and Health Benefits: Female calves generally experience fewer complications during birth.

Using SSS, the incidence of dystocia and related reproductive issues is reduced, leading to healthier cows, lower veterinary costs, and higher reproductive efficiency.

3. Social Benefits: Fewer unproductive male calves mean a reduction in stray cattle roaming public spaces. This lowers the risk of road accidents and crop damage, improving safety and community well-being.

4. Environmental Impact: By increasing herd productivity with fewer animals, SSS contributes to **resource efficiency and sustainability**. Less feed, water, and land are required per unit of milk produced, reducing the environmental footprint of dairy operations.

5. Support from Government Schemes: Under initiatives like the Rashtriya Gokul Mission, subsidized sexed semen doses, AI services, and training programs provide farmers with easier access to SSS, promoting widespread adoption and rural empowerment. Overall, SSS is a win-win technology, offering tangible economic, social, and environmental benefits. It empowers farmers, strengthens India's dairy sector, and contributes to sustainable rural development.

Constraints and Challenges of Sex Sorted Semen Technology

Despite its revolutionary potential, Sex Sorted Semen (SSS) technology is not without limitations. **High cost** is the first major constraint. A single sexed semen straw costs around ₹100, significantly higher than conventional semen. While government subsidies reduce this burden, smallholder farmers still find the upfront expense challenging, especially for large-scale herd expansion.**Lower conception rates** are another concern. Due to the sorting process, sperm concentration in sexed semen is lower (2–4 million per dose) compared to conventional semen (20 million per dose). This can lead to approximately **10–15% lower pregnancy rates**, making precise heat detection and skilled insemination critical.

Technical expertise is essential for successful SSS application. Artificial insemination with sexed semen requires **trained AI technicians**, accurate estrus detection, and pre-rectal examinations to ensure the cow is in optimal reproductive condition. Poor handling or imprecise timing can drastically reduce conception success.

Other challenges include **limited awareness among farmers**, shortage of **high-quality indigenous bulls**, delayed sexual maturity of heifers, and the potential **risk of inbreeding** if a few elite sires are overused. Additionally, the technology requires **expensive laboratory infrastructure**, including flow cytometers and processing equipment, which can cost 4–5 crore rupees, limiting widespread availability.Despite these hurdles, ongoing training programs, farmer awareness campaigns, and technological improvements are gradually mitigating these constraints, making SSS increasingly feasible for Indian dairy operations.

Future Prospects for Indian Dairy Sector

Training AI technicians, paravets, and extension officers is vital to maximize conception rates and ensure proper handling of sexed semen. Subsidy schemes and microfinance options can further reduce cost barriers, encouraging adoption among economically weaker farmers.Furthermore, SSS can be effectively integrated with **indigenous breeds** such as Gir, Sahiwal, Tharparkar, and Murrah buffaloes, preserving genetic diversity while enhancing productivity. By increasing the proportion of productive female calves, farmers can achieve **higher milk yields, reduced stray male populations, and better resource efficiency**, contributing to environmental sustainability.Ultimately, widespread adoption of SSS will strengthen India's dairy sector, enhance rural livelihoods, and position the country as a global leader in innovative, sustainable dairy practices.

Conclusion

Sex Sorted Semen technology is more than just a reproductive innovation; it is a transformative tool for sustainable dairy farming in India. By ensuring more female calves, the technology directly boosts milk production, reduces herd management challenges, minimizes health complications, and improves farmer income.While challenges such as higher costs, lower conception rates, and technical requirements exist, they are gradually being addressed through training, government support, and improved laboratory infrastructure. Farmers, veterinarians, and extension workers have a shared responsibility to promote this technology, enabling smallholder farmers to adopt modern breeding practices confidently.With strategic

implementation, Sex Sorted Semen can reshape the Indian dairy landscape, ensuring enhanced productivity, food security, environmental sustainability, and socio-economic upliftment. Adoption of this technology at scale promises a future where India's dairy farmers remain competitive, resilient, and prosperous.

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Pic: Sex Sorted Semen straw being used for Artificial Insemination in dairy cattle

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NEONATAL CARE IN ANIMALS

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Introduction

Neonatal care is a critical component of veterinary practice because the early life period from gestation, through birth, and especially the first weeks of life, is when animal offspring are most vulnerable. Mortality rates are high during this neonatal period, and many of the factors determining survival and long-term health are already operating before and immediately after birth. Effective neonatal care involves understanding and managing physiological, environmental, nutritional, and immunological challenges. In dogs and cats, the neonatal period is marked by very specific risks. According to Pereira et al. (2022) in "Neonatology: Topics on Puppies and Kittens", mortality in kennels and catteries is often due not just to environmental conditions after birth, but also to things that happen during pregnancy, gestation, fetal development, delivery, and the early postpartum period. Lawler's earlier work (2008) also emphasised the need for pediatric management in clinical settings to anticipate and prevent neonatal problems.

Physiological vulnerability of neonates:

Newborn animals are born with immature thermoregulatory, immune, and metabolic systems. This makes them highly dependent on external support for survival. Their inability to regulate body temperature, low energy reserves, and susceptibility to infections highlight the need for specialised care immediately after birth.

Genetic and Congenital Factors

Certain neonatal losses are linked to genetic defects or congenital malformations (e.g., cleft palate, heart defects, skeletal abnormalities).

Umbilical Cord and Navel Care

The umbilical cord is a potential entry point for bacteria. In farm animals like calves and foals, navel infections can cause septicemia and joint ill. Disinfection and monitoring of the umbilical site are critical aspects of neonatal management.

Use of Technology in Neonatal Monitoring

Advances like thermal imaging, digital weighing systems, and portable blood glucose meters now assist in early detection of hypothermia, dehydration, or metabolic issues. In intensive farms, monitoring systems track neonatal activity and feeding patterns to prevent losses.

Role of maternal health and pregnancy

Neonatal survival begins even before birth. Maternal nutrition, health status, and management during gestation directly influence birth weight, vitality, and the strength of newborns. Problems such as dystocia, placental insufficiency, or maternal malnutrition predispose neonates to higher mortality.

Thermoregulation and environmental support

Hypothermia is a leading cause of early neonatal loss. Since neonates cannot maintain stable body temperature, providing a warm, hygienic environment is crucial. Maintaining ambient warmth and reducing drafts prevents secondary complications like hypoglycemia and respiratory distress.

Colostrum Intake and Passive Immunity Transfer

Adequate colostrum ingestion within the first few hours of life provides essential immunoglobulins, energy, and growth factors. Failure of passive transfer leaves neonates defenceless against common pathogens. Monitoring colostrum quality, timing, and intake is a key preventive measure.

Nutritional Demands and Growth Monitoring

Neonates require frequent feeding because of limited energy reserves and rapid metabolic needs. Growth rate in the first 24–48 hours is a strong predictor of survival. Regular weighing and nutritional supplementation (when needed) are part of neonatal management.

Risk Identification and Early Intervention

Factors such as low birth weight, abnormal behaviour, weak reflexes, and poor weight gain identify neonates at risk.

Prompt veterinary intervention—warming, assisted feeding, or fluid therapy—significantly improves survival outcomes.

Neonatal Disease Prevention and Management

Neonates are highly vulnerable to bacterial, viral, and parasitic infections due to immature immunity. Hygiene, proper maternal vaccination, and timely veterinary support are essential for preventing outbreaks in kennels, farms, and catteries.

Veterinarian's Role in Neonatal Care

1. **Prenatal and Maternal Management** Veterinarians play a proactive role even before birth. They monitor the dam's nutrition, vaccination, and health status during pregnancy to ensure optimal fetal development. Guidance on proper breeding management, prevention of dystocia, and timely intervention in high-risk pregnancies improves neonatal outcomes
2. **Assistance During Parturition** During delivery, veterinarians assist in recognising signs of dystocia, prolonged labour, or fetal distress. Timely interventions such as assisted delivery or cesarean section can be life-saving for both mother and offspring. Their expertise ensures minimal stress and trauma during whelping or calving.
3. **Immediate Postnatal Support** Veterinarians assess neonates right after birth for breathing, reflexes, vitality, and congenital abnormalities. They ensure airway clearance, stimulate respiration if required, and monitor body temperature. Initial checks also include umbilical cord care to prevent infection.
4. **Colostrum Management and Nutrition** A crucial responsibility is ensuring that newborns receive adequate, good-quality colostrum within the critical first hours. In cases of maternal rejection, poor lactation, or orphaned neonates, veterinarians provide alternatives such as colostrum substitutes or milk replacers, alongside feeding protocols.
5. **Disease Prevention and Health Monitoring** Veterinarians implement hygiene protocols to prevent infections in kennels, farms, or catteries. They monitor for early signs of hypothermia, hypoglycemia, dehydration, or congenital defects. Vaccination schedules and deworming programs are designed to protect neonates once maternal antibodies wane.
6. **Growth and Development Tracking** Regular weighing and physical assessments help track growth rates. Veterinarians identify "at-risk" neonates with poor weight gain or

abnormal behavior and recommend interventions like nutritional support, fluid therapy, or hospitalization.

7. **Farmer and Breeder Education** Beyond direct medical care, veterinarians act as educators. They train farmers and breeders on neonatal handling, hygiene, feeding practices, and early warning signs of illness. This knowledge transfer reduces preventable losses in both companion animals and livestock.
8. **Research and Policy_**Contribution Veterinarians also contribute to advancing neonatal medicine through research on nutrition, immunity, and disease management. They play a role in shaping farm and kennel policies for better neonatal survival and welfare standards.

Conclusion

Neonatal care plays a decisive role in improving the survival, health, and long-term productivity of animals. Since the neonatal period is marked by physiological immaturity, successful outcomes depend on careful management of maternal health, optimal environmental conditions, timely colostrum intake, and vigilant monitoring of growth and vitality. Early recognition of risk factors such as low birth weight, hypothermia, and feeding difficulties allows rapid intervention, which significantly reduces mortality. Integrating preventive care, nutritional support, and disease control measures ensures stronger, healthier offspring. Ultimately, neonatal veterinary care is not just about saving lives in the first few days—it sets the foundation for the animal's overall well-being and future performance.

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ENSURING GENETIC PURITY OF SEEDS: CONVENTIONAL VS MOLECULAR METHODS

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Introduction

Seeds constitute the most fundamental and critical input in agriculture, directly influencing productivity and profitability. The quality of seeds is determined by genetic purity (true to the parental genotype), physical purity (free from inert matter, weed seeds, and other crop seeds), germination (to ensure uniform crop establishment), and seed health (absence of seed-borne pathogens and pests). A healthy, true-to-type seed guarantees better yield and superior quality produce, ultimately ensures higher income to farmers.

In India, the Seeds Act, 1966 was the first legislation enacted to regulate seed quality, while the Seed Rules, 1968, detailed seed certification, testing, and labelling procedures. These regulatory frameworks are implemented through apex institutions such as the Central Seed Certification Board, State Seed Certification Agencies, and State Seed Testing Laboratories. Seed certification agencies, functioning under the Seeds Act, enforce defined genetic purity standards for various seed classes. According to Indian Minimum Seed Certification Standards (IMSCS), breeder seeds require 100% genetic purity, whereas foundation and certified class seeds requires 99.5% and 99% respectively. Ensuring genetic authenticity is therefore fundamental to seed quality control, as the success of high-yielding varieties depends largely on the consistent supply of true-to-type seeds.

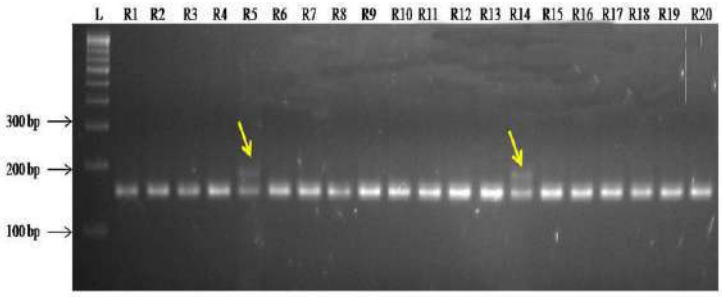
Genetic purity of seed lots, however, is continually threatened by multiple factors such as developmental variations, spontaneous mutations, genetic drift, natural cross-pollination with

undesirable types, selective pressure from diseases, presence of pollen shedders in male sterile lines, mechanical admixtures during harvest and transport, lapses in maintaining isolation distances, mislabelling, and human errors in multiplication procedures. Any reduction in genetic purity leads to decline in yield, uniformity, and market quality, eventually contributing to genetic deterioration of varieties over time.

Conventional Vs Molecular methods

Traditionally, genetic purity testing has been conducted through the Grow-Out Test (GOT), which relies on morphological markers expressed during different stages of crop growth period. GOT serves as both a pre-control and post-control measure to detect genetic contamination. The genetic reliability of a variety is determined by comparing its morphological traits with those of an authenticated reference sample. However, reliable trait expression is often contingent on favourable environmental conditions. Stress or sub-optimal conditions may suppress or alter phenotypic traits, making detection of off-types unreliable. Moreover, self-pollinated crops typically exhibit higher uniformity, while cross-pollinated crops present greater variability, further complicating the assessment. In GOT, a representative seed sample (100-1000 g, depending on crop) is submitted to the Seed Certification Agency, and at least 400 plants are raised along with a reference sample. The crop is monitored throughout its growth cycle for off-types. Although GOT remains an official standard, it is time-consuming, labour intensive, and requires large field areas, making it inefficient for large-scale or high-throughput testing.





With advances in biotechnology, DNA-based molecular markers have emerged as highly efficient alternatives for genetic purity testing. Markers such as RFLP, RAPD, SSR, ISSR, and SNP are widely utilized in plant genetics, breeding, taxonomy,

and germplasm characterization. Among these, Simple Sequence Repeats (SSR) are particularly preferred due to their high polymorphism, reproducibility, co-dominance, abundance in the genome, and compatibility with high-throughput, automated genotyping platforms. In DNA fingerprinting, seedling leaf tissue (collected within 5-10 days of sowing) serves as the sample, and standard molecular protocols *viz*., DNA extraction, PCR amplification and electrophoresis are followed to detect the contamination. Unlike GOT, results can be generated within a single day. Under conventional laboratory throughput, 100-200 samples/day can be analysed, while advanced automation enables testing of several thousand samples. Molecular markers provide high-resolution, precise, and environment-independent information on genetic identity, thereby offering a reliable, rapid, and cost-effective alternative to morphological testing for purity assessment. International Seed testing Association (ISTA) has also approved DNA based variety testing in crops in like Wheat, Oat, Maize and Peas.

The conventional GOT approach is adequate for distinguishing cultivars with clear morphological differences and remains relevant where financial and infrastructural constraints limit molecular adoption. However, with the increasing number of commercial inbred lines, hybrids, and closely related varieties, depending solely on morphological markers is highly insufficient. Many modern cultivars derived from genetically similar pools exhibit overlapping phenotypic traits, making their unambiguous identification through GOT difficult. In contrast, molecular markers directly assay the DNA sequence, providing a robust, reproducible, and environment-independent means of varietal identification. Unlike phenotypic traits, DNA profiles remain stable across environments and crop stages. Molecular markers also enable discrimination of even closely related genotypes, thus offering greater precision in maintaining and monitoring genetic purity.

Public and private sector labs involved in DNA Fingerprinting for varietal discrimination and genetic purity

S. No.	Lab	Location	Services
I	**Public sector labs**		
1.	National Bureau of Plant Genetic Resources (NBPGR), Delhi	New Delhi	Offers DNA fingerprinting of varietal samples and GM testing.

2.	Centre for DNA Fingerprinting & Diagnostics (CDFD), Hyderabad	Telangana	Plant DNA Fingerprinting, Barcoding, Hybrid Purity Testing, Varietal ID, Basmati purity testing.
3.	Rajiv Gandhi Centre for Biotechnology (RGCB), Kerala	Thiruvanantha-puram	Offers DNA Fingerprinting (microsatellite, etc), hybrid seed testing, species/varietal discrimination.
4.	Telangana State – International Seed Testing Authority (TISTA) (International Seed Services)	Telangana	Has molecular / DNA / protein-based testing for genetic purity, varietal / parental line purity and identification.
5.	State DNA Finger Print Laboratory, Coimbatore / Tamil Nadu Government	Tamil Nadu	DNA Finger Print laboratory for seed certification; genetic purity of notified paddy varieties (SSR markers).
II	**Private sector labs**		
1.	Indo-American Hybrid Seeds (INDAM)	Bangalore	ISTA & NABL accredited testing; DNA fingerprinting of high-value hybrid seeds; varietal authenticity; genetic purity; parental line purity.
2.	Ajeet Seeds Pvt. Ltd. (PBRC – Plant Biotechnology Research Centre)	Maharashtra / Telangana	NABL accredited DNA Diagnostic Lab; Services include Molecular GOT / M-GOT hybrid purity, parental line purity, DNA fingerprinting.
3.	Namdhari Seeds Pvt. Ltd.	Bangalore	Their QC labs accredited; offer Genetic Purity Analysis (GPA), DNA fingerprinting among their

			seed health / molecular biology services.
4.	Delta Agrigenetics Pvt. Ltd.	Multiple states	Their QC (Quality Assurance) facility does genetic purity using SSR, ISSR, AFLP markers; DNA fingerprinting etc.
5.	SGS India	Mumbai	Offers "seed genetic purity" services; DNA & PCR based methods, SNP etc.; varietal off-type resolution.

Conclusion

While Grow-Out Test (GOT) remains useful for crops with simple genetic backgrounds and in situations where resources are limited, molecular marker-based assays represent the future of genetic purity testing, particularly for hybrids and high-value crops. These technologies not only ensure the supply of true-to-type, high-quality seeds but also safeguard varietal integrity, enhance productivity, and improve farm profitability. As costs of DNA-based assays decline and accessibility widens, the Indian seed industry is likely to transition towards routine molecular fingerprinting, moving closer to the goal of achieving near 100% genetic purity assurance for farmers.

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REVOLUTIONIZING RURAL FARMING: HOW ARTIFICIAL INTELLIGENCE IS TRANSFORMING INDIAN AGRICULTURE

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Introduction

Indian agriculture has long been the lifeline of the country, employing nearly half of its population and contributing significantly to rural livelihoods. However, the sector faces growing challenges like climate variability, shrinking landholdings, rising input costs, labour shortages and fluctuating market prices. Traditional methods though valuable are increasingly insufficient to address these pressing issues and ensure sustainable growth for the farming community. In this context, Artificial Intelligence (AI) emerges as a disruptive technology that has the potential to redefine farming practices. By offering data-driven solutions, AI can transform agriculture into a more precise, efficient and resilient system capable of overcoming the complex challenges that farmers face today.

AI can assist farmers in making better decisions, predicting outcomes, optimizing inputs and even connecting them to markets in ways that were previously unimaginable. Such advancements can enhance productivity, reduce risks and improve profitability, ensuring that farming remains a viable livelihood option for millions of rural households. (Anonymous, 2024). However, the deployment of such technology in rural India is not without barriers. The key to bridging this digital divide lies in Agricultural Extension Education, which serves as a vital link between technology developers and the rural farming community. Extension

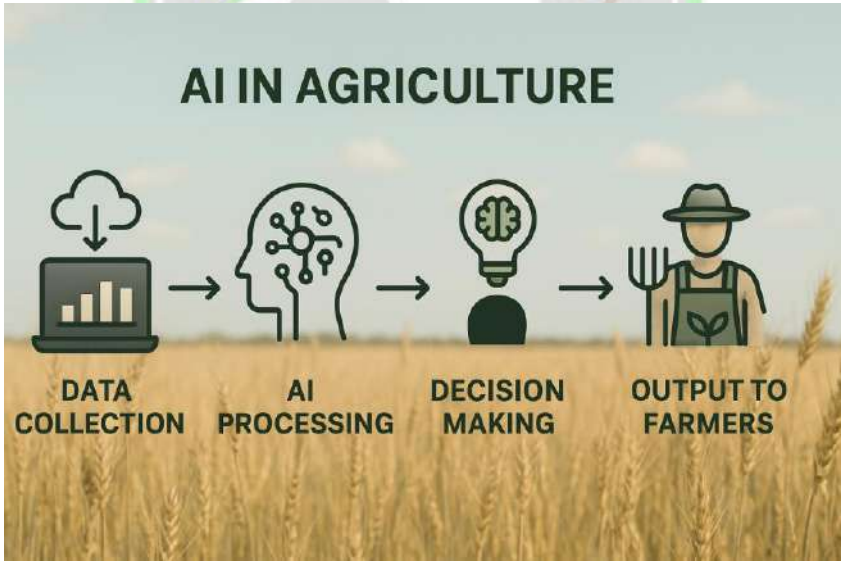
personnel, when properly trained and equipped, can make AI not only accessible but also impactful, ensuring that its benefits reach farmers across all regions.

Understanding AI in agriculture

Artificial Intelligence in agriculture involves the use of machines or software to mimic human intelligence, learning from data, recognizing patterns and making predictions or decisions. When integrated with tools like remote sensing, mobile applications, weather forecasting and big data, AI becomes a powerful enabler for:

- Crop health monitoring
- Pest and disease detection
- Weather-based advisories
- Market trend analysis
- Yield estimation
- Input optimization (fertilizer, water, seeds)

These tools are transforming farming from intuition-based to data-driven, increasing productivity while reducing cost and uncertainty.



Real-world AI applications in indian agriculture

1. AI sowing app (Microsoft & ICRISAT Initiative)

In Andhra Pradesh, a pilot project used AI to recommend the best sowing dates based on soil moisture, weather conditions, and crop cycles. The outcome? Cotton farmers experienced a 30% increase in yield.

2. Plantix mobile app

An AI-based image recognition tool that allows farmers to upload pictures of diseased plants. The app diagnoses the problem and offers remedies in local languages.

3. CropIn technologies

Provides satellite imagery and AI-driven analytics for crop performance, field-level risk assessment and traceability. Used by FPOs and agribusinesses to improve productivity and compliance.

4. e-Choupal & DeHaat platforms

These platforms integrate AI to offer personalized advisories, input sourcing, weather updates and access to markets bridging the rural information gap.

5. AgNext technologies

Uses AI for quality analysis in procurement. Farmers can now receive fair pricing based on real-time quality assessments of produce like milk, grain and fruits.

Role of agricultural extension in AI dissemination

Despite the power of AI, its success depends on how well farmers adopt and use these tools. This is where extension education becomes crucial. Here's how:

1. Bridging the knowledge gap

Many farmers have never heard of AI, let alone understand how to use it. Extension agents serve as knowledge intermediaries, simplifying complex technologies into farmer-friendly formats.

2. Capacity building through training

Extension professionals can organize: Skill training workshops, Mobile-based learning modules, Demonstrations and field days.

These initiatives help farmers learn how to operate apps, understand advisories and trust technology.

3. Localization of content

Extension educators help adapt AI tools to local dialects, crops, cultural preferences and resource conditions ensuring contextual relevance.

4. Feedback to developers

Extension staff collect on-ground feedback to improve AI solutions.

For example, if an app gives wrong pest diagnosis due to local pest variation, extensionists can inform developers to update the dataset.

5. Integration with traditional knowledge

Farmers trust their instincts and ancestral knowledge. Extensionists can blend AI advisories with local practices to enhance acceptance.

Key challenges in implementing AI in rural india

1. **Digital illiteracy**
   - A large proportion of Indian farmers are not digitally literate.
   - Many still use basic phones and cannot navigate apps.
2. **Lack of infrastructure**
   - Poor internet connectivity, electricity shortage and lack of repair centres hinder tech usage.
3. **Language and cultural barriers**
   - Most AI apps are in English or Hindi, while rural India is linguistically diverse.
   - Misunderstanding or misinterpreting digital advice is common.
4. **Cost and Accessibility**
   - While some tools are free, others come with costs beyond the reach of marginal farmers.
5. **Scepticism and Fear of technology**
   - Many fears losing control over farming decisions or distrust new technology.
   - The role of trusted extension workers becomes vital to overcome this.

Strategies for effective AI adoption through extension

1. **AI inclusion in extension curriculum**

Agriculture universities and training institutes must include AI literacy in the curriculum of students and extension workers. This ensures a future-ready human resource.

2. **Digital Kisan Kendra's and ICT centres**

Set up AI demonstration labs and ICT centres in rural blocks where farmers can try tools before adoption.

3. **Women and youth empowerment**

Train rural youth and farm women as digital agriculture facilitators who assist others in using AI tools and platforms.

4. **Mass media and ICT platforms**

Use community radio, WhatsApp groups, Youtube and digital boards at panchayat offices to spread AI-related awareness and updates.

5. **Public-Private Partnerships (PPP)**

Encourage partnerships between government extension services and Agri-tech start-ups for field-level deployment of AI tools.

Case Study: AI Success in Andhra Pradesh

In 2016, Microsoft, in partnership with ICRISAT (The International Crop Research Institute for the Semi-Arid Tropics), initiated a pilot project in Devanakonda Mandal in the Kurnool district of Andhra Pradesh. The pilot had a sample base of 175 farmers who were alerted on their mobile phones about suitable cropping dates, land preparation, and soil test-based fertiliser utilisation. This helped increase crop output by around 30%. In 2017, this project was expanded to cater to approximately 3,000 farmers in Karnataka and Andhra Pradesh during the Kharif cycle for a host of crops like groundnut, ragi, maize, rice, and cotton, among others. The increase in crop yield following the AI intervention ranged from 10-30% across all crops (Nagpal and Jasmeen, 2017).

This was possible only because extension workers served as enablers, ensuring trust, understanding, and skill-building.

Future scope and integration

1. **AI and Climate-Smart agriculture**

AI tools can support extension strategies on climate-resilient agriculture by forecasting droughts, suggesting water-saving crops and managing heat stress in livestock.

2. **AI in market linkage**

Extension services can guide farmers to AI-based e-mandis, real-time price platforms and digital warehousing systems to avoid distress sales.

3. **AI-Powered farmer feedback systems**

Farmers can use voice-based AI helplines to give feedback on policies, seeds or subsidies strengthening bottom-up communication in agriculture planning.

Role of policymakers and extension framework

For long-term sustainability, the National Extension System must be restructured to integrate digital technologies like AI. Key policy suggestions:

- Incentivize AI capacity building in SAUs and KVKs.
- Mandate AI trials in frontline demonstrations.
- Include AI awareness modules in PM-Kisan Samman Nidhi training events.
- Provide subsidies for rural AI tools under the SMAM or Digital india programme.

Conclusion

Artificial Intelligence has the power to make farming more precise, profitable and sustainable. But the real transformation will occur only when AI reaches the grassroots where a farmer in a remote village can make informed decisions using a simple app, thanks to a well-trained extension worker by his side. The dream of AI in Indian agriculture is not just about machines and algorithms; it is about human connections, trust-building and empowering the last-mile farmer. Extension education is not just relevant, it is the essential backbone of this revolution, ensuring that technology translates into meaningful change in the lives of farmers.

By aligning the latest AI advancements with traditional extension wisdom, India can create a model where digital tools are not distant, complex technologies but farmer-friendly solutions that strengthen local decision-making. This integration will not only enhance productivity but also build resilience, sustainability and inclusiveness in agriculture.Ultimately, the success of AI in Indian agriculture will be measured not by the sophistication of technology but by its acceptance and use by farmers at the grassroots. With strong extension support and farmer-cantered approaches, India can lead the world in building a truly inclusive model of digital agriculture that empowers every farmer.

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REVIEW ON EUTROPHICATION IN AQUATIC ECOSYSTEMS

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Abstract

Eutrophication is one of the most severe ecological challenges facing aquatic ecosystems worldwide. It results primarily from the enrichment of water bodies with nutrients, particularly nitrogen (N) and phosphorus (P), which accelerate algal growth and disrupt ecosystem balance. While natural eutrophication is a slow geological process, cultural or anthropogenic eutrophication has intensified due to human activities such as agricultural runoff, industrial discharge, and untreated sewage. The effects are profound, including harmful algal blooms (HABs), oxygen depletion, biodiversity loss, and ecosystem degradation. This review examines the major causes of eutrophication, focusing on natural processes, agricultural practices, and industrial or domestic inputs. It further explores the ecological, economic, and human health effects associated with eutrophic conditions. Control measures are also discussed, ranging from nutrient management and biomanipulation to advanced technological and policy interventions. Although several strategies have been implemented globally, challenges remain due to diffuse pollution sources and climate change impacts. A multidisciplinary approach involving ecological monitoring, sustainable farming, public awareness, and legislative frameworks is essential for effective management. By integrating scientific understanding with practical applications, sustainable solutions can mitigate eutrophication and protect aquatic resources for future generations.

Keywords: Eutrophication, Aquatic ecosystem, Nutrient enrichment, Algal blooms, Control measures

Introduction

Aquatic ecosystems play a crucial role in supporting biodiversity and human livelihoods. However, rising human population, urbanization, and industrialization have accelerated nutrient loading in freshwater and marine systems. Eutrophication, defined as the enrichment of water bodies with nutrients leading to excessive growth of algae and aquatic plants, has emerged as a global environmental issue. While some nutrient inputs are natural, human activities are now the predominant contributors. Understanding its causes, effects, and control measures is vital for maintaining ecological balance and water quality.

Causes of Eutrophication

1. Natural Eutrophication

Natural eutrophication occurs over centuries as lakes age and accumulate sediments and nutrients. Rainfall, flooding, and stormwater runoff gradually enrich aquatic systems with nitrogen and phosphorus, promoting algal and phytoplankton growth.

2. Cultural (Anthropogenic) Eutrophication

Human-induced nutrient loading, or cultural eutrophication, is the primary modern driver. Runoff from agricultural lands containing fertilizers, livestock manure, and aquaculture effluents significantly increases nutrient concentrations in lakes and rivers.

3. Industrial and Domestic Inputs

Untreated sewage, detergents, and industrial effluents also contribute to nutrient enrichment. Phosphorus from household detergents and nitrogen from urban wastewater are major nonpoint sources, particularly in urbanized regions.

Effects of Eutrophication

Eutrophication disrupts aquatic ecosystems ecologically. Dense algal blooms reduce sunlight penetration, decreasing photosynthesis and aquatic plant diversity. When blooms die, decomposition depletes dissolved oxygen, causing hypoxia that kills fish and other aquatic organisms.

Economically, eutrophication impairs fisheries, aquaculture, and tourism. Harmful algal blooms (HABs) can cause fish kills, reduce recreational value, and increase water treatment costs. For

instance, coastal eutrophication has contributed to declining fish populations and seafood safety concerns.

Human health is also at risk, as some cyanobacteria produce toxins that contaminate drinking water supplies. These toxins may cause liver damage, neurological disorders, and skin irritations in humans and livestock.

Control Measures

One approach is **nutrient management**. Reducing fertilizer application, treating sewage before discharge, and banning phosphorus-based detergents have proven effective in several countries. Advanced wastewater treatment can significantly reduce phosphorus and nitrogen inputs.

Biomanipulation is another strategy. This involves altering food web dynamics, such as introducing fish species that control algal blooms or harvesting aquatic plants that absorb excess nutrients. However, its success depends on site-specific ecological conditions.

Technological and legislative measures include dredging nutrient-rich sediments, ecological restoration, and enacting water protection policies. Public awareness and stakeholder participation are crucial to ensure long-term success and minimize diffuse nutrient sources.

Conclusion

Eutrophication represents a significant threat to aquatic ecosystems, biodiversity, and human societies. While natural nutrient enrichment occurs slowly, anthropogenic drivers have accelerated this process, leading to harmful algal blooms, oxygen depletion, and water quality deterioration. Effective control requires integrating ecological, technological, and policy-based approaches. Reducing external nutrient inputs from agriculture, industry, and households remains the most sustainable solution. Innovations like advanced wastewater treatment, biomanipulation, and dredging offer promising but context-dependent results. Ultimately, successful mitigation of eutrophication depends on coordinated action between scientists, policymakers, and local communities. Public education and international cooperation are equally vital in combating this global challenge. If managed properly, eutrophication can be controlled, restoring aquatic ecosystems to balance and ensuring their sustainability for future generations.

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Volume: 05 Issue No: 10

GENE PYRAMIDING: A SINGLE LINE OF GENES

Article ID: AG-VO5-I10-17

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Introduction

Pyramiding is the accumulation of genes into a single line or cultivar. A pyramid could be constructed with major genes, minor genes, defeated genes, effective genes, ineffective genes, race-specific genes, non race-specific genes, or any other type of host gene that confers resistance. In a gene pyramiding scheme, strategy is to cumulate into a single genotype, genes that have been identified in multiple parents. The use of DNA markers, which permits complete gene identification of the progeny at each generation, increases the speed of pyramiding process. In general, the gene pyramiding aims at the derivation of an ideal genotype that is homozygous for the favorable allele's at all n loci.

It includes-

a. Stacking of traits
b. Stacking of events
c. Stacking of genes

A genetically modified organism (GMO) and all subsequent identical clones resulting from a transformation process are called collectively a transformation event. If more than one gene from another organism has been transferred, the created GMO has stacked genes (or stacked traits), and is called a gene stacked event.

Widely used for combining multiple disease resistance genes for specific

races of a pathogen. Pyramiding is extremely difficult to achieve using conventional methods. Consider - phenotyping a single plant for multiple forms of seedling resistance - almost impossible. Important to develop 'durable' disease resistance against different races. Main use- to improve existing elite cultivar. Eliminates extensive phenotyping, Control linkage drag Reduces breeding duration.

TYPES OF GENE PYRAMIDING

a. Conventional technique

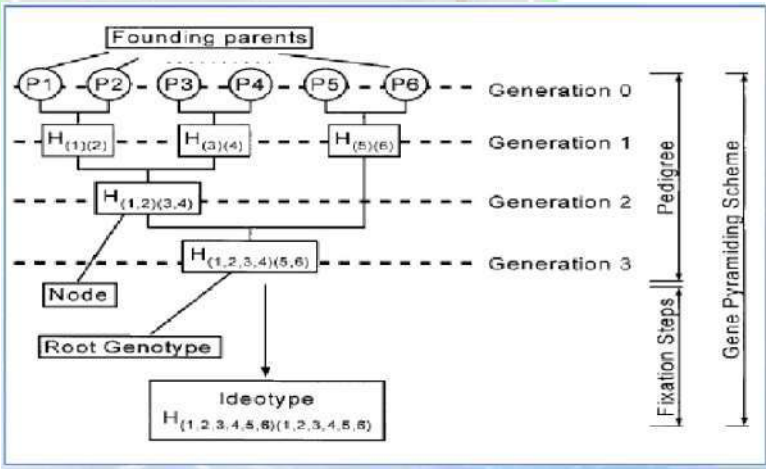
Serial gene pyramiding: Genes are deployed in same plant one after other

b. Molecular technique

Simultaneous gene pyramiding: Genes are deployed at time in a single plant.

GENE PTRAMADING OF SIX GENES

In a gene pyramiding scheme, strategy is to cumulate into a single genotype, genes that have been identified in multiple parents. The use of DNA markers, which permits complete gene identification of the progeny at each generation, increases the speed of pyramiding process.

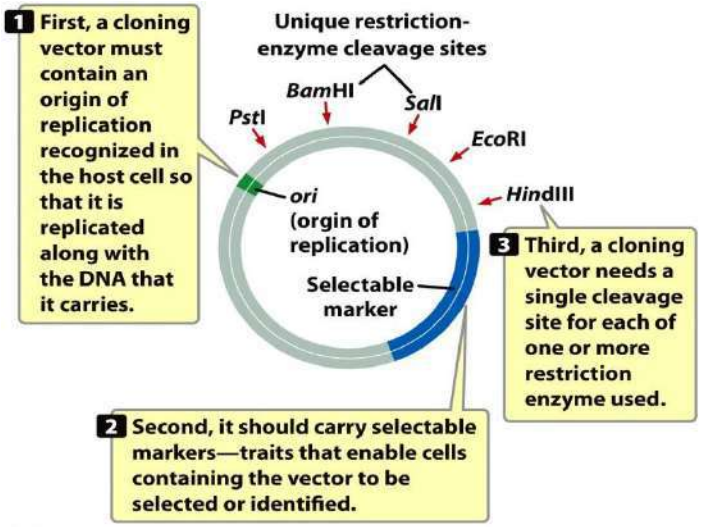


In general, the gene pyramiding aims at the derivation of an ideal genotype that is homozygous for the favorable alleles at all n loci. The gene pyramiding scheme can be distinguished into two parts (Figure). The first part is called a **pedigree**, which aims at cumulating of all target genes in a single genotype called the root genotype. The second part is called the **fixation step** which aims at fixing the target genes into a homozygous state i.e. to derive the ideal genotype from the one single genotype. Each node of the tree is called an intermediate genotype and has two parents.

Cloning Genes: It is amplifying a specific piece of DNA via a bacteria cell

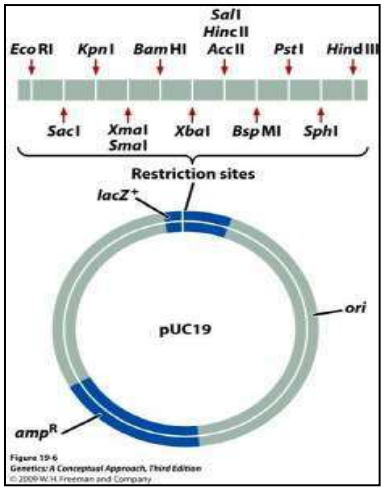
Cloning vector: a replicating DNA molecule attached with a foreign DNA fragment to be introduced into a cell has features that make it easier to insert DNA and select for presence of vector in cell.

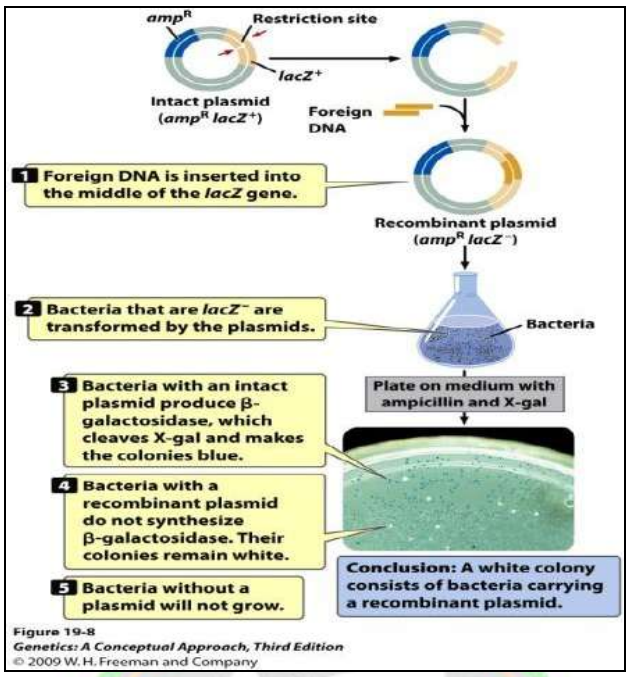
- Origin of replication
- Antibiotic resistance gene
- Cloning site



- Plasmid vectors
- Linkers: synthetic DNA fragments containing restriction sites
- Transformation of host cells with plasmids

Selectable markers are used to confirm whether the cells have been transformed or not.





Pyramiding of Genes

- Two or more transgenes can be sequentially introduced into a plant by conventional iterative procedures.
- Pyramided crylAc and crylC Bt genes in broccoli controlled diamond back moth.
- Most promising approach for the introduction of multiple genes into plants.
- Quick & Simple.
- Tend to co-integrate at the same chromosomal position in a high proportion of transgenics.
- In Arabidopsis, six genes (including two selectable marker genes) on two T-DNAs were deployed to produce copolymer, (
- The availability of metabolic precursors had to be increased by redirecting intermediates, manipulating Protein expressing and gene suppressing transgenes.
- Chimeric polycistronic constructs that incorporate internal ribosome entry sites (IRESs) from different viruses

- Different protein sequences are connected in a single open reading frame via short linker sequences.
- A polyprotein incorporating coat proteins of tobacco mosaic tobamovirus and soybean mosaic potyvirus was expressed in tobacco to yield plants resistant to multiple viruses.
- Single transgenes can also be used to simultaneously suppress multiple genes containing fused sequences of several target genes under the control of a single promoter, but in most cases resulted in Co-suppression or post-transcriptional gene silencing.

Case Study:

Pyramiding transgenic resistance in elite indica rice cultivars against the sheath blight and bacterial blight

S. Maruthasalam et al., Plani Cell Reporter (2007), 1 26:791-SW IX**),** Revised: 5

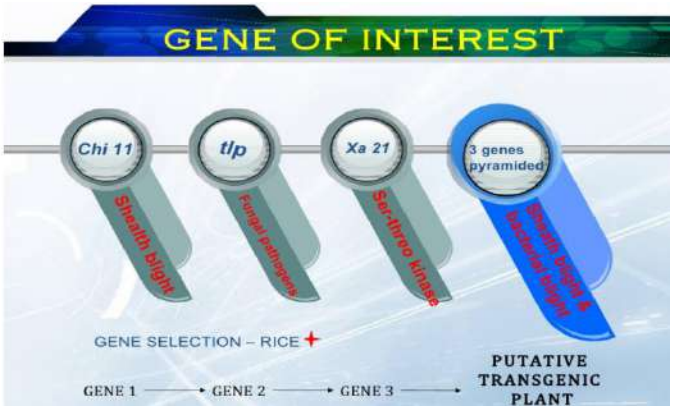
- Indica rice cultivars - cotransformed with genes

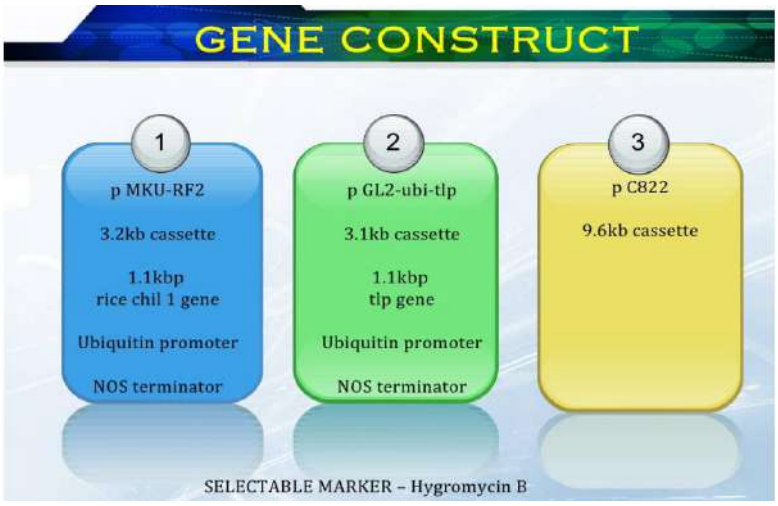
✓ Rice chitinase (chill)

✓ Thaumatin-like protein (tip) (fungalpathogens)

✓ Serine-threonine kinase (Xa21) (bacterial blight resistance)

- Particle bombardment (Callus and imature embryo)
- Varieties - PB1, ASD16, ADT 38 , IR72 AND WHITE PONNI
- Putative transgenic lines analysed PCR, Southern Blot hybridization and Western Blotting showed stable integration and expression of the transgenes in a few independent transgenic lines.





- Chill - genomic DNA - Hindlll -to release 3.2 kbp chitinase expression cassette and blotted onto the membrane **a-32P dCTPIabeled 1.0 8 kbp chil 1 coding sequence by digesting pMKU-RF2 with Pstl.**
- tip gene- the genomic DNA-Hindlll -to release the 3.1 kbp TIP expression cassette **a-32P dCTP-Iabeled 1.1 kbp TIP coding sequence by digesting 3.1 kbp TLP expression cassette with BamHI.**
- Xa21 -genomic DNA-EcoRV-to release 3.8 kbp Xa21 **Hybridized with a-32P dCTP-labeled 3.8 kbp Xa21 coding sequence by digestingpC822 with EcoRV.**

Gene Conformation:

1. PCR based detection
2. Southern Blotting

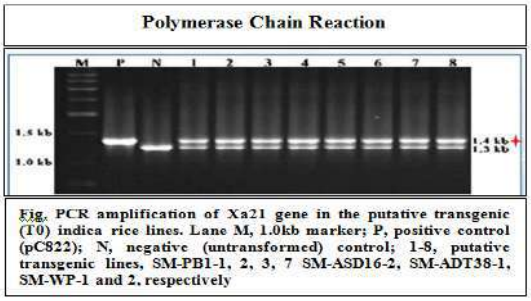
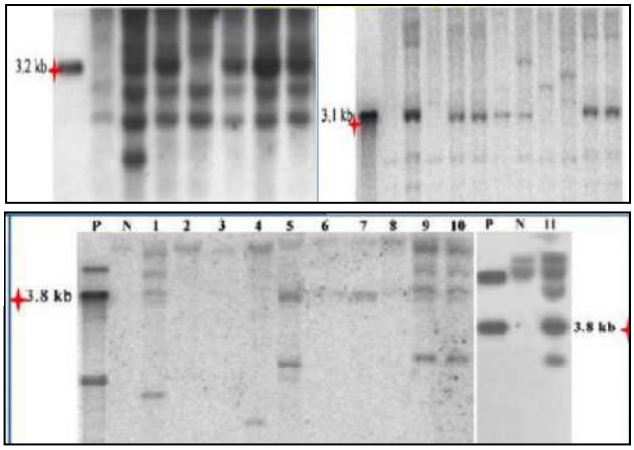


Fig. PCR amplification of Xa21 gene in the putative transgenic (T0) indica rice lines. Lane M, 1.0kb marker; P, positive control (pC822); N, negative (untransformed) control; 1-8, putative transgenic lines, SM-PB1-1, 2, 3, 7 SM-ASD16-2, SM-ADT38-1, SM-WP-1 and 2, respectively



Global Status of Approved GM Crops with Stacked Genes

Trait	Crop	Genes	Method	Company	Events
Herbicide tolerance + Fertility restored	Canola	Bar, bamase or bastar; neo	Agrobacterium/ Linked genes, 1T-DNA	Aventis Crop Science	MS1,RF1,MS1, RF2,PHY14, PHY35,PHY36
Herbicide tolerance + Fertility restored	Chicory	Bar, bamase; neo	Agrobacterium/ Linked genes, 1T-DNA	Bejo Zaden BV	RM3-3, RM3-4, RM3-6
Multiple virus resistance	Squash	Neo, CP-CMV, CP-ZYMV, CP-WMV2	Agrobacterium/ Linked genes, 1T-DNA	Asgrow (USA), Seminis Vegetable Inc. (Canada)	CZW-3
Multiple virus resistance	Squash	Neo*, CP-ZYMV, CP-WMV2	Agrobacterium/ Linked genes, 1T-DNA	Upjohn (USA), Seminis Vegetable Inc. (Canada)	ZW20
Modified colour + Herbicide tolerance	Carnation	surB+, dfr, hfl	Agrobacterium/ Linked genes, 1T-DNA	Florigene Pty Ltd.	4,11,15,16
Modified colour + Herbicide tolerance	Carnation	surB+, dfr, hfl	Agrobacterium/ Linked genes, 1T-DNA	Florigene Pty Ltd.	959A,988A, 1226A, 1351A, 1363A, 1400A
Insect resistant + Herbicide tolerance	Cotton	Bxn, cry1AC, neo	Agrobacterium/ Linked genes, 1T-DNA	Calgene Inc.	31807/31808
Insect + virus resistant	Potato	Cry3A, PLRVrep, neo or EPSPS	Agrobacterium/ Linked genes, 1T-DNA	Monsanto	RBMT21-129, RBMT21-350, RBMT22-082
Insect resistant	Maize	Bar, cry1AC,	Biolistic/3	Dekalb	DBT418

+ Herbicide tolerance		pinll+	plasmid co-transformation	Genetics Corporation	
Insect resistant + Herbicide tolerance	Maize	cry1AC, EPSPS, gox	Biolistic/3 plasmid co-transformation	Monsanto	MON802, MON809, MON810, MON8325

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MEDICAL TERMINATION OF PREGNANCY IN BITCHES: PHARMACOLOGICAL STRATEGIES AND CLINICAL PROTOCOLS

Article ID: AG-V05-I10-18

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Abstract

Mismating represents a prevalent clinical concern in canine practice, with its incidence rising in parallel with expanding street dog populations and unregulated breeding practices. Accurate confirmation of pregnancy via transabdominal ultrasonography is essential prior to initiating any intervention, as the administration of abortifacients to non-pregnant bitches can result in severe systemic adverse effects. This communication provides a comprehensive review of currently available methods, with an emphasis on identifying the most effective and clinically appropriate approach for pregnancy termination in bitches.

Keywords: Abortifacient, Mismating, Ultrasonography, Termination of pregnancy, Bitch

Introduction

Unplanned pregnancy resulting from mismating is also referred to as accidental mating, unwanted mating, or misalliance is a frequently encountered clinical issue in small animal veterinary practice. Mismating is defined as unintended copulation between a female dog (bitch) and a male, which may lead to an undesired pregnancy.

Medical termination of pregnancy

MTP in bitches involves the administration of pharmacological agents that selectively disrupt or antagonize the hormonal pathways essential for the maintenance of gestation. Commonly employed abortifacients include estrogenic compounds, prostaglandins, dopamine agonists (anti-prolactin agents), and progesterone receptor antagonists. Each class of drug induces pregnancy termination by interfering with key endocrine mechanisms primarily

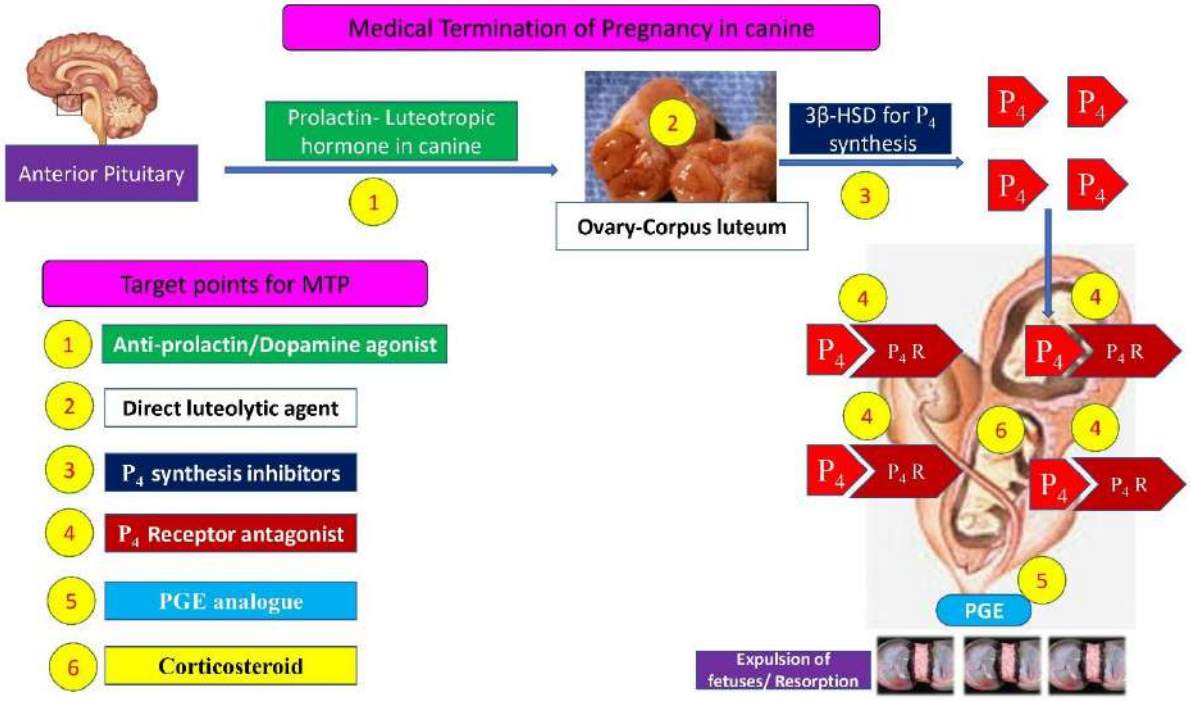
progesterone and prolactin signaling that support embryonic implantation and placental function during gestation.

Indications

- Prevention of pregnancy in bitches bred at an inappropriately young or advanced age
- Strategic reproductive management of genetically valuable purebred females
- Mitigation of pet overpopulation
- Avoidance of the birth of non-pedigree or phenotypically undesirable offspring
- Financial or logistical constraints faced by owners in rearing a litter
- Temporary inability to provide adequate care due to planned travel or extended absence

Criteria for MTP

A detailed reproductive history was obtained, including observation of estrus behavior, occurrence of coital lock, and precise timing of mating. Clinical evaluation was complemented by vaginal exfoliative cytology to confirm estrus status. Bitches were scheduled for re-evaluation at 32-35 days post-coital lock to confirm pregnancy via ultrasonography. Upon confirmation of pregnancy, medical termination of pregnancy (MTP) was initiated in accordance with established protocols (Figure in flow diagram).



Drugs used for MTP

1. Anti-prolactin (Dopamine agonist)

If a veterinarian wants to manipulate the diestrual phase of the estrous cycle in a bitch, a simple administration of anti-prolactin could be sufficient. Hypothalamic control of prolactin secretion is unique from other anterior pituitary hormones because it is through inhibition by dopamine that prolactin secretion is controlled. So, anti-prolactin drugs are also called "dopamine agonists." The prolactin hormone increases its support to the corpus luteum (CL) after 32-35 days of pregnancy and maintains the CL functions. Hence, administration of anti-prolactin results in a decrease in the function of the CL and a decrease in the concentration of progesterone, resulting in the termination of pregnancy (Parmar *et al*., 2020).

Commonly used dopamine agonists in canine practice are Cabergoline and Bromocriptine. But bromocriptine has more side effects when compared to cabergoline.

Cabergoline is a dopamine receptor agonist with a high affinity for D2 receptors. It has a direct inhibitory effect on lactotrophs and stimulates the release of dopamine by tubero infundibular neurons or suppressing secretion of serotonin (Sridevi, 2015). Availability: 0.25 mg and 0.5 mg tablets in different trade names (Cabgolin^{R}). Cabergoline should be administered @5µg/kg BID per oral for 7-10 days or until the expulsion of all the fetuses, which is confirmed by follow-up ultrasonography.

2. Direct luteolytic agent

The agent induces luteolysis of the corpus luteum, resulting in a marked decline in circulating progesterone concentrations. This hormonal withdrawal triggers uterine smooth muscle contraction, exerts an ecbolic effect, and promotes cervical dilation, collectively facilitating pregnancy termination. The commonly used luteolytic agent in veterinary practice is Cloprostenol sodium at the dose rate of 2-5 µg/kg body weight can be used at 48 hours interval for 7-10 days or until the expulsion of all the fetuses, which is confirmed by follow-up ultrasonography (Sridevi, 2015). Common side effects include vomiting, defecation, respiratory distress, panting, and excessive salivation. To mitigate these cholinergic side effects, pre-treatment with atropine sulfate (0.04 mg/kg body weight, intramuscularly) 5-10 minutes prior to the Cloprostenol sodium injection is recommended (Srinivas *et al.,* 2008).

3. Progesterone synthesis inhibitor

In the domestic dog, the ovarian corpora lutea (CL) constitute the primary source of

progesterone throughout gestation, as no functional placental progesterone synthesis has been demonstrated. Consequently, pharmacological disruption of progesterone production or action via administration of progesterone synthesis inhibitors or progesterone receptor antagonists effectively induces pregnancy termination from day 32 of gestation through to term (Concannon *et al*., 1990).

Epostane, a synthetic steroid molecule, acts by inhibiting the enzyme *3β-hydroxysteroid dehydrogenase* (3β-HSD), thereby blocking the conversion of pregnenolone to progesterone. When administered orally at a dosage of 2.5–5 mg/kg once daily for 7 days or until complete fetal expulsion is confirmed by follow-up ultrasonography. It is not commercially available in the Indian market, limiting its clinical utility in this region.

4. Progesterone receptor antagonist/progesterone receptor blockers:

The drug binding to the intracellular progesterone receptor presents in the uterine smooth muscles and prevent the binding of progesterone in their receptors, results in abortion.

1. Mifepristone (RU 486) found to be effective in pregnant bitches when administered after day 32 of gestation @ 2.5mg/kg orally BID for 4.5 days (9 doses). Pregnancy was terminated without any side effects within 3-6 days of treatment.

Availability: Trade name: Killpreg, Unwanted Kit, Mifty kit, Clear Kit and MTP Kit, it contains ***one tablet of mifepristone (200 mg), 4 pills of misoprostol (200µg).***

Administration: Mifepristone @2.5mg/kg orally BID for 4.5 days and Misoprotol @ 2 pills per vaginally (irrespective of the body weight, 48 hours once). Mechanism action of misoprostol (Prostaglandin E2 analogue) postulated to be promoting cervical ripening and dilation, as well as by enhancing uterine contractility. Additionally, it may potentiate the anti-progestogenic effect of mifepristone.

2. Aglepristone (RU 534) another selective progesterone receptor modulator, is administered subcutaneously at 10 mg/kg BID for up to 7 days or until complete fetal expulsion is confirmed via follow-up ultrasonography. It is marketed in India as Alizine, supplied in 10 mL vials with a concentration of 30 mg/mL.

5. Estrogen analogues:

Estrogen analogues exerts its action by 1. Closure of utero-tubular junction, 2. Direct embryotoxicity and 3. Delays oviductal transport of embryo (due to edema of the oviduct), resulted in prevention of implantation of embryo.

S.No	Estrogen analogues	Dosage regimen
1	Estradiol valerate	3 - 7 mg (once 4 - 10 days post breeding)
2	Estradiol Benzoate	0.5 - 3 mg every other day for total of 3 injections from 4 to 10 days post breeding
3	Estradiol cypionate	0.5 - 1 mg (once within 3 days post breeding)

Side effects: Bone marrow suppression leads to fatal anaemia, pyometra, extended estrum, vulvar enlargement, hyper pigmentation of skin and alopecia. Use of estrogen for the medical termination of pregnancy is not recommended in canine.

6. Corticosteroids:

In dogs, administering corticosteroids during mid-gestation specifically after 30 days of pregnancy can induce pregnancy termination. This occurs through the activation of endogenous physiological pathways that closely resemble those naturally involved in the onset of parturition, effectively mimicking the hormonal and biochemical signals that lead to labor and fetal expulsion. However complete termination of pregnancy not achieved and dead fetus expelled if administered at term (Sridevi, 2015). Tab: Dexamethasone: 0.1- 0.2 mg BID PO for 5 - 10 days or Inj: Dexamethasone: 5 mg BID intramuscular for 10 days.

Combined protocols:

1. A combination regimen of cabergoline (5 µg/kg, orally, BID) and cloprostenol sodium (1 µg/kg, subcutaneously, once daily at 48-hour intervals) was administered until complete fetal expulsion, as confirmed by follow-up ultrasonography. In the authors' clinical experience, this protocol consistently resulted in the expulsion of all fetuses within 5 to 6 days of treatment initiation.
2. A combined oral regimen of cabergoline (5 µg/kg, BID) and mifepristone (2.5 mg/kg, BID for 4.5 days) was administered, resulting in complete fetal expulsion within 5 to 6 days of treatment initiation.
3. A combined protocol consisting of subcutaneous cloprostenol sodium (1µg/kg administered once daily at 48-hour intervals) and oral mifepristone (2.5mg/kg, twice daily for 4.5 days) was employed, resulting in complete fetal expulsion within 5 to 6 days of treatment initiation.

Clinical response following MTP

1. Appearance of onset of brownish vaginal discharge, often accompanied by increased vulvar licking.
2. Decrease in the size of the abdomen
3. Expulsion of fetuses (If pregnancy more than 45 days)
4. MTP is performed earlier in gestation (≤45 days), fetal resorption typically occurs, clinically manifesting only as persistent brownish vaginal discharge without visible fetal expulsion.

These clinical responses serve as practical, non-invasive indicators of treatment efficacy and should be corroborated with follow-up ultrasonography to confirm complete uterine clearance and rule out retained fetal or placental tissue.

Conclusion

A combination therapy has demonstrated superior efficacy in the early expulsion of fetuses compared to the use of individual drugs alone. Among various protocols reviewed and evaluated, the combination of cabergoline and low-dose cloprostenol has emerged as particularly effective, offering both enhanced clinical outcomes and a favorable safety profile with minimal side effects. Furthermore, this regimen is cost-effective relative to alternative therapeutic protocols. Based on these advantages improved efficacy, reduced adverse effects, and economic feasibility the authors recommend the cabergoline and low-dose cloprostenol combination as a preferred treatment strategy for early fetal expulsion in bitches presented for medical termination of pregnancy.

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SEAHORSES AS BIOINDICATORS OF COASTAL ENVIRONMENTAL HEALTH

Article ID: AG-V05-I10-19

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Abstract

Seahorses (*Hippocampus* spp.) are among the most fascinating and ecologically significant fishes inhabiting shallow coastal ecosystems such as mangroves, coral reefs and seagrass meadows. Due to their sedentary lifestyle, site fidelity and sensitivity to environmental fluctuations, they serve as ideal bioindicators of coastal ecosystem health. As increasing anthropogenic pressures such as pollution, eutrophication and habitat destruction which continue to threaten marine habitats, the monitoring of seahorse populations can provide valuable insight into ecological changes and environmental quality. This article shows the biological, ecological and biochemical attributes that make seahorses reliable indicators of environmental health, along with methods of monitoring and their implications for conservation management.

Keywords: Bioindicator, Syngnathidae, UVC, Fidelity, eDNA and CITES

1. Introduction

Coastal ecosystems play a crucial role in global biodiversity and human livelihoods, offering vital services such as nutrient cycling, nursery habitats and carbon sequestration. However, these ecosystems face significant threats from human-induced pressures such as pollution, sedimentation, coastal development, and overexploitation. Monitoring the health of such ecosystems requires the use of reliable indicators that can reflect the cumulative impact of these stressors. Bioindicators are organisms whose biological responses provide measurable evidence of environmental quality. Fish species, being directly exposed to waterborne pollutants

and habitat changes, serve as ideal bioindicators of aquatic health. Among these, seahorses (*Hippocampus* spp.) are particularly suitable due to their restricted movement, dependence on specific habitats, and sensitivity to subtle environmental variations. As a result, changes in seahorse populations can effectively mirror the ecological status of coastal habitats.

2. Ecological Significance of Seahorses

Seahorses belong to the family Syngnathidae and are distributed widely across tropical and temperate coastal waters. Their habitats include seagrass beds, mangroves, coral reefs, estuaries and macroalgal zones-ecosystems known for high productivity and biodiversity. They are carnivorous, feeding primarily on planktonic and benthic crustaceans such as copepods, amphipods and mysid shrimps, thus occupying a critical trophic level in coastal food webs.

Ecologically, seahorses are considered **umbrella species**—protecting their habitats ensures the survival of numerous associated organisms. Their camouflage abilities and prehensile tails allow them to anchor to vegetation or corals, minimizing energy expenditure in dynamic environments. Because they are poor swimmers and inhabit well-defined areas, their distribution and abundance directly reflect the health of their immediate habitat. A decline in seahorse population often signals habitat degradation, loss of structural complexity or contamination.



3. Criteria for Seahorses as Bioindicators

To function effectively as bioindicators, species must exhibit certain characteristics—sensitivity to pollutants, ease of monitoring, ecological relevance and a measurable response to environmental changes. Seahorses meet all these criteria:

3.1 Site Fidelity and Sedentary Behaviour

Seahorses exhibit strong site fidelity, often remaining within a small home range for extended periods. This sedentary nature means that any physiological or behavioural changes observed are reflective of local environmental conditions rather than migratory influences.

3.2 Sensitivity to Environmental Stressors

Seahorses are highly sensitive to water quality parameters such as salinity, temperature, dissolved oxygen, and pollution. Studies have shown that exposure to contaminants like heavy metals (cadmium, lead, mercury) and organic pollutants can alter metabolic processes, reduce reproductive performance, and induce oxidative stress.

3.3 Reproductive Sensitivity

The male brood pouch, which incubates embryos until parturition, provides a unique opportunity to monitor reproductive health. Any alterations in brood size, embryonic deformities, or pouch abnormalities can indicate sub-lethal environmental stress.

3.4 Trophic and Ecological Dependence

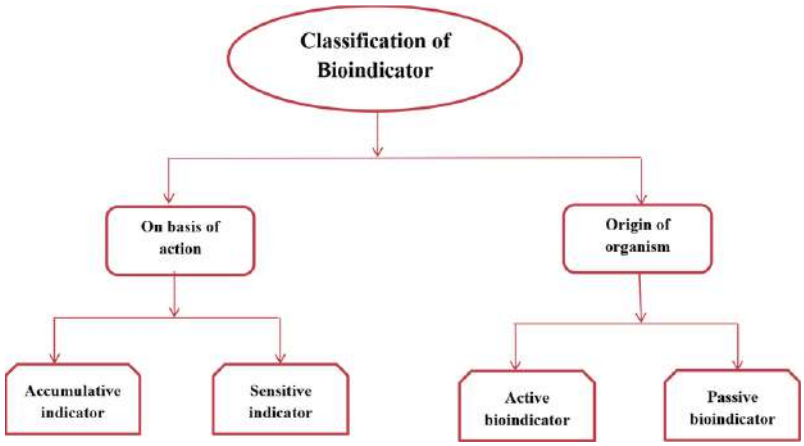
As habitat-dependent species, seahorses rely on seagrass and coral structures for anchorage, feeding, and reproduction. Therefore, their presence or absence can be a direct indicator of habitat quality.

4. Indicators of Environmental Degradation

Environmental degradation in coastal ecosystems is clearly reflected in the abundance, morphology, and behavior of seahorses. The destruction of critical habitats such as seagrass meadows, mangroves, and coral reefs due to coastal development, dredging, and bottom trawling severely affects seahorse populations. Habitat fragmentation reduces structural complexity, which limits their ability to anchor, feed, and reproduce. Similarly, nutrient enrichment from aquaculture effluents and agricultural runoff promotes eutrophication and algal blooms, leading to hypoxic conditions. Pollutants such as heavy metals and organic contaminants can bioaccumulate in seahorse tissues, resulting in biochemical disturbances including oxidative stress, lipid peroxidation, and reduced antioxidant enzyme activity—conditions that weaken their physiological health and reproductive success.

In addition, sedimentation and increased turbidity caused by land-based activities reduce water clarity and light penetration, negatively affecting seagrass growth and primary productivity. The resulting decline in prey availability and holdfast structures disrupts seahorse feeding efficiency and camouflage behavior. Moreover, climate change poses an emerging threat; rising sea surface temperatures and ocean acidification alter reproductive timing, embryonic development, and larval survival rates. These stressors collectively drive changes in seahorse distribution, with several *Hippocampus* species showing a tendency to migrate toward

cooler regions. Thus, fluctuations in seahorse population density and physiological condition serve as sensitive indicators of environmental degradation in coastal habitats.



5. Analytical and Monitoring Approaches

Effective monitoring of seahorses as bioindicators involves integrating ecological, biochemical, and molecular techniques:

5.1 Field Surveys

Traditional methods such as underwater visual census (UVC) and transect surveys provide information on population density, sex ratio, and habitat association. Photographic identification and mark-recapture studies aid in tracking individual seahorses over time.

5.2 Biochemical Biomarkers

Biomarkers such as antioxidant enzymes (catalase, superoxide dismutase, glutathione peroxidase) and stress proteins (HSP70) indicate physiological responses to contaminants. Measurement of these parameters in seahorse tissues provides early warning signals of pollution.

5.3 Stable Isotope and Trace Metal Analysis

Stable isotope ratios ($\delta^{13}C$ and $\delta^{15}N$) are used to trace trophic relationships and detect changes in food web structure due to pollution. Similarly, tissue analysis can reveal bioaccumulation of heavy metals and organic toxins.

5.4 Environmental DNA (eDNA)

Recent advances in molecular ecology enable detection of seahorse DNA fragments in water samples. This non-invasive technique helps monitor seahorse presence in turbid or degraded habitats where visual observation is difficult.

5.5 GIS and Habitat Mapping

Integrating seahorse population data with Geographic Information System (GIS) mapping allows spatial analysis of habitat degradation, aiding in identifying critical conservation zones.

6. Conservation and Management Implications

The use of seahorses as bioindicators has significant implications for ecosystem management and conservation policy:

- **Ecosystem-Based Management (EBM):** Monitoring seahorse populations supports the implementation of EBM strategies that address both species protection and habitat restoration.
- **Marine Protected Areas (MPAs):** Data on seahorse distribution can guide the designation of MPAs, ensuring that ecologically sensitive areas are prioritized for protection.
- **Community Participation:** Local fishers and coastal communities can be involved in citizen-science monitoring programs, promoting awareness and sustainable harvesting practices.
- **Policy Integration:** Since all seahorse species are listed under CITES Appendix II, integrating bioindicator-based monitoring into national biodiversity policies strengthens compliance with international conservation mandates.

7. Conclusion

Seahorses are valuable sentinels of coastal environmental health, offering insights into the complex interactions between biological organisms and their habitats. Their sedentary lifestyle, high habitat specificity, and physiological sensitivity make them excellent models for detecting ecosystem disturbances caused by pollution and habitat degradation. Incorporating seahorse-based bioindicators into long-term monitoring frameworks enhances our ability to predict environmental changes and evaluate restoration success. Future research should focus on standardizing bioindicator protocols, integrating molecular biomarkers, and understanding adaptive responses of seahorses under climate change scenarios to ensure sustainable management of coastal ecosystems.

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FUNGAL DISEASES IN SILKWORM (*Bombyx mori* L.)

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Introduction

Fungal Diseases in Silkworms

Fungal diseases (mycosis) in silkworm are caused by parasitic fungi. Two major kinds of such diseases are Muscardine and Aspergillosis. There are more than 10 types of fungi, which cause Muscardine, and signs of the disease vary with the type of infecting fungus. Depending on the colour of the spores of fungus, which covers the body of the silkworm giving characteristic colour have been named as white muscardine, green muscardine, yellow muscardine, black muscardine, red muscardine etc.

1. White Muscardine

Causative Agent:

Beauveria bassiana (family Moniliaceae, order Moniliales, class Fungi Imperfecti). Locally, it is known as Sunna katu roga, and is widespread across sericulture regions.

Route of Infection

Infection occurs primarily through direct contamination of the silkworm's body, where germinating conidia penetrate the cuticle. Major sources of infection include mummified larvae, contaminated rearing equipment such as seat paper and trays, and dead wild Lepidopteran larvae from mulberry fields. The disease is extremely contagious, as conidia are easily dispersed through air. Outbreaks are most common during the rainy and winter seasons, when low temperatures and high humidity provide favourable conditions.

The life cycle of *Beauveria* involves three main stages: conidium, vegetative mycelium, and aerial mycelium. Conidia are typically colourless, globular to oval in shape. Under optimal environmental conditions, conidia germinate within 8–10 hours after contact with the silkworm's body. Following germination, the fungal hyphae penetrate the cuticle and multiply internally. As the infection progresses, vegetative hyphae emerge from the host's body surface, developing into aerial hyphae that produce numerous conidiophores. These conidiophores branch into smaller structures, each bearing one or two conidia, thus completing the cycle and ensuring rapid disease transmission.

Symptoms:

- Loss of appetite, sluggish behaviour, and reduced skin elasticity
- Vomiting and diarrhoea prior to death
- Freshly dead larvae remain elastic, but within 24 hours the body hardens and mummifies
- The corpse becomes coated with white, powdery spores, giving a dry stick-like appearance
- Pupae shrink, wrinkle, and harden into a whitish mummy
- In moths, the body stiffens and wings fall off easily
- Eggs appear pale and fail to hatch due to fungal contamination



Preventive Measures:

- Disinfect rearing rooms, trays, and appliances thoroughly
- Surface sterilize eggs with 2% formalin
- Maintain optimal ventilation and prevent dampness
- Keep larval beds thin and dry to avoid spore germination
- Remove and destroy diseased larvae before sporulation
- Apply fungicides such as Formalin chaff, Dithane M-45, or Captan mixed with china clay

Formalin Chaff Application

Formalin chaff is prepared using paddy husk that is charred or roasted without allowing it to turn into ash. The required concentration of formalin varies depending on the larval stage: 0.4% for I and II instars, 0.5% for III instar, 0.6% for IV instar, and 0.8% for V instar. The formalin solution is mixed thoroughly with the burnt paddy husk in a 1:10 ratio by volume. The treated mixture is then sprinkled evenly over the larvae and covered with paraffin paper. After 30 minutes, the paper is removed, and feeding is resumed. This application is generally carried out after each moult but must be done half an hour before the resumption of feeding. In case of severe disease incidence, the treatment can be repeated daily after bed cleaning.

Special care should be taken to avoid applying formalin chaff when the larvae are either settling for a moult or already in moult. As a preventive measure, especially during the rainy and winter seasons when muscardine incidence is common, formalin chaff should be applied once in every instar—before brushing, and after the I, II, III, and IV moults, as well as on the fourth day of the V instar.

Dithane M-45 or Captan Application

For the chemical management of muscardine, the fungicides Dithane M-45 and Captan are commonly used in combination with levigated china clay. The recommended concentration is 1% during I–III instars and 2% during IV–V instars.

The prepared mixture is dusted uniformly over the silkworms, especially on newly hatched larvae and after each moult, ensuring that the application is done half an hour before feeding resumes. The required quantity is approximately 2–3 g per 100 cm^2 of rearing bed area for I–III instars, and 4–5 g per 100 cm^2 for IV–V instars.

It is important to note that dusting should not be done while the larvae are in the moulting stage or actively feeding. Unlike formalin chaff treatment, the beds do not require covering with paraffin paper after dusting. Feeding can safely be resumed 30 minutes post-application.

2. Green Muscardine

Causative Agents:

Green muscardine disease in silkworms is caused by **hyphomycetous fungi**, primarily *Nomuraea rileyi* and *Spicaria prasina*. These fungi belong to the **family Moniliaceae**, division **Eumycota**, subdivision **Deuteromycotina**, class **Hyphomycetes**, and order **Moniliales**.

Both pathogens are entomopathogenic fungi that invade the host body, proliferate internally, and ultimately cover the larval surface with characteristic green conidial masses, hence the name *green muscardine*.

Route of Infection

Infection occurs through direct penetration of the silkworm's cuticle by fungal conidia. Outbreaks are most common during autumn, late autumn, and winter seasons, when environmental conditions favour fungal growth. The pathogen exhibits three developmental stages—conidium, vegetative mycelium, and aerial mycelium—similar to the progression observed in white muscardine. The conidia are oval, slightly pointed at one end, light green in colour, and single-celled. Under favourable conditions of 20–24°C, conidia germinate within 20 hours.

Following germination, the vegetative mycelium develops germ tubes that elongate into fine, filamentous structures. These mycelia subsequently give rise to numerous colourless, bean-shaped hyphae, which in turn differentiate into conidiophores. The conidiophores are wheel-shaped and unbranched, each bearing several sterigmata that carry chains of conidia at their tips. This cycle ensures continuous propagation and rapid spread of infection among silkworm populations.

Symptoms:

- Initially, the dead body of the larva appears white in colour.
- Dark brown irregular lesions appear on the ventral, dorsal and lateral sides.
- In serious case the silkworm vomits fluid, has diarrhoea and dies.
- After death the soft corpse gradually hardens.
- Initially the whole body covered with white mycelia.
- After 10-15 days these white mycelia produce fresh green conidia and worm looks green.
- The entire body, except the head, will be covered with green powdery material and the larvae look like dry green stick.
- Infected pupa the thoracic region appears shrunk and the abdomen wrinkled. The pupae are hard, lighter, mummified and greenish colour.

Preventive Measures:

Similar to those of white muscardine.

3. Yellow Muscardine

Yellow muscardine disease of silkworms is caused by the fungal pathogen ***Isaria farinosus*** or ***Paecilomyces farinosus***. The disease affects both young and late-stage larvae, but the **mortality rate is particularly high during the 5th instar, mounting, and cocooning stages.** The external symptoms of yellow muscardine closely resemble those of **white muscardine**, with one major distinction—the presence of a **large number of yellow-coloured conidiophores** covering the larval body. The fungal spores are typically **oval or spherical in shape.**

Outbreaks of yellow muscardine are most frequently observed during the **autumn season**, when environmental conditions are favourable for fungal growth and spread.

4. Black Muscardine

Black muscardine disease of silkworms is caused by fungal pathogens such as ***Oospora destructor, Beauveria brongniartii,*** or ***Metarhizium anisopliae*.** Compared to other types of muscardine, its incidence is relatively low. The disease generally appears during **hot summer and autumn rearing seasons**, when conditions are favourable for fungal growth.

The clinical symptoms are similar to those of **white muscardine**, with the primary distinguishing feature being the development of a **large number of black conidiophores** on the surface of infected larvae. This results in a **characteristic blackened appearance** of the cadavers.

5. Brown Muscardine

Brown muscardine disease, also referred to as **aspergillosis**, is caused by multiple species of the genus **Aspergillus** (more than 10 species have been reported). These fungi are **widely distributed in nature** and normally behave as **saprophytes**, becoming pathogenic only under favourable conditions of temperature and humidity.

The disease is highly destructive, particularly to **young silkworm larvae**, which usually succumb within **2–3 days of infection.** The distinguishing feature is the development of **greenish-yellow conidiophores intermingled with brown shades** on the surface of the infected larvae.

A notable characteristic of *Aspergillus* is its ability to **grow and sporulate on rearing equipment, walls, and floors of rearing houses, as well as on moist chopping boards.** This environmental persistence makes the pathogen difficult to eradicate. Hence, **thorough**

disinfection of all rearing materials and surroundings is essential to prevent the occurrence and spread of brown muscardine.

6. Aspergillosis

Aspergillosis is a fungal disease of silkworms caused by species of the genus *Aspergillus*. These fungi are not only pathogenic to silkworms (*Bombyx mori*) but are also capable of infecting plants, animals, stored grains, animal feeds, dairy products, leather, and various insects. The disease is particularly prevalent among young instar larvae under conditions of high humidity.

The causative fungi belong to the *Aspergillus* and *Sterigmatocystis* groups, which are classified under the family **Moniliaceae**, class **Fungi Imperfecti**. Several species have been identified as pathogenic to silkworms, including *A. flavus, A. sojae, A. parasiticus, A. flavipes, A. nidulans, A. melleus, A. fumigatus, A. elegans, A. niger, A. oryzae,* and *A. ochraceus*.

Although most *Aspergillus* species are saprophytic, more than 15 species have been reported to infect the mulberry silkworm. Among them, *A. flavus, A. oryzae,* and *A. tamarii* are considered the most significant. In India, Patil (1989) reported the occurrence of *A. flavus* in *B. mori*.

Susceptibility of Silkworms

Newly hatched larvae are the most vulnerable to infection, while resistance improves during larval growth and peaks in the 5th instar stage. However, resistance declines again during the pupation stage. Susceptibility is highly influenced by environmental factors:

Humidity: Disease incidence is low at 70% relative humidity but increases significantly as humidity rises.

Temperature: The optimal temperature for conidial germination is between **30–35°C**.

Symptoms

Infected larvae exhibit the following signs:

- Cessation of feeding on mulberry leaves
- Lethargy and sluggish movement
- Stiffening of the body and abnormal body tension
- Glossy or lustrous appearance before death Of the fungal pathogens, *A. flavus* conidia are exceptionally resistant to environmental stress and can survive for a year or longer, making them a persistent threat in rearing environments.



Specific Types of Aspergillosis

1. Aspergillus oryzae Disease

- Symptoms resemble those of brown muscardine but differ in spore coloration
- Spores appear light yellow mixed with dirty brown instead of typical muscardine shades

2. Aspergillus corallus Disease

- Very mild infection with low incidence compared to other fungal diseases
- Characterized by the production of orange-yellow spores on the larval body

Environmental Management

Methods to Manage High Temperature and Low Humidity

- Avoid rearing house with asbestos or tin roof.
- Raise shade trees around the rearing house, cover the roof with coconut thatches, grass or palm leaves.
- Apply 'Cool Guard' to the roof top.
- Feed mulberry leaves with higher moisture content. Harvest mulberry leaves during cooler hours, sprinkle water and preserve them in dark and cooler area.
- Keep windward windows and floor level ventilators closed during hot period of the day.
- Provide wet gunny cloth curtain to the windows and doors.
- Wipe floor with water during day time once at 11 AM and again at 3 PM.
- Increase the frequency of feeding from 2-3 to 3-4 times a day.
- Feed reduced quantity of leaves during noon and more during night.
- During hot period, cover the bed with old newspaper, after feeding.

Methods to Manage Low Temperature and High Humidity

- Regulate air circulation without causing suffocation.
- Use heaters (electrical or charcoal) to raise room temperature.
- Dust dry slaked lime powder on the rearing room floor.

- Dust dry slaked lime powder on the silkworms, after bed cleaning or before feeding in the morning.
- Avoid over feeding. Feed only the quantum of mulberry leaves, the larvae consumes during the feed period.
- Avoid accumulation of silkworm waste and faeces in the bed.
- Feed comparatively more mature leaves than the leaves fed during normal period.

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WEED MANAGEMENT: SYNERGISTIC USE OF MECHANICAL, BIOLOGICAL AND CHEMICAL CONTROLS IN VEGETABLE CROPS

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Abstract

Weed management is a crucial aspect of crop production, as weeds compete with crops for nutrients, water, light, and space, often leading to severe yield and quality losses. Effective control requires the adoption of diverse methods suited to crop type, weed flora, and agro-ecological conditions. Cultural practices such as crop rotation, mulching, soil solarization, and use of competitive cultivars reduce weed pressure naturally. Mechanical methods like tillage, hand hoeing, and flame weeding provide effective control in small-scale and organic farming systems. Biological approaches, including the use of insects, pathogens, and competitive plants, offer eco-friendly options for suppressing problematic weeds. Chemical methods, particularly herbicides, ensure rapid and large-scale control but must be used judiciously to avoid resistance and environmental concerns. Recent biotechnological advances, such as herbicide-tolerant crops, have further strengthened integrated weed management strategies. Combining these approaches into an Integrated Weed Management (IWM) system ensures sustainable productivity, environmental safety, and long-term profitability in crop cultivation

Keywords

Weed management, vegetable crops, herbicides, biological control, yield loss.

Introduction

Vegetable crops are nutrient-rich, high-value commodities, but their productivity is severely constrained by weeds. Due to their shallow roots, short stature, and slow initial growth, vegetables are highly vulnerable to weed competition, leading to yield losses of 30–70%. Weeds

not only compete for resources but also act as alternate hosts for pests and pathogens, reducing both yield and quality. Moreover, weed infestations increase labour costs, delay harvesting, and lower market value. Since vegetable production is often intensive and input-demanding, effective weed management is essential. An integrated approach combining cultural, mechanical, biological, and chemical methods offers a sustainable solution for minimizing weed pressure and ensuring profitable vegetable production.

Weed Management

There are about 374000 plant species currently known in the world. When one grows any of the economic species of plants, invariably a variety of undesirable vegetation come up simultaneously which competes with the crop for all growth factors. These undesirable and competitive plants are known as "weeds".

This habit makes them vulnerable to weed competition, which has a negative impact on the quantity as well as the quality parameters

In India, the loss caused by weeds accounts for 37 per cent, insects 29 per cent, diseases 22 per cent and others 12 per cent reported a yield loss of about USD 11 billion due to weeds alone in India.

Yield of the tomato **(*Solanum lycopersicum* L.)** was decreased by 48%–71% when the vegetable plants were growing in competition with weeds such as large crabgrass **(*Digitaria sanguinalis*.**

Pepper **(*Capsicum annuum L.*)** weeds such as purple nutsedge **(*Cyperus rotundus L.*)** could decrease the fruit yield by up to 44%

The fruit number of the bell pepper **(*C. annum*)** was decreased by 94% if its growth was interfered with by the weed Palmer amaranth **(*Amaranthus palmeri*)**

Yield loss due to weeds in different vegetables

Crop	Reduction in Yield (%)
Okra	40 -80 %
Potato	52%
Bottle gourd	40%
Onion	40 -80 %

Cabbage	45 – 80 %
Carrot	90 %
Tomato	92-95%
Brinjal	30 -35 %
Chilli	60 -70 %
Garlic	94.8 %
Radish	86 %

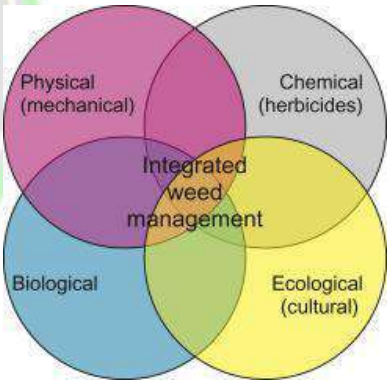
Crop Weed Competition

Allelochemicals from some weeds adversely affect the germination and root shoot growth of crop seedlings. The extent of yield losses depends on the type of weed flora, intensity and duration of weed competition and soil and climatic factors.

Weed Management

1.**Integrated Weed Management**

To manage weeds through a combination of various strategies, including cultural, mechanical, biological, chemical and biotechnological methods.



It is a system approach to maintain the weed population below the economic threshold level by adopting all available means of weed control

2.Cultural Methods

- Optimum Time of Sowing
- Proper Row Spacing
- Weed Competitive Cultivar
- Crop Rotation
- Soil Solarization
- Mulching
- Stale Seedbed





- Irrigation
- Allelopathic Weed Management

3.Mechanical Methods

- Tillage
- Hand Hoeing
- Hand Pulling
- Flame Weeding





4.Biological Method

- Biological control involves the use of living organisms such as insects, other animals and competitive plants for weed control.
- *Zygogramma bicolorata* was the only effective insect bioagent against parthenium.
- *Puccinia abrupta var. partheniicola* and *Puccinia xanthii var. parthenii-hysterophorae*, can be used to control parthenium.
- *Bactra verutana* was another insect bioagent used against *Cyperus rotundus*

5.Chemical Method

Crops	Herbicide	Trade name	Dose (kg ha^{-1})	Time of application
Tomato, okra, garlic, cabbage, cauliflower	Fluchloralin	Basallin	0.85-1	Pre plant incorporation
Transplanted tomato, brinjal, potato, okra, brassica crops, legumes	Trifluralin	Crisalin	0.75-0.9	Pre plant incorporation
Carrot, radish, potato, garlic, chilli, okra, tomato, brinjal, cabbage, cauliflower	Pendimethalin	Stomp	0.75-1.5	Pre emergence
Potato	Alachlor	Lasso	2-3	Pre emergence
Transplanted tomato and cucurbits	Butachlor	Machete	2	Pre emergence

Direct seeded and Transplanted tomato and potato	Metribuzin	Lexone, sencor	0.2-0.35	Pre or early post emergence
Direct seeded and Transplanted tomato and potato	Oxyfluorfen	Goal	0.24-0.36	Early post emergence
Onion and garlic	Oxadiazon	Ronstar	0.7-4	Post emergence
Tomato, Brinjal and chilli	Quizalofop-p-ethyl	Targa super	0.04-0.05	Post emergence
Carrot and radish	Fenoxaprop-p-ethyl	Puma super	0.05-0.075	Post emergence

6.Biotechnological Method

- **Glyphosate:** Herbicide tolerant crops like sugar beet, soyabean etc are genetically engineered to develop resistance against herbicide glyphosate.
- **Glufosinate:** Bialaphos is a pro-herbicide that is converted by the plants into Glufosinate or its ammonium salt L-phosphinothricin (PPT) which is an active ingredient in several nonselective herbicides such as sweep power. phosphinothricin resistant potato and tomato were developed
- Sulfonylurea herbicides inhibit Acetolactate synthase (ALS) in plants is involved in the biosynthesis of the amino acids like leucine, isoleucine and valine. For example, sulfonylurea resistant soybeans, canola etc.

Conclusion

Weed competition is a major constraint in vegetable production, reducing yield and quality through resource competition and allelopathic effects. Yield losses vary with weed flora, intensity, duration, and environmental conditions. Integrated Weed Management (IWM) is the most sustainable solution. Cultural methods like crop rotation, mulching, solarization, and stale seedbeds help suppress weeds. Mechanical options such as tillage, hoeing, and flame weeding are effective for small farms. Biological agents like *Zygogramma bicolorata* and *Bactra verutana* offer eco-friendly control. Judicious herbicide use remains vital but requires caution to

prevent resistance and residues. Biotechnological innovations, including herbicide tolerant crops, provide future opportunities for sustainable weed management.

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REVIEW ON CAUSES, EFFECTS AND CONTROL MEASURES OF ACID RAIN

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Abstract

Acid rain is a major environmental concern caused by the emission of sulfur dioxide (SO_2) and nitrogen oxides (NO_x) into the atmosphere, where they undergo chemical transformation into sulfuric and nitric acids. These acids fall to the Earth through wet or dry deposition, significantly affecting terrestrial and aquatic ecosystems. Both natural processes, such as volcanic eruptions and lightning, and anthropogenic activities, including fossil fuel combustion, industrial discharges, and vehicular emissions, contribute to acid rain formation. Acid rain has wide-ranging impacts: it acidifies soils and water bodies, reduces soil fertility, leaches essential nutrients, damages crops and forests, corrodes buildings, and adversely affects human health through respiratory and skin problems. Effective control requires both technological and policy measures. Strategies include emission reduction through cleaner fuels, installation of scrubbers in industries, adoption of renewable energy, and neutralization techniques like liming in water bodies and soils. Additionally, public awareness and stringent environmental policies are crucial for mitigation. Acid rain exemplifies a global transboundary pollution issue that demands international cooperation and sustainable solutions. This review provides insights into its causes, impacts, and effective management approaches.

Keywords: Acid rain, Air pollution, SO_2, NO_2 Environmental impact, Control measures

Introduction

Acid rain is recognized as one of the most serious global environmental challenges, with consequences that extend across ecosystems, economies, and human health. The term “acid rain” was first introduced by Robert Angus Smith in 1872, describing the acidic nature of precipitation around industrial towns in the United Kingdom (Smith, 1872). Since then, acid rain has been widely studied as a critical outcome of air pollution, particularly in the context of the rapid industrialization and urbanization that have characterized the modern era.

By definition, acid rain refers to any form of precipitation — including rain, snow, fog, sleet, or dry deposition of acidic gases and particles — with a pH lower than 5.6 (Galloway et al., 1976). This acidity arises primarily from the atmospheric conversion of sulfur dioxide (SO_2) and nitrogen oxides (NO_x) into sulfuric (H_2SO_4) and nitric acids (HNO_3) (Cullis & Hirschler, 1980). These precursor gases are released predominantly through human activities such as the combustion of fossil fuels in power plants, motor vehicles, and industrial processes, though natural sources like volcanic eruptions and lightning also play a role (Sonwani & Maurya, 2018).

The environmental impacts of acid rain are diverse and alarming. In terrestrial systems, acid precipitation reduces soil fertility by leaching essential nutrients such as calcium and magnesium while mobilizing toxic metals like aluminum. This process negatively affects crop productivity and forest ecosystems (Singh & Agrawal, 2007). In aquatic systems, lakes and rivers experience lowered pH levels, leading to biodiversity decline, fish mortality, and disruption of food webs. Acidification also affects microbial processes, thereby altering nutrient cycles (Jacobson et al., 1988).

The built environment is also significantly impacted. Historical monuments, buildings, and sculptures constructed from limestone and marble deteriorate rapidly under acid deposition due to chemical weathering (Abbasi et al., 2013). Metals like copper and zinc corrode, resulting in heavy economic losses for infrastructure maintenance. Furthermore, human health suffers from direct and indirect consequences of acid rain. Exposure to acidic pollutants contributes to respiratory illnesses such as asthma, chronic bronchitis, and throat irritation, while contaminated food and water sources indirectly affect health (Sonwani & Maurya, 2018).

Given its transboundary nature, acid rain is not confined to the regions producing the pollutants. Prevailing winds carry SO_2 and NO_x across national borders, resulting in international environmental disputes. For example, acid rain originating in one industrialized country can

impact neighboring ecosystems thousands of kilometers away. Consequently, international cooperation has been essential in addressing this issue, leading to landmark agreements such as the 1979 Convention on Long-Range Transboundary Air Pollution (CLRTAP).

This review explores the underlying causes of acid rain, the extensive ecological and health-related effects, and the strategies that have been proposed and implemented to mitigate its occurrence. By examining both natural and anthropogenic drivers, as well as the consequences on multiple systems, this paper emphasizes the urgency of integrated and sustainable management approaches.

Causes of Acid Rain

Natural Sources

Volcanic eruptions are a major natural contributor to acid rain, releasing vast quantities of SO_2 into the atmosphere. Forest fires, decaying vegetation, and biological processes, such as anaerobic decomposition, also release sulfur compounds that form acidic precipitation. Lightning produces nitrogen oxides that combine with water to form nitric acid, another key component of acid rain (Sonwani & Maurya, 2018).

Anthropogenic Sources

Human activity remains the dominant driver of acid rain. Combustion of fossil fuels in power plants, oil refineries, and industrial facilities releases significant SO_2 and NO_x emissions. Motor vehicle exhaust in urban areas further contributes to atmospheric acidification (Saxena & Sonwani, 2019). Once emitted, these gases travel long distances and react with water vapor and oxidants to produce strong acids.

Atmospheric Reactions

The chemical transformation of SO_2 and NO_x involves photochemical reactions in the presence of sunlight, producing sulfuric and nitric acids that mix with precipitation. Dry deposition also occurs, where acidic particles settle directly on surfaces before being washed off by rainfall. This dual mechanism amplifies the scale and persistence of acid rain (Cullis & Hirschler, 1980).

Effects of Acid Rain

Acid rain severely impacts terrestrial ecosystems. Soils exposed to acidic deposition lose essential nutrients, while toxic metals are mobilized, impairing plant growth and reducing agricultural productivity.

Forest decline has been documented in many regions due to nutrient depletion and foliar damage (Singh & Agrawal, 2007).

Aquatic systems are highly vulnerable to acidification. Lakes and rivers with poor buffering capacity exhibit sharp declines in biodiversity, with fish and amphibians particularly sensitive to lowered pH levels. Acidified waters also disrupt plankton and microbial communities, destabilizing aquatic food chains (Jacobson et al., 1988).

Built structures and human health are also affected. Acid rain corrodes historical monuments, weakens metals, and degrades fabrics. Humans experience respiratory problems such as asthma and chronic cough, alongside potential neurological and kidney issues due to long-term exposure (Sonwani & Maurya, 2018; Kunt & Özkan, 2023).

Control Measures

Technological Interventions

Technologies such as flue-gas desulfurization ("scrubbers") in industries and catalytic converters in vehicles significantly reduce SO_2 and NO_x emissions. Shifting to cleaner fuels, renewable energy, and energy-efficient practices also curtails emissions at the source (Abbasi et al., 2013).

Neutralization Approaches

Liming is widely used to neutralize acidic soils and water bodies. Adding lime restores pH balance, reduces toxicity, and promotes recovery of aquatic and terrestrial ecosystems, though it is often a temporary solution (Sivaramanan, 2015).

Policy and Awareness

Stringent regulations on emissions, such as caps on SO_2 in power plants, have proven effective in countries like the USA. Public awareness campaigns and international cooperation are essential to addressing the transboundary nature of acid rain (Gerson et al., 2016).

Conclusion

Acid rain represents one of the most pressing global environmental threats, arising mainly from the combustion of fossil fuels and unchecked industrial activities. While natural processes such as volcanic eruptions and lightning contribute to its occurrence, anthropogenic emissions of SO_2 and NO_x remain the dominant sources. Its ecological effects are profound: it disrupts soil chemistry, reduces agricultural and forest productivity, acidifies freshwater bodies, and destabilizes aquatic ecosystems. Moreover, the corrosion of monuments and infrastructure

imposes economic burdens, while human health is jeopardized through respiratory, neurological, and dermatological complications. In conclusion, acid rain exemplifies the interconnectedness of environmental issues, transcending borders and affecting diverse systems. Its control requires a balanced combination of science, technology, policy, and public participation. Long-term sustainability can only be achieved by addressing root causes, particularly reducing fossil fuel dependency, and fostering international collaboration.

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ADDRESSING GENDER ISSUES FOR EMPOWERING RURAL WOMEN IN INDIAN AGRICULTURE THROUGH DIGITAL TECHNOLOGY

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Abstract

Rural women in India play a vital role in agriculture. Digital technologies can help women engage more efficiently in agriculture, boost their productivity, and enhance their livelihoods. Women contributions often go unnoticed, both socially and economically, as they are seldom recognized as "farmers" in official documentation, receive minimal or no compensation for their efforts, and are largely excluded from decision-making processes, land ownership rights, and access to institutional credit or government programs with digital initiatives. Women with their significant contributions in agriculture, encounter more difficulties than men. This limitation hinders their ability to reach their full potential. In spite of these obstacles, multiple efforts are being made to encourage the adoption of digital technology by women farmers to close the digital gap. Women-Led Information Network and Digital Agro-Innovation Hub are the platforms that aims to link women farmers with agricultural specialists who can offer them information on sustainable farming methods, market possibilities, and financial management strategies and emphasizes the encouragement of digital technologies in agriculture. This hub provides training and mentorship opportunities for women farmers on using mobile apps for farm management, engaging with online marketplaces, and employing drones for precision farming. Additionally, the hub grants women farmers access to digital resources such as weather applications, crop management software, and e-learning tools. The study will highlight on aspects pertaining to integrating rural women into digital technological aspects related to

agriculture for their overall empowerment. This in turn, will help in understanding of gender justice as an essential step towards achieving food security, poverty reduction, and sustainable rural development through narrowing technological divide. Recognizing the escalating role of digital technology, the women in agriculture will be in a position to lead the holistic community development and ensure inclusive economic growth if they are given sufficient backing related to digital empowerment. Their involvement is not supplementary, it is imperative. Empowering rural women in agriculture is, therefore, not purely an option but a requirement for comprehensive national development through the use of digital technology.

Key words: Digital Technology, Gender Issues, Rural Women

Introduction

Rural women stand at the forefront of driving social, economic, and environmental change in building a 'New India'. Nearly 80% of rural women are engaged in agriculture, making their empowerment and integration into the agricultural workforce crucial. Strengthening their role can serve as a catalyst for economic progress, while also ensuring food and nutritional security and reducing poverty and hunger. This approach represents a mutually beneficial pathway toward achieving the Sustainable Development Goals by 2030. India is an agrarian economy with about 54.6 percent of total workforce engaged in agricultural and allied sector activities (Census 2011). Women are extensively engaged in the activities pertaining to agriculture and allied sector. The workforce participation rate for rural females is significantly higher at 41.8 percent against urban women participation rate of 35.31 percent (MoSPI, 2017).

The government has launched several flagship schemes and programmes aimed at enhancing the status of rural women by providing livelihood opportunities and access to paid employment. Initiatives such as the Prime Minister's Employment Generation Programme (PMEGP), National Rural Livelihoods Mission, Deen Dayal Upadhyay Grameen Kaushalya Yojana (DDU-GKY), Pradhan Mantri Kaushal Vikas Yojana (PMKVY), Beti Bachao Beti Padhao, and Pradhan Mantri Matru Vandana Yojana (PMMVY) have played a pivotal role in promoting gender equality and fostering the socio-economic empowerment of women in India. Alongside these initiatives, the integration of digital technologies further amplifies their impact by equipping rural women with the skills and resources needed to maximize opportunities in both agriculture and allied sector. **Digital literacy and empowerment** of rural women not only enhance their agricultural output but also strengthen their participation in the digital economy,

ensuring inclusive growth. **Digital tools** such as mobile apps, e-marketplaces, and precision farming technologies enable rural women to manage farms more efficiently, improve productivity, and gain direct access to buyers, reducing dependence on middlemen.

Women-Led Information Network and Digital Agro-Innovation Hub are the platforms that aims to link women farmers with agricultural specialists. By leveraging **digital platforms**, rural women can access real-time information on weather, market prices, crop management, and government schemes, which directly contributes to better decision-making and sustainable livelihood opportunities. With the help of **digital technologies**, women farmers can transition from being invisible contributors in agriculture to recognized stakeholders driving food security, poverty reduction, and rural development.

Challenges Faced by Rural Women in Agriculture

- **Lack of recognition as "farmers" in official records**- According to India Human Development Survey (IHDS) data shows that **83% of agricultural land is inherited by male members** and **less than 2% by female counterparts**. Because of this, many women are not legally recognized as farmers (The Hindu)
- **Minimal or no compensation for agricultural work**- The study found that women in agriculture activities like sowing, threshing etc. receive much lower wages than men, as in 2005-06, female earnings in sowing were **31% lower** than male earnings and by 2019-20, disparity narrowed but still about **17.97% lower than men.** (Singh and Kuar, 2022)
- **Exclusion from decision-making, land ownership, and institutional credit**- even when women hold land titles, their holdings are usually smaller in size, lower in quality, and more fragmented, reducing their real decision-making power. (ScienceDirect)
- **Limited access to government schemes and digital initiatives**- Because women are often not recognized as farmers (no land title, etc.), they are excluded from many government schemes, subsidies, insurance, and credit schemes. For instance, the GIDR paper points out that non-recognition means inability to access institutional credit and get subsidies
- **Gender-specific difficulties compared to men in agriculture**- A study shows that, women's wages in sowing, threshing, etc. are significantly lower than men for comparable work. (Sharma and Singh ,2021).

Barriers to Realizing Full Potential

1. **Structural and societal limitations**

- **Women's land ownership is less** -Despite laws that aim to improve women's land rights, patriarchal norms, poor implementation, and social customs continue to impose restrictions. Nearly 16,000 land records from 12 states/Union Territories, with sex-disaggregated data finds that women have fewer single titles, smaller and poorer-quality landholdings.(Kelkar and Narayanan, 2023)
- **Socio-economic constraints-** In informal employment women face systemic constraints i.e., lack of legal protection, job insecurity, insufficient access to benefits, and income instability. These structural and socio-economic constraints reduce their ability to leverage opportunities in agriculture and allied sectors. (Sinha and Dutta, 2025)
- **Women remain largely marginalized in farming-** one of the report of Press Institute of India, 2023 stated that women are doing more of the farming work (especially because men migrate), they remain marginalised: limited access to high-quality inputs (seeds, fertilisers), extension services, weather info, etc. Also technological resources and information are often directed more towards male farmers

2. **Digital divide restricting access to knowledge and resources.**

- **Lack of mobile technology**- A study of Joseph and Thomas, 2024 stated that rural women encountered major to access mobile technologies are low digital literacy, poor infrastructure (mobile network, devices) and cost issues.
- **Expectations of families**- social norms and patriarchal expectations prevent women from freely accessing technology or participating in digital training (Singh and Kaur, 2022)
- **Remote areas-** A study shows that tribal women have no internet access or social media, and heavily affected by remoteness, low infrastructure, linguistic and educational barriers. These constraints lead to digital exclusion of women. (Joseph and Abraham, 2023)
- **Less access to ICTs**- rural women had significantly less access to ICTs (Internet, devices) compared to men as they face major constraints i.e., lack of education, infrastructure deficits, cultural/gender discrimination, insufficient government policy support and training (Farooq and Shahzad, 2022).

Efforts to Bridge the Gap

1. **Initiatives encouraging women farmers to adopt digital technology.**
   - **Digital Green's Video-Based Support**: A randomized evaluation in India found that video-based agricultural training increased women farmers' productivity and profits at a low cost. This model has been scaled throughout India.
   - **AI for SURE Program in Andhra Pradesh**: this training program encourages self-help group (SHG) women to embrace artificial intelligence and digital tools to expand their businesses globally. Nearly 700 SHG women have launched businesses after prior training in branding and financial management, with 160 undergoing specialized AI training.
2. **Women-Led Information Network** – connecting women farmers with agricultural experts.
   - **Digital Nari Initiative in Uttar Pradesh**: this initiative empowers rural women by promoting entrepreneurship, financial literacy, and self-reliance. Over 10,000 women have participated, many transitioning to new roles with expanded skill sets.
   - **Swayam Sampurna FPO in Odisha**: Thousands of women farmers under the Swayam Sampurna Farmer Producer Organisation (FPO) in Odisha are transforming agriculture by embracing digital tools to secure their livelihoods, boost climate-smart crop production, and make data-driven decisions.
3. **Digital Agro-Innovation Hub** – platform to promote digital tools in agriculture
   - **Kudumbashree Technology Advancement Programme (K-TAP) in Kerala**: This initiative was lacunched by Kerala government to modernize the agricultural sector and ensure sustainable income for women farmers. Moreover, the initiative has acquired over 180 modern agricultural technologies in partnership with leading Indian research institutions, enabling women farmers to enhance agricultural output and produce value-added products adhering to export standards.
   - **Drone Didi Scheme in Varanasi**: a group of women known as the 'Drone Didis' is transforming agriculture by using drones to spray fertilizers and pesticides. Trained at the Drone Academy, these women have provided drone spraying services across 2,581 acres, earning approximately Rs 3.38 lakh in ten months. This initiative enhances agricultural productivity and empowers women economically and socially.

Government Initiatives Supporting Digital Agriculture for Women in India

- **Digital Agriculture Mission (2021-2025):** It promotes digital technologies like AI, IoT, blockchain, and remote sensing in farming. Women farmers can access precision agriculture tools, digital advisories, and financial services through this initiative.
- **National e-Governance Plan in Agriculture (NeGPA):** It focuses on the digital transformation of agriculture by integrating ICT-based solutions. Special provisions are made for women farmers, including mobile-based advisories and digital market access.
- **Mahila Kisan Sashaktikaran Pariyojana (MKSP):** A sub-component of the National Rural Livelihood Mission (NRLM), MKSP aims to empower women in agriculture. Digital tools are used to train women in climate-resilient practices and sustainable farming.
- **KisanSuvidha App:** A mobile app providing weather updates, market prices, and expert guidance. It enables women farmers to make informed decisions in agriculture.
- **PM KISAN & Direct Benefit Transfers:** Ensures financial support directly to farmers' bank accounts, including women farmers. Encourages financial independence and access to credit for women in agriculture.
- **AGRI STACK:** A digital database that helps create farmer-centric digital services. Women farmers can access customized support for inputs, finance, and markets.

Services and Opportunities Provided by Digital Platforms

1. **Training and mentorship for women farmers-** Digital platforms such as YouTube, Digital Green, and Krishi Vigyan Kendras' online portals offer video-based agricultural training and expert mentorship. These programs help women acquire modern farming skills, improve productivity, and connect with successful agripreneurs across regions.
2. **Use of mobile apps for farm management**- Mobile apps like Kisan Suvidha, Plantix, and AgriApp provide women farmers with real-time crop monitoring, pest diagnosis, and nutrient management advice. This enables rural women to make informed decisions, reduce input costs, and manage farms independently.
3. **Access to online marketplaces and e-commerce-** Digital platforms such as e-NAM, AgriBazaar, and DeHaat allow women farmers to sell produce directly to buyers, eliminating middlemen. Through these marketplaces, rural women gain fair prices, wider market access, and opportunities to brand and market value-added products.

4. **Application of drones for precision farming-** Drone technology helps women monitor large fields, spray fertilizers, and detect crop stress efficiently. Initiatives like "Drone Didi" in Varanasi show how such tools reduce labor burden, increase income, and open new livelihood avenues in digital agriculture services.
5. **Availability of digital resources (weather apps, crop management software, e-learning tools)-** Tools like Meghdoot App, ICAR's e-learning modules, and online weather platforms provide localized forecasts, pest alerts, and seasonal advisories. These digital resources empower rural women to plan agricultural activities better, enhance resilience to climate change, and continuously learn new techniques.

Impact on Women Empowerment

- **Strengthening Knowledge and Skills in Agriculture**-Digital tools and e-learning platforms provide women with access to modern agricultural practices, crop management, and marketing knowledge. This continuous learning enhances their technical competence and confidence, enabling them to become decision-makers in their farming enterprises.
- **Promoting Gender Justice and Inclusion**-Digital initiatives bridge the gender gap by giving women equal access to information, training, and financial services. They create a more inclusive environment where women's voices are recognized in community decision-making and policy implementation.
- **Improving Livelihoods and Financial Independence**-Online marketplaces, mobile banking, and digital payment systems allow women farmers to earn directly for their produce and services. This financial autonomy helps them invest in better inputs, support their families, and gain control over household and farm-related decisions.
- **Contribution to Food Security, Poverty Reduction, and Sustainable Rural Development**-By increasing productivity through digital innovation, women play a crucial role in ensuring household and community food security. Their active participation in sustainable farming practices contributes to poverty alleviation, climate resilience, and balanced rural development.

Conclusion

Recognizing digital technology as a powerful catalyst for women's empowerment is crucial in modern agriculture. Rural women are not merely supplementary contributors; their

active participation is essential for enhancing productivity, decision-making, and sustainable development. By integrating digital tools, women farmers can access knowledge, markets, and financial resources, enabling them to take leadership roles in their communities. Digital empowerment bridges the gender gap, promotes economic inclusion, and strengthens social equity in rural areas. Ensuring that women have the skills, infrastructure, and opportunities to utilize technology is key to achieving food security and poverty reduction. Ultimately, empowering rural women through digital technology drives holistic community development and contributes significantly to national progress.

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VERTICAL FARMING: A SUSTAINABLE SOLUTION TO URBAN AGRICULTURAL CHALLENGES

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Abstract

Vertical farming is an innovative agricultural method designed to tackle the growing challenges of urbanization, including limited land availability, rapid population growth, and environmental stress. It involves cultivating crops in vertically stacked layers within controlled environments, utilizing advanced techniques such as hydroponics, aeroponics, and artificial lighting. This system enables efficient water use, minimizes dependency on arable land, and ensures year-round production irrespective of external climatic conditions. By producing food closer to urban consumers, vertical farming reduces transportation costs and associated carbon emissions. Furthermore, its adaptability allows the integration of renewable energy and smart technologies for improved productivity and resource management. However, the large-scale adoption of vertical farming faces obstacles such as high initial capital investment, significant energy consumption, and dependence on advanced technology. Overcoming these challenges will require supportive policies, technological advancements, and sustainable energy solutions. With continued innovation, vertical farming holds great potential as a long-term, space-efficient strategy for ensuring food security and environmental sustainability in expanding cities.

Keywords: Vertical farming, sustainability, urban agriculture, controlled environment.

Introduction

Vertical farming has been given many different definitions depending on the size, density, amount of control, layout, building type, location, and purpose of use. As a result, depending on the stakeholder, vertical farming is viewed as a marginal crop production activity up to a system that is essential for providing future food security. Future confusion is created by

the interchangeable use of "vertical farming" as an activity and vertical farm as a noun. In its simplest form, "vertical farming" as an activity can be defined as the multilayered production of plants to increase yield per surface area. In this review, vertical farm as a noun will be defined as a highly controlled indoor plant production system.

"A multilayer indoor plant production system in which all growth factors, such as light, temperature, humidity, carbon dioxide concentration (CO_2), water, and nutrients, are precisely controlled to produce high quantities of high-quality fresh produce year-round, completely, independent of solar light and other outdoor conditions."

Vertical farms are divided according to size and purpose of use:

1. Plant factory with artificial lighting (PFAL), an industrial-scale vertical farm located in a devoted building.
2. Container farm, a modular vertical farm contained in a shipping container.
3. In-store farm, a vertical farm located at the place of consumption or purchase.
4. Application farm, a vertical farm appliance integrated into a home or office.

What is Vertical Farming?

Vertical farming is the practice of growing crops in vertically stacked layers, typically indoors. It often incorporates Controlled Environment Agriculture (CEO), which optimizes plant growth by regulating environmental factors such as temperature, humidity, light, CO2 concentration, and nutrient delivery.

1. Definition: Vertical farming is maximizing space efficiency by growing crops upwards rather than outwards. This can take place in various structures, from repurposed warehouses and shipping containers to purpose-built high-rise buildings.

2. Key Components: The success of vertical farming hinges on several critical components:

- Stacked Layers: Crops are grown on multiple levels, significantly increasing the yield per square foot of land area.
- Controlled Environment: Sophisticated systems monitor and adjust temperature, humidity, and CO2 levels to create optimal growing conditions for specific crops, minimizing external environmental risks.
- Artificial Lighting: Natural sunlight is supplemented or entirely replaced by LED lighting, which can be precisely tuned to the specific light spectrum and intensity

required by different plants at various growth stages, promoting faster growth and higher yields.

- Hydroponics, Aeroponics, or Aquaponics: These soilless growing techniques are fundamental to vertical farming, enabling efficient nutrient delivery and water conservation.



Fig 1

Methodology

A.Design system and Environment optimization in Vertical Farming

In this study, the main objective is to develop a high-yield, low-footprint agricultural model that operates efficiently in vertically stacked layers. The system design process incorporates modular construction using lightweight, durable materials suitable for retrofitting existing urban buildings or constructing standalone farming units. These structures are equipped with climate-controlled enclosures to allow year-round production irrespective of external weather conditions.

Controlled Environment Agriculture (CEO) principles are applied to regulate the optimal growth conditions, and the parameters such as temperature, humidity, and CO2 concentration are managed precisely through automated sensors and IoT-based monitoring systems. Artificial light is provided using full-spectrum LED lights, tuned specifically to match the photosynthesis requirements of selected crops during different stages of growth. Biomass accumulation and energy efficiency are modulated to maximize in the lighting schedule.

Using three different soilless systems in plant cultivation, it is carried out as hydroponics, aeroponics, and aquaponics. Easy to evaluate for resource use efficiency, adaptability, and crop yield. In a hydroponics system, plants are grown with their roots submerged in nutrient-rich aqueous solution. To determine their effectiveness in urban farms various hydroponic subsystems were tested, such as Nutrient Film Technique (NFT), Deep Water Culture (DWC).

In an aeroponics system, the roots are suspended in air and sprayed with atomized nutrient mist. This setup was assessed for water for oxygenation efficiency, water conservation, and rapid plant development. Meanwhile, the aquaponic system integrates fish culture with hydroponics, where fish waste provides nutrients for plants, and plants filter the water before it returns to the aquaculture tank. This closed-loop design is monitored to maintain biological equilibrium and evaluate its viability in resource-scarce urban locations.

By varying parameters, the environmental optimization trials were conducted, such as light wavelength, airflow patterns, nutrient composition, and irrigation cycles. Crops such as lettuce, spinach, basil, and microgreens were used as model species due to their short growth cycles and suitability for indoor environments. Data were collected on germination rate, growth duration, chlorophyll content, and total yield to compare the performance of each system. These tests were repeated under controlled conditions to ensure accuracy and reproducibility.

B. Crop Layout, Monitoring, and Resource Utilization Strategy

Development of crop layout patterns within vertical stacks to optimize light distribution, nutrient delivery, and airflow. Layer configurations were examined for plant density, shadow casting, and ease of access. The vertical columns and trays were arranged based on plant morphology and phototropic behavior to minimize competition for light and space.

Each layer's irrigation system was designed to deliver water and nutrients efficiently, minimizing runoff and recirculating unused solutions through filtration units. For aeroponic and aquaponic systems, mist generation and biofiltration parameters were adjusted based on real-time data inputs from moisture sensors, pH meters, and nutrient monitors.



Fig 2

To enhance monitoring capabilities, multispectral imaging cameras and light-sensing drones were employed to analyze plant health, detect deficiencies, and monitor growth patterns. These sensors provided continuous feedback to a control system, enabling predictive maintenance and dynamic adjustment of environmental parameters. The use of machine learning algorithms helped refine nutrient schedules and anticipate plant needs based on environmental trends and past growth data

Finally, the vertical farming modules were evaluated for scalability and economic feasibility in urban contexts. Parameters such as construction cost, labor requirement Parameters such as construction cost, labor requirements, energy consumption, return on investment (ROI), and per-square-foot yield were calculated to determine practical applicability.

This structured methodology enables a comprehensive understanding of how vertical farming systems can be engineered, optimized, and scaled to meet the food demands of growing urban populations while minimizing environmental impact.

System Components and Technologies in Vertical Farming

In controlled environmental conditions with vertically stacked layers that combine the architecture, plant biology, and engineering to grow the crops. A core component of vertical farming is the integration of Controlled Environmental Agriculture (CEA) technologies that control the temperature, humidity, CO2 levels, lighting, and nutrient delivery.

Artificial lighting, particularly using LED technologies, is essential for plant photosynthesis in vertical farms. LEDs can be adjusted in intensity and wavelength to suit for various growth stages of crops, and enhance productivity while reducing energy consumption. Automation and smart technologies play a crucial role in managing farm operations. Sensors, Internet of Things (IOT) devices, and data-driven software systems are used to monitor plant health, optimize resource inputs, and reduce labor requirements. Vertical farming relies on soilless cultivation methods such as hydroponics, aeroponics, and aquaponics. Its use is to minimize water use when compared to traditional farming.

Hydroponics: It involves growing plants with their roots submerged in nutrient-rich water solutions. Systems such as Nutrient Film Technique (NFT), Deep Water Culture (DWC), and drip systems provide required nutrients directly to the plant root, facilitating rapid growth and higher yields.

Aeroponics: This takes a further step by suspending plant roots in air and delivering nutrients through a fine mist. This method maximizes oxygen availability to the roots and significantly conserves water. Though more technologically demanding, aeroponics supports efficient nutrient uptake and minimal disease risk.

Aquaponics: Integrates hydroponics with aquaculture, creating a closed-loop ecosystem. Fish waste provides organic nutrients for the plants, while plants filter and purify the water for the fish. This system promotes circular resource use, making it both sustainable and environmentally friendly.

Conclusion

Vertical farming represents a promising and sustainable solution to the growing challenges of urban agriculture. By utilizing vertical space, integrating advanced technologies, and employing soilless cultivation systems, it addresses critical issues such as land scarcity, water usage, and climate dependence. While challenges remain in terms of cost, energy demand, and scalability, ongoing research, technological innovation, and supportive policies can help overcome these limitations. As cities continue to expand and the global population grows, vertical farming can play a transformative role in ensuring food security, reducing environmental impact, and creating resilient urban food systems. It is not merely an alternative farming method, but a forward-looking strategy for sustainable urban development.

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SAVING OUR LAKES: HOW ALGAE CAN PREVENT EUTROPHICATION

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Introduction

Lakes are not just scenic natural wonders; they are lifelines that sustain both people and wildlife. They provide us with drinking water, food, recreation, and serve as habitats for countless aquatic organisms. Yet, these vital ecosystems are increasingly under threat from a process known as eutrophication. This condition develops when water bodies become overloaded with nutrients, especially nitrogen and phosphorus. Sources such as agricultural fertilizer run-off, untreated sewage, and industrial effluents pour in excessive nutrients, overwhelming the lake's natural balance. In effect, lakes become "overfed," leading to murky waters, oxygen depletion, and the collapse of aquatic life.

When most people think of algae in lakes, the image that comes to mind is of thick, green mats spreading across the surface, blocking sunlight, and suffocating fish. It is true that uncontrolled algal growth can be destructive, but this is only one side of the story. Under carefully managed conditions, algae can actually become nature's own clean-up crew, absorb excess nutrients and help restore the health of lakes. Instead of being seen only as troublemakers, algae may hold the key to solving one of the biggest water quality challenges of our time.

EUTROPHICATION

Eutrophication is the process by which a lake or river becomes enriched with nutrients to the point that it disrupts the natural ecological balance. Under natural conditions, this enrichment happens very slowly over centuries, as nutrients from surrounding soil and rocks

gradually seep into the water. This gradual process is a normal part of lake aging and rarely poses a threat. However, human activities have accelerated eutrophication to a dangerous pace, causing in just decades what would normally take centuries.

The excessive nutrients, particularly nitrogen and phosphorus, act as powerful fertilizers. Algae and aquatic plants grow explosively, often covering the water surface entirely. At first, this growth might look like a sign of abundance, but beneath the surface, the story is much darker. The dense mats of plants and algae block sunlight, preventing submerged plants from carrying out photosynthesis. Without light, these plants die, and when algae also die in large numbers, bacteria decompose them, consuming vast amounts of oxygen in the process. This oxygen depletion, called hypoxia, creates "dead zones" where fish and other aquatic animals cannot survive. The once-clear water turns murky, foul-smelling, and lifeless, leaving behind an ecosystem in collapse.

CAUSES OF EUTROPHICATION

The primary cause of eutrophication is the excessive input of nutrients into water bodies, and much of this originates from human activity. Modern agriculture is one of the largest contributors. Farmers apply chemical fertilizers rich in nitrogen and phosphorus to increase crop yields, but when heavy rains occur, much of this fertilizer washes off the fields and ends up in streams and lakes. Untreated or poorly treated sewage is another major source, adding not only nutrients but also organic matter that further stresses aquatic systems.

Industrial effluents, especially from food processing, chemical manufacturing, and textile production, release nutrient-rich discharges into water systems, adding to the load. Even in households, the use of phosphate-based detergents contributes quietly to nutrient pollution every time laundry water enters drainage systems. Beyond direct discharges, deforestation and poor land management practices lead to soil erosion, which carries nutrient-rich sediments into rivers and lakes.

ROLE OF ALGAE IN PREVENTING EUTROPHICATION

Although often blamed for eutrophication, algae can serve as natural protectors of water quality. By absorbing nitrogen and phosphorus, they reduce nutrient pollution and prevent harmful algal blooms. Through photosynthesis, algae release oxygen, supporting aquatic life in oxygen-depleted environments. Their nutrient-rich biomass can be harvested and repurposed into biofertilizers, animal feed, or bioenergy. In managed systems like treatment ponds and wetlands,

algae act as biofilters and strengthen aquatic food chains, offering a sustainable, eco-friendly approach to restoring freshwater ecosystems.

THE SCIENCE BEHIND ALGAE IN EUTROPHICATION CONTROL

Algae play a multifaceted role in controlling eutrophication by efficiently absorbing nitrogen and phosphorus, thus preventing nutrient accumulation and harmful algal blooms. Through photosynthesis, they release oxygen, supporting aquatic life and mitigating hypoxia. Their nutrient-rich biomass can be harvested and repurposed into biofertilizers, feed, or biofuels, offering sustainable waste recycling. In engineered systems, algae act as biofilters, removing pollutants cost-effectively. As the foundation of aquatic food chains, they convert nutrients into organic matter that sustains higher organisms. Additionally, algae capture carbon dioxide, reducing water acidity and contributing to climate change mitigation—making them vital allies in ecosystem restoration.

CHALLENGES OF USING ALGAE IN PREVENTING EUTROPHICATION

Despite their promise, algae-based eutrophication management faces notable challenges. Uncontrolled growth can lead to toxin release or oxygen depletion, worsening water quality. Their effectiveness depends on environmental conditions, making them seasonally unreliable. Harvesting microscopic algae is technically complex and costly, and without it, stored nutrients may re-enter the system. Selecting safe, efficient species requires further research. Additionally, financial, infrastructural, and regulatory hurdles, along with public concerns, limit large-scale adoption while necessitating careful management of ecological, technical, and social factors.

Conclusion

Once seen as lake nuisances, algae are now recognized as potential problem solvers. They absorb excess nitrogen and phosphorus, curbing nutrient overload and releasing oxygen to support aquatic life. When harvested, algae can be repurposed into fertilizers, feed, or bioenergy thereby transforming pollution into a resource. Though challenges like harmful blooms, harvesting complexity, and financial barriers exist, algae offer a natural, sustainable solution to eutrophication. With careful management, they can help restore and protect freshwater ecosystems for future generations.

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GREEN GOLD: HOW MICROALGAE ARE REVOLUTIONIZING WASTEWATER TREATMENT

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Introduction

Water, the lifeline of our planet, is under increasing stress from rapid urbanization, industrial activity, and intensive agriculture. These sectors generate large volumes of wastewater filled with nutrients, heavy metals, and chemical residues that, if left untreated, contaminate rivers, lakes, and groundwater. This pollution threatens ecosystems, agriculture, and human health, while freshwater scarcity continues to worsen in many regions. Conventional treatment methods, though effective, are often energy-demanding, costly, and difficult to maintain, especially in resource-limited areas. This has created an urgent need for alternative, eco-friendly approaches that are both efficient and affordable.

Microalgae offer one such solution by naturally absorbing and transforming pollutants from wastewater. These tiny photosynthetic organisms remove nitrogen, phosphorus, and toxic metals while producing oxygen that supports bacterial breakdown of organic matter. At the same time, they generate biomass rich in proteins, lipids, and carbohydrates, which can be converted into fertilizers, animal feed, biofuels, and other products. This dual benefit transforms wastewater treatment from a burden into an opportunity, aligning with circular economy principles where waste becomes a resource. In this way, microalgae are redefining wastewater management by combining environmental protection with economic potential.

PURIFICATION OF WASTE WATER BY MICROALGAE

Microalgae clean wastewater by using the very pollutants that contaminate it as fuel

for their growth. Rich in nutrients like nitrogen and phosphorus, wastewater becomes an ideal medium for these microscopic organisms. Instead of letting these compounds flow into rivers and lakes where they trigger harmful algal blooms, microalgae absorb them and convert them into cellular material. At the same time, they capture and immobilize heavy metals such as cadmium, chromium, and lead, either by binding them onto their cell walls or storing them inside their cells. This natural filtration process not only reduces nutrient overload and toxicity but also produces algal biomass that is rich in proteins, lipids, and carbohydrates, which can later be used for fertilizers, biofuels, and animal feed. Another powerful way microalgae purify wastewater is by creating an oxygen-rich environment. Through photosynthesis, they release oxygen into the water, which supports aerobic bacteria that break down organic matter such as fats, proteins, and carbohydrates. This partnership lowers the biochemical oxygen demand (BOD) and chemical oxygen demand (COD).

MECHANISMS OF MICROALGAE IN TREATING WASTEWATER

1. Denaturation of Organic Pollutants

Microalgae release natural enzymes and metabolites that can modify the structure of complex organic pollutants. This process, known as denaturation, breaks down harmful substances such as dyes, proteins, and synthetic chemicals into simpler, less toxic forms. Once altered, these pollutants become easier for microalgae or associated bacteria to degrade, reducing the overall toxicity of wastewater.

2. Volatilization of Compounds

During photosynthesis, microalgae raise the pH of their surroundings as they absorb carbon dioxide and release oxygen. This shift in pH can convert ammonium ions into ammonia gas, which then escapes into the atmosphere. This process called volatilization. In a similar way, sulfur-based compounds and other volatile substances can be released, lowering the pollutant load of the water.

3. Decomposition of Organic Matter

The oxygen generated during photosynthesis plays a crucial role in supporting aerobic bacteria in the water. These bacteria work alongside microalgae to decompose organic pollutants like fats, proteins, and carbohydrates. This partnership accelerates the breakdown of complex organic matter into harmless end products such as carbon dioxide and water, reducing both the chemical and biological oxygen demand of the wastewater.

4. Nutrient Absorption and Assimilation

Excess nitrogen and phosphorus are among the biggest drivers of water pollution, often causing uncontrolled algal blooms in lakes and rivers. Microalgae help by directly absorbing these nutrients from wastewater and using them for growth. This not only prevents eutrophication but also generates nutrient-rich algal biomass, which can later be harvested and transformed into fertilizers, biofuels, or animal feed.

5. Heavy Metal Removal

Heavy metals like lead, cadmium, mercury, and chromium pose significant challenges in wastewater treatment because they are toxic and persistent. Microalgae can bind these metals through negatively charged groups on their cell walls, a process known as biosorption. Some species also internalize metals, storing them in vacuoles or altering them into less harmful forms. This makes microalgae a cost-effective and sustainable option for industries struggling with heavy metal contamination.

CHALLENGES IN SCALING UP MICROALGAE-BASED SYSTEMS

While microalgae offer an exciting and sustainable alternative for wastewater treatment, moving from laboratory experiments to full-scale systems is far from simple. One of the major hurdles is the high cost of building and operating large algal cultivation facilities. Growing microalgae requires controlled conditions such as adequate sunlight or artificial lighting, proper mixing of water, and balanced nutrient availability. In open ponds, environmental factors like temperature fluctuations, contamination from unwanted microorganisms, and variable sunlight can reduce efficiency. On the other hand, closed systems such as photobioreactors offer more control but are significantly more expensive to install and maintain, making large-scale adoption a financial challenge.

Harvesting and processing algal biomass also remain difficult at scale. Since algae are microscopic and suspended in water, separating them requires energy-intensive methods like centrifugation, filtration, or chemical flocculation. These steps often consume more energy than the amount of energy that can be recovered from the algal biomass itself, raising questions about economic feasibility. If these barriers can be addressed, microalgae have the potential to move from niche applications to mainstream wastewater treatment solutions.

Conclusion

Microalgae represent a transformative step in the way we think about wastewater

treatment. Unlike conventional methods that focus solely on pollutant removal, algae-based systems combine purification with resource recovery, making them both eco-friendly and economically viable. Their ability to absorb nutrients, degrade organic pollutants, and capture heavy metals positions them as natural allies in addressing global water challenges. Although technical and financial hurdles remain in scaling up these systems, continuous research and innovation are steadily closing the gap. As the world moves toward sustainable solutions, microalgae highlight the strength of nature's smallest organisms, showing that even tiny life forms can drive big changes for a better future.

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WATERLOGGING & SALINITY: SILENT KILLERS OF FARMLAND – AND HOW TO FIGHT THEM

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Introduction

For many centuries most of the farmers depend on the fertility status and productivity of soil for major crop production and yield improvements. Productive and fertile soils will increase the crop yield and improve the crop quality. But in recent times the major problem the farmers face is “waterlogging and soil salinity”.

Unlike pest and diseases, the symptoms for these both problems appear slowly. We cannot identify the symptoms of these problems easily. They cause disruption of the crop yield and gives losses to the various farmers. These problems are majorly present in areas like Punjab, Haryana, Uttar Pradesh, Gujarat, Tamil Nadu, and Andhra Pradesh of India. According to recent studies, over 8 million hectares of land in India suffer from waterlogging and soil salinity.

This article takes you through the causes, impacts, and remedies for waterlogging and soil salinity in Indian agriculture.

What is Waterlogging?

Waterlogged soil is soil that is saturated with water for long period of time, which restricts air (oxygen) from reaching plant roots, leading to anaerobic (oxygen-deprived) conditions. This saturation occurs due to factors like prolonged rainfall, poor drainage, or a high groundwater table, and it harms most plants by impairing root function, hindering growth, and potentially causing root rot and plant death**.**

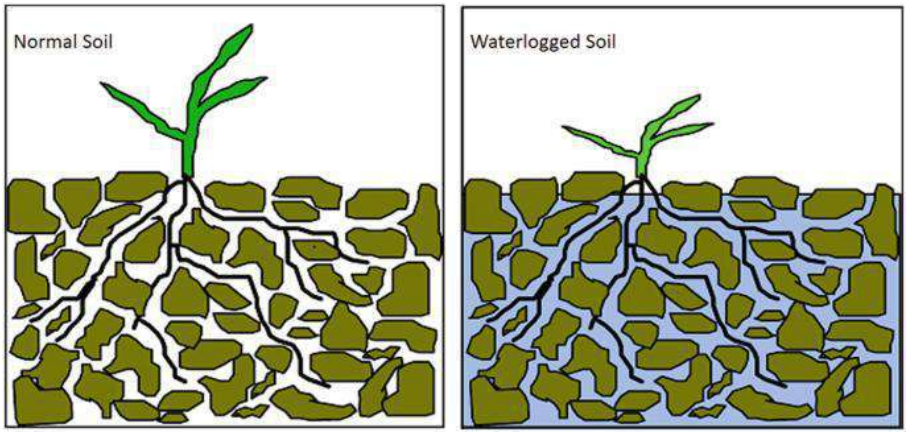


Fig.1 Comparison between normal soil and waterlogged soil

Causes of Waterlogging

- **Heavy Rainfall:** Excessive and prolonged rainfall can overwhelm the soil's ability to drain water.
- **Over-Irrigation:** Farmers, especially in canal-irrigated regions, often flood fields excessively to "be safe." Unfortunately, this water has nowhere to go and raises the water table.
- **High Groundwater Levels:** A shallow or rising groundwater table can saturate the soil from below.
- **Poor Drainage:** Inadequate natural or artificial drainage systems prevent excess water from escaping the soil.

What happens in waterlogged soil?

- **Lack of Oxygen:** The most significant issue is the lack of oxygen for plant roots, which need oxygen to respire and produce energy.
- **Anaerobic Conditions:** The absence of oxygen creates an anaerobic environment in the soil, which can lead to the buildup of toxic compounds and damage plant cells.
- **Root Damage:** Plant roots suffer from oxygen deprivation, leading to reduced growth and death of root tips.
- **Impaired Nutrient Uptake:** Damaged roots cannot absorb nutrients and water effectively, causing symptoms like wilting and yellowing leaves, even though the soil is wet.



Fig.2 Waterlogged soil

Remedy for Waterlogging

- Providing adequate drainage for draining excessive stagnating water around the root system.
- Spray of growth retardant of 500 ppm cycocel for arresting apical dominance and thereby promoting growth of laterals
- Foliar spray of 2% DAP + 1% KCl (MOP)
- Nipping terminal buds for arresting apical dominance and thus promoting growth sympodial branches (as in cotton) for increasing productivity
- Spray of 40 ppm NAA for controlling excessive pre-mature fall of flowering/buds/young developing fruits and pods
- Spray of 0.5 ppm brassinolide for increasing photosynthetic activity
- Foliar spray of 100 ppm salicylic acid for increasing stem reserve utilization under high moisture stress
- Foliar spray of 0.3 % Boric acid + 0.5 % $ZnSO_4$ + 0.5 % $FeSO_4$ + 1.0 % urea during critical stages of the stress

What is soil salinity?

Soil salinity is the presence of high concentrations of dissolved salts in the soil, which can be harmful to plant growth by reducing water uptake and causing salt toxicity.



Fig.3 Soil salinity

It is measured by the electrical conductivity (EC) of a soil extract, with higher EC values indicating greater salt concentration. Salinity occurs naturally or can result from human activities like excessive irrigation with salty water, inadequate drainage, or the excessive use of some fertilizers.

Causes of Salinity

- **Irrigation with Saline Water**: In arid and semi-arid regions, groundwater often contains dissolved salts.
- **Waterlogging**: High water tables bring salts to the surface through capillary rise.
- **Fertilizer Misuse**: Excessive application of fertilizers without organic matter builds salt concentration.
- **Sea Water Intrusion**: In coastal regions, seawater enters agricultural fields, especially where groundwater extraction is high.
- **Climate Factors**: High evaporation rates in hot regions concentrate salts in the root zone.

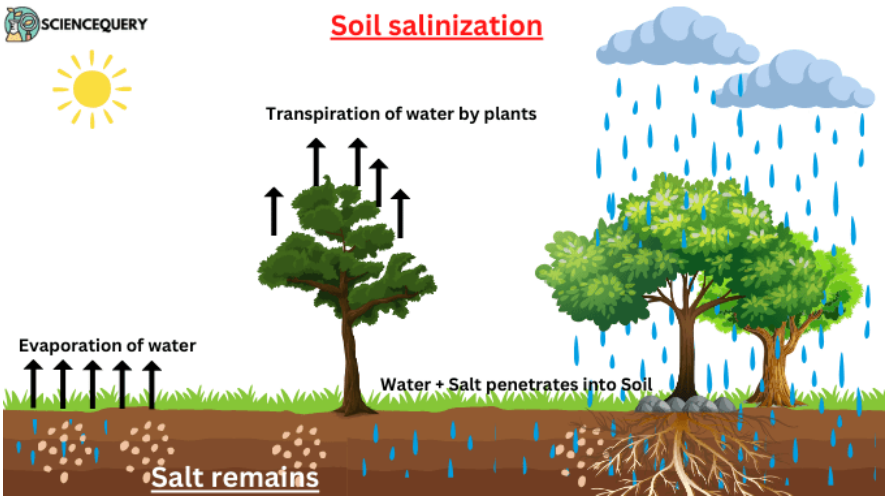


Fig.4 Soil salinization process

Symptoms of Soil Salinity

- White crust of salts visible on the soil surface
- Patchy crop stands: healthy plants in some spots, stunted in others
- Burning of leaf tips, yellowing, and poor flowering
- Failure of seed germination in sensitive crops

Solutions for Soil salinity

- **Salt Leaching:** Applying fresh water to the soil surface and allowing it to infiltrate and drain through the soil helps flush out excess salts from the root zone.
- **Improved Drainage:** Installing subsurface drainage systems intercepts and removes salty groundwater, preventing it from rising into the root zone.
- **Land Grading:** Levelling and grading the land can improve water distribution and help manage salinity levels.
- **Surface Salt Removal:** In cases of high surface salinity, scraping or removing surface salt crystals can provide immediate relief.
- **Salt-Tolerant Crops:** Selecting and planting crop varieties that are naturally resistant to salinity can maintain agricultural productivity.
- **Organic Matter and Fertilizers:** Incorporating organic materials like straw, compost, and manure into the soil increases organic matter, which improves soil structure and drainage.
- **Biofertilizers:** These products contain microorganisms that improve nutrient availability and plant growth while potentially reducing the need for chemical fertilizers.

Comparison between Waterlogging and Salinity

Aspect	Waterlogging	Soil Salinity
Definition	Excess water in the soil for a long time, reducing air spaces	Accumulation of too many salts in the soil
Main Cause	Poor drainage, heavy rainfall, floods, over-irrigation	Overuse of groundwater, poor-quality irrigation water, less rainfall, high evaporation
Effect on Soil	Soil becomes sticky, lacks oxygen	Soil becomes hard, white crust forms on surface
Effect on Roots	Roots suffocate due to lack of air	Roots cannot absorb water due to high salt concentration
Effect on Crops	Yellowing of leaves,	Wilting, burning of leaf

	stunted growth, crop failure in severe cases	tips, poor germination, low yield
Common in Areas	Low-lying fields, canal-irrigated regions	Dry, hot regions with high evaporation and irrigation
Short-term Solution	Drain excess water using channels, raised beds	Apply more water (leaching) to wash salts below root zone
Long-term Solution	Improve drainage, grow water-tolerant crops, adopt proper irrigation scheduling	Use salt-tolerant crops, improve irrigation quality, adopt gypsum/organic amendments

Case Study

Multiple studies and reports confirm that cashew plantations on saline-prone uplands in Andhra Pradesh have offered a better income stream for farmers than cultivating rice. The shift away from traditional cereal crops in these marginal environments is driven by the cashew's resilience to harsh conditions and its high commercial value as an export-oriented crop.

Conclusion

Waterlogging and soil salinity are not permanent problems for the soil. They can be cured through proper management practices. Farmers should identify the symptoms properly and perform the necessary management practices. Across India, success stories prove that farmers can reclaim their fields and secure livelihoods.

"Healthy soils are not inherited from our ancestors; they are borrowed from our children. Protect them today, or lose them forever."

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DROUGHT TOLERANCE IMPROVEMENT IN PEARL MILLET: STATUS AND PROSPECTS

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Introduction

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is a hardy, climate-resilient nutri-cereal and the fourth most important food crop in India after rice, wheat and maize. Distinguished by its rapid growth, high photosynthetic efficiency and balanced nutritional composition, it is well adapted to environments where most staple cereals fail to survive. The crop thrives under extreme agro-climatic conditions, including low soil fertility, high pH, aluminium toxicity, high salinity, low and erratic rainfall, high temperature and moisture scarcity. At the global level, pearl millet ranks sixth among cereals-after maize, rice, wheat, barley and sorghum-and plays a critical role in food, fodder and nutritional security in some of the most drought-prone and resource-limited regions, especially in sub-Saharan Africa (SSA) and Asia, with India as a major production hub. It is cultivated on more than 30 million hectares worldwide, with Africa accounting for over 18 million hectares and Asia for more than 10 million hectares. In addition to being a staple food and animal feed, pearl millet is increasingly valued as an industrial raw material for alcohol, biofuel, starch and processed food production, underscoring its versatility and economic significance.

In India, pearl millet is cultivated on an area of 7.36 mha with production of 10.67 million tonnes and productivity of 1499 kg/ha. More than 90% production is contributed by states of Rajasthan, Maharashtra, Uttar Pradesh, Gujarat and Haryana. Predominantly cultivated in kharif season during June/July to September/October, summer cultivation is also gaining pace in parts of Gujarat, Rajasthan and Uttar Pradesh where ensured irrigation is available. Nutritionally pearl millet is superior to cereals such as wheat, rice, maize and sorghum and its

grains are rich source of carbohydrates, proteins, fats, fibre, starch, vitamins and micronutrient such as iron and zinc. Pearl millet possesses a more balanced amino acid profile than maize or sorghum and its lipid fraction is rich in health-promoting polyunsaturated fatty acids, notably omega-3 and omega-6. On a 100 g basis, the grain provides about 360 kcal of energy, 12 g moisture, 12 g protein, 5 g fat, 2 g minerals, 1 g fibre, 67 g carbohydrates, 42 mg calcium, 242 mg phosphorus and 8 mg iron. Naturally gluten-free, pearl millet provides high-quality protein, making it an excellent dietary option for individuals with gluten intolerance. It maintains an alkaline nature even after cooking and possesses a low glycaemic index (GI), making it suitable for diabetic diets. The grain is rich in slowly digestible starch (SDS) and resistant starch (RS), which contribute to its low GI, promote a healthy gut microbiome, support colon hydration, and help prevent constipation. Its regular inclusion in the diet has been associated with a reduced risk of cardiovascular diseases and certain forms of cancer.Recognising its exceptional nutritional value and climate resilience, the Government of India designated pearl millet as a "nutri-cereal" in 2018 and incorporated it into the Public Distribution System (PDS). In 2023, the Hon'ble Prime Minister of India rebranded millets as *Shree Anna* to highlight their nutritional superiority and ecological adaptability. Year 2023 was celebrated as "International Year of Millets".

Drought stress in pearl millet

Drought impacts pearl millet differently depending on its timing, intensity, duration and severity. Although inherently drought-tolerant, yield losses are aggravated by poor soil fertility, low water-holding capacity and minimal agronomic inputs (Bidinger and Hash, 2004). In drought-prone African regions, harvestable yields can be as low as 150 kg/ha and about 500 kg/ha in average rainfall years (McIntire et al. 1989). In India's A1 pearl millet zone (western Rajasthan, Gujarat, Haryana), productivity is often below 400 kg/ha (Manga and Kumar, 2011). The flowering stage is the most drought-sensitive, with terminal drought (flowering–maturity) causing 55–67 % yield loss compared to 0–16 % under midseason drought (panicle initiation–flowering) (Bidinger et al. 1987a, b). Losses result from reductions in grain number, grain mass, panicle mass and harvest index (Bidinger, 2002; Mahalakshmi and Bidinger, 1985).

Stress during grain filling decreases grains per unit area and grain size (Mahalakshmi et al. 1991) and reduces photosynthetic traits, green leaf area, relative water content, and seed yield per panicle (Addisie and Yemane, 2011). Grain abortion, mainly due to impaired fertilization, ovary growth and sucrose supply further reduces yield (Fussell et al. 1991; Boyer and

McLaughlin 2007; Turc and Tardieu 2018). Early-stage drought in semi-arid regions can cause seedling death, reducing crop stand and yield (Carberry et al. 1985; Soman and Peacock 1985). It leads to leaf rolling, reduced leaf area and lower stomatal conductance (Ali and Golombek 2016) and under osmotic stress (PEG-induced), negatively affects germination, seedling growth and root development (Shivhare and Lata 2019). At anthesis, water stress decreases water potential, stomatal conductance, photosynthesis and transpiration (Subramanian and Maheswari 1989) with combined drought and high irradiance further inhibiting CO_2 assimilation (Masojidek et al. 1991). Drought also alters biochemical composition, increasing soluble sugars, proteins, free amino acids and proline while reducing relative growth rate, leaf area, net assimilation rate and water potential (Ashraf et al. 2001a,b; Goyal et al. 2001).

Mechanisms of drought tolerance

Pearl millet, predominantly cultivated in water-deficit regions, adapts to drought through three primary mechanisms-escape, avoidance and tolerance. **Drought escape** involves completing the life cycle before severe water stress, aided by early flowering, rapid growth and high photosynthetic capacity, traits inherited from its wild progenitors and evident in cultivars like HHB-67. **Drought avoidance** enables plants to maintain favourable water balance under stress by reducing transpiration via low stomatal conductance, adjusting flowering time, increasing root-to-shoot ratio and using asynchronous tiller emergence to bypass critical stress periods. **Drought tolerance** allows yield maintenance at low water potential through osmotic adjustment, accumulation of osmoprotectants, deeper rooting and efficient post-anthesis water use with tolerant genotypes often exhibiting better tiller growth, stay-green traits and variable root system architectures. Together, these mechanisms-regulated by physiological processes such as stomatal control, osmotic regulation and root system plasticity-enable pearl millet to survive and produce under severe and variable drought conditions.

Genetic resources for drought tolerance

Pearl millet possesses remarkable genetic diversity, with about 56,580 accessions from 46 countries conserved across 70 global gene banks (Mathur 2012). Landraces dominate these collections (88%) followed by breeding materials (6%), wild relatives (3.2%), improved varieties (0.8%) and 2% unknown origin. Early flowering, a key drought-escape mechanism, varies widely in pearl millet: 52–77 days in Indian germplasm and 53–85 days in exotic lines (Murty et al. 1967), with global variation extending from 33 to 140 days (Harinarayana et al. 1988).

Notably early genotypes include IP-4021 (33 days) from Gujarat, several SR lines from Rajasthan, Pittaganti from the Eastern Ghats, and IP-4066, IP-9496, and IP-9426 (Kumar and Appa Rao 1987; Yadav et al. 2017). Landraces, well-adapted to their native ecologies, are an invaluable source of alleles for stress adaptation, particularly drought tolerance (Yadav and Weltzien 2000). Their adaptive potential has been documented across drier regions, with the highest frequency of ultra-early flowering (33–40 days) in Pakistan (18%), followed by Ghana (7.9%) and Togo (2.7%) (Upadhyaya et al. 2017). Some, like CZP-9802, derived from drought-adapted germplasm, have been released for arid regions of north-western India (Yadav et al. 2008), while Iniadi, a West African landrace, has been used globally for earliness and genetic variability (Andrews and Kumar 1996). Studies reveal substantial diversity for flowering time, photoperiod sensitivity, and drought tolerance within landraces (Upadhyaya et al. 2017). However, while yield potential under drought is relatively well understood, the genetic and physiological bases of drought adaptation remain less explored.

Crosses between exotic populations and local landraces have shown superior biomass, grain, and stover yield compared to exotic parents alone (Yadav 2008), combining large panicles from exotic types with earliness from landraces. Landrace-derived populations often display stable tillering and flowering under stress, outperforming high-yielding genotypes in adverse environments (Yadav and Weltzien 2000). Hybrids, with about 25% yield superiority over composites in arid/semi-arid climates, owe their advantage to higher panicle number and early flowering (Yadav et al. 2012). Breeding methods such as mass selection (Yadav and Bidinger 2007) have been effective in improving yield under low-moisture conditions. Still, direct use of landraces often requires productivity enhancement to achieve economic yields, making their combination with elite high-yielding varieties a preferred strategy (van Oosterom et al. 2003, 2006). Such crosses have frequently shown greater drought tolerance than either parent (Presterl and Weltzien 2003; Yadav 2008).

The success of a new cultivar in drought-prone regions is often gauged by at least a 15% yield advantage. In evaluations of 169 landraces, Yadav and Bidinger (2008) identified significant heterosis for biomass, grain, and stover yields in specific male-sterile × landrace combinations. Landrace populations also recorded the highest mean drought Resistance Index (3.99), while elite composites were most drought-sensitive (DRI –3.64) (Yadav 2010). Notable drought-tolerant cultivars include ‘Okashana-1’ (ICMV 88908) and ‘Okashana-2’ (SDMV

93032), popular in southern Africa for drought resistance, seed size, and disease resistance (Daisuke 2005; Reifschneider and Hussain 2004). In India, Pusa Composite-443, developed using the Jakhrana landrace, was released for the drought-prone A1 zone. Recent initiatives, such as the ICAR–ICRISAT partnership trials, focus on developing drought-tolerant hybrid parental lines (B and R) using genomic selection for harsh environments (Anonymous 2019).

Table 1: Hybrids and varieties of pearl millet released and notified for drier zone in India

SNo	Hybrid/variety	Parentage	Developer Institution	Released /Notified year	Characters
1	GHB-538 (MH 2561) Maru Sona	ICMA 95444 x J-2340(Imp)	ICAR-AICRP, PM, Jamnagar	2024	Early maturing, complete cylindrical panicles, grey brown globular seed, highly resistant to DM, blast and other foliar diseases, resistant to insect and pest, DF: 45 days, GY: 1939 kg/ha
2	GHB-1294(MH 2555) Maru Moti	ICMA 93333 x J-2632	ICAR-AICRP, PM, Jamnagar	2024	Early maturing, complete lanceolate panicles, grey brown hexagonal seed, resistant to DM, blast and other foliar diseases, resistant to insect and pest, resistant to drought , DF: 46, GY: 2223 kg/ha
3	MPMH-42 (MH 2553) Shree Anna Bajri 42	ICMA 92777 x MIR 519-1	ICAR-AICRP Pearl millet, PC Unit , Jodhpur	2024	Early maturing, complete conical panicles, grey globular seed, highly resistant to DM, blast and other foliar diseases, resistant to insect and pest, resistant to drought DF:45, GY: 2113 kg/ha
4	MPMH-35(MH 2474) Maru Sampada	ICMA 94555 x MIR 1252	ICAR-AICRP on Pearl millet, PC Unit, Jodhpur	2022	Early maturing, compact lanceolate panicles, grey coloured, highly resistant to downy mildew, blast,

					insect pests and resistant to smut DF: 44, GY: 2190 kg/ha
5	HHB-67 Imp 2	ICMA 843-22 x H-77/833-2-202-6	CCS HAU, Hisar & ICRISAT	2021	Extra early maturity, highly resistant to moisture stresses, resistant to downy mildew. The second commercial cultivars developed using marker-assisted selection in India Df: 44, GY: 2000 kg/ha
6	RHB-228(MH 2098)	ICMA 843-22 x RIB 15S076	ICAR-AICRP on PM, RARI, Jaipur	2021	Early maturing, compact panicles, medium size grains, grey brown, highly resistant to downy mildew, blast, insect pests and resistant to smut DF: 45, GY: 2757 kg/ha
7	Central pearl millet hybrid-BHB-1602	ICMA 88004 x BIB 16810	ICAR-AICRP-PM, SKRAU, Bikaner	2020	Early maturing, compact, conical ear heads, grey brown, globular grains, highly resistant to downy mildew, blast, insect pests and resistant to smut DF: 45, GY: 2529 kg/ha
8	Central pearl millet hybrid RHB-223	ICMA 96666 x RIB-3135-18	ICAR-AICRP on PM, RARI, Jaipur	2018	Early maturing, brown anthers, long brown bristles, resistant to DM, blast and smut, resistant to shoot fly, stem borer and grey weevil, tolerant to stress DF: 44, GY: 2969 kg/ha
9	PB-1756	PSP91 x PP107	Bayer Bio Science Hyderabad	2018	Early maturing, tolerant to moisture stress and lodging, resistant to downy mildew, blast, smut and ergot, tolerant to shoot fly and stem borer

					DF: 45, GY: 2698 kg/ha
10	JKBH 1008	JKMS 1954A x JKR 16010	JK Agri Genetics, Hyderabad	2016	Early maturing, yellow anther colour, cylindrical compact earheads, grey coloured globular grains, resistant to downy mildew and blast DF: 46, GY: 2383 kg/ha
11	MPMH-21 (MH 1777)	ICMS 93333 x MIR 524	AICRP-Pearl Millet, Jodhpur	2016	Early maturing, brown anthers, lanceolate compact ear heads, grey brown hexagonal grains, resistant to downy mildew, blast and smut DF: 47, GY: 2469 kg/ha
12	HHB-272(MH 1837)	HMS 47A x AC 04/13	AICRP on Pearl Millet, CCS HAU, Hisar	2016	Early maturing, brown anthers, lanceolate compact ear heads, grey globular grains, resistant to blast DF: 45, GY: 2421 kg.ha
13	HHB-234 (MH 1561)	HMS 7A x H77/833-2-202	AICPMIP, CCS HAU, Hisar	2013	Early maturing, candle shaped earheads with small bristles, medium seed size and tolerant to downy mildew DF: 48, GY: 1756 kg/ha
14	Bio 70 (MH 1632)	11A x R 207	Bioseed Research India Pvt. Ltd., Hyderabad	2012	Early maturing, conical compact earheads, yellow anther colour, globular grey seed and tolerant to downy mildew DF: 48, GY: 2023 kg/ha
15	RHB-177(MH 1486)	ICMA 843-22 x RIB 494	AICPMIP, RARI, Jaipur	2011	Early maturing, medium tall, cylindrical bristled earheads, resistant to downy mildew, light yellow anthers DF: 46, GY:2047 kg/ha
16	RHB- 154	ICMA 95444	AICPMIP,	2009	Early maturing, medium

		x RIB 57S/05	ARS, Durgapura, Jaipur		tall, resistant to downy mildew, tolerant to lodging, light yellow anthers, cylindrical earhead DF: 48, GY:2552 kg/ha
17	GHB-538	ICMA 95444 x J 2340	AICPMIP, MRS, Jamnagar	2005	Early maturity, highly resistant to moisture stresses, resistance to downy mildew and lodging DF: 47, GY:2453 kg/ha
18	HHB 67 Improved	ICMA 843-22 x H 77/833-2-202	AICPMIP, CCS HAU, Hisar	2005	Extra early maturity, highly resistant to moisture stresses, resistant to downy mildew. The first commercial cultivars developed using marker-assisted selection in India DF: 41, GY: 2024 kg/ha
	OPVs				
1	Mandor Bajra Composite-2	-	A.R.S, Mandor, Jodhpur	2011	Early maturing, medium height, medium long semi compact cylindrical earheads, obvate grey coloured seed DF: 48, GY: 1478 kg/ha
2	Pusa Composite 443 (MP 443)	-	AICPMIP, IARI, New Delhi	2009	Early maturity, medium tall, rod shaped earheads with bold grain DF: 48, GY: 1691 kg/ha
3	CZP-9802	-	CAZRI, Jodhpur	2003	70-72 days, medium tall, good tillering, thin stem, narrow leaves, thin candle-shaped earheads, yellowish grains of medium size, drought

					tolerant, very high stover of good quality DF: 49, GY: 1303 kg/ha

Prospects of improvement for drought tolerance

Pearl millet (*Pennisetum glaucum* L.) is naturally adapted to arid and semi-arid regions, but with climate change intensifying drought frequency and severity, there is an urgent need to further strengthen its resilience. The prospects for improvement are promising due to the crop's vast genetic diversity, the availability of advanced genomic tools, and evolving climate-smart production systems.

1. Genetic material with broad genetic base

   Most of the genetic material selected for drought prone areas has narrow genetic base. This requires large scale testing of germplasm under drought prone environments and selection of broadly adapted material for development of high yielding hybrids/varieties.

2. Rigorous testing under target production environment

   Due to high genotype x environment interaction in drought prone ecologies, testing of the material has to be carried out for multi locations and multi years.

3. Better hybrids for drought prone areas

   Hybrids yielded significantly higher under drought stress than the open-pollinated varieties and have shown yield advantage up to 35% over OPVs. Better adapted hybrids needs to be developed after rigorous testing. Stress needs to be put on development of dual-purpose hybrids with excellent fodder quality as well as high grain yield.

4. Genomics-assisted breeding

   High throughput genotyping has made available genome sequence of pearl millet and made available wealth of genomic resources which can be utilized for precise mapping of genomic regions/QTLs conferring drought tolerance. Due to complex nature of the trait, marker assisted selection facilitates in transfer of QTL/candidate genes via marker assisted selection with precision.

5. Large global germplasm collections, including diverse landraces and wild relatives, provide a rich reservoir of alleles for traits such as deep rooting, early vigour, stay-green, osmotic adjustment and efficient water use. Advances in genome-wide association

studies (GWAS), genomic selection, and marker-assisted breeding are enabling precise identification and pyramiding of drought-resilient alleles. Emerging tools such as CRISPR/Cas gene editing and speed breeding can accelerate the introgression of complex adaptive traits.

6. High-throughput phenotyping platforms, coupled with remote sensing and UAV-based canopy monitoring are improving the accuracy and efficiency of screening under managed drought environments. Integrating physiological trait selection (e.g., transpiration efficiency, canopy temperature depression) with genomic predictions can help in developing cultivars resilient across variable water-deficit scenarios.
7. The next decade is likely to see the release of **multi-trait, climate-resilient hybrids and varieties** that combine drought tolerance with high yield, grain quality, and fodder value. Such cultivars, when deployed alongside **climate-smart agronomic practices** like soil moisture conservation, precision irrigation, and bio-priming, will play a pivotal role in sustaining productivity in drought-prone ecologies.

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AFRICAN TULIP TREE (*SPATHODEA CAMPANULATA*) IN THE NILGIRIS: ORNAMENTAL BEAUTY OR ECOLOGICAL CATASTROPHE?

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1. Introduction

1.1 The Nilgiris: A Biodiversity Paradise Under Siege

The Nilgiris District, situated in the southern portion of the Western Ghats mountain range, represents one of the world's most significant biodiversity hotspots. This 2,565 square kilometer region, once covered in a mosaic of tropical montane forests—locally called "sholas"—interspersed with grasslands, has experienced catastrophic habitat transformation over the past two centuries. Recent assessments indicate that the district has lost approximately 80% of its native vegetation, replaced by tea estates, coffee plantations, exotic tree plantations, and invasive species (Mongabay, 2016). The Western Ghats harbor over 325 globally threatened species, with at least 41% of freshwater fish species classified as globally threatened (Dahanukar et al., 2004; UNESCO, 2012).

Against this backdrop of ecological crisis, the African Tulip Tree (*Spathodea campanulata*) has proliferated throughout the region, planted extensively for ornamental purposes in public gardens, residential areas, and along roadsides. This large evergreen to semi-deciduous tree, native to tropical Africa (from Senegal to Angola and Tanzania), was introduced to South Asia in the late 1800s and has since established populations across India, including all districts of Tamil Nadu (India Biodiversity Portal, 2016).

1.2 Research Objectives and Scope

This study addresses a critical knowledge gap regarding the true ecological and economic value of *S. campanulata* in the Nilgiris context. Specifically, we examine:

1. The global invasive potential and documented ecological impacts

2. Scientific evidence of medicinal properties and their practical applicability
3. Timber and economic value assessment
4. Toxicity to native pollinator populations
5. Specific threats to the Nilgiris ecosystem
6. Evidence-based policy recommendations

2. Global Invasive Status: A Tree Among the "World's Worst"

2.1 International Recognition as Major Threat

Spathodea campanulata has been nominated as one of the "World's 100 Worst" invasive alien species by the IUCN Invasive Species Specialist Group (Lowe et al., 2000, 2004). This designation places it among only 31 terrestrial plant species globally recognized for their exceptional invasiveness and ecological damage. The species has been declared a Class 3 pest in Queensland, Australia, under the Land Protection Act 2002, and Hawaii's Division of Forestry and Wildlife has designated it as one of the state's "Most Invasive Horticultural Plants" (BIISC, 2022).

2.2 Mechanisms of Invasion

The invasive success of *S. campanulata* derives from several biological characteristics:

Rapid Growth and Reproduction: The tree grows at extraordinary rates of up to 6 feet (1.8 meters) per year and reaches reproductive maturity within 3-4 years (BIISC, 2022). This rapid lifecycle enables swift colonization of disturbed areas.



Image 1: African Tulip trees found in the Nilgiris hills between Mettupalayam to Coonoor

Prolific Seed Production: Each tree produces masses of wind-dispersed seeds contained in boat-shaped capsules measuring 15-27 cm in length. Seeds are flat, thin, and broadly winged, facilitating long-distance dispersal (CABI, 2025). Studies in Cuba documented germination rates as high as 80%, with seed dispersal coinciding with rainy periods to maximize establishment success (Labrada, 2009).



Image 2: African Tulip flower exhibiting prolific reproductive organs for seed production

Vegetative Propagation: The species reproduces not only through seeds but also via root suckers, making standard cutting methods ineffective for removal. When cut, trees readily resprout from root systems, ensuring persistence even after apparent eradication (CABI, 2025).



Image 3: Vegetative propagation of African Tulip tree

Ecological Plasticity: *S. campanulata* demonstrates remarkable adaptability, thriving in various soil types and elevations up to 2,000 meters. It tolerates both humid conditions and dry seasons of up to six months, enabling colonization across diverse habitat types (PROTA, 2025).



Image 4: African tulip tree exhibiting ecological survivability in the Nilgiris

2.3 Global Case Studies of Ecological Devastation

Pacific Islands: Ecosystem Collapse

In the Pacific Islands, *S. campanulata* has caused some of the most severe documented impacts. In Fiji, the species invades agricultural areas, forest plantations, and natural ecosystems, "smothering other trees and crops as it grows, becoming the prevailing tree in these areas" (GISD, 2025). Research by Brown and Daigneault (2014) documented that novel forests dominated by *Spathodea* result in negative effects to socio-economic activities including agricultural production and tourism, severely affecting ecosystem service provision.

A comprehensive cost-benefit analysis in Fiji revealed that despite the significant economic investment required, managing *S. campanulata* yields monetized benefits of $3.7 for every $1 spent, even without considering non-monetized biodiversity and cultural benefits (ScienceDirect, 2014). This demonstrates that the economic case for control is compelling even from a purely financial perspective.

In Hawaii, major infestations occupy "almost every rainforest valley along the northern and eastern slopes of Kaua'i, O'ahu, Hawai'i, and East Maui" (BIISC, 2022). The species was aerially seeded in the 1920s for reforestation, with 30,000 trees planted throughout the state in the early 1900s—a decision now recognized as ecologically catastrophic.

Cuba: Agricultural and Forest Invasion

Studies in Cuba's Escambray mountains documented *S. campanulata* affecting approximately 60,000 hectares of forest, coffee plantations, and abandoned land (Labrada, 2009). In some sites, densities reach 12,000 plants per hectare, creating monospecific stands that exclude native vegetation. The species reproduces rapidly through seeds, with germination rates of 80% and seed dispersal facilitated by hurricanes in highland areas.

Caribbean and Central America: Spreading Threat

While *S. campanulata* is now widespread in Guatemala, Costa Rica, and Panama, it has not yet become problematic in these countries—highlighting the critical importance of preventative control measures before populations explode (Labrada, 2009).

3. Medicinal Properties: Scientific Evidence vs. Traditional Claims

3.1 Antimalarial Activity: The Most Substantiated Claim

Of all traditional medicinal uses, the antimalarial properties of *S. campanulata* have received the most rigorous scientific validation. Research by Amusan, Adesogan, and Makinde (1996) isolated three antimalarial compounds from stem bark: ursolic acid (3β-hydroxyurs-12-en-28-oic acid), tomentosolic acid (3β-hydroxyurs-12,19-dien-28-oic acid), and 3β,20β-dihydroxyurs-12-en-28-oic acid. This landmark study marked the first report of ursolic acid and its derivatives as antimalarial compounds.

In Vivo Studies: When tested against *Plasmodium berghei berghei* in mice, hexane and chloroform extracts of stem bark demonstrated blood schizontocidal action and prophylactic properties, suppressing parasitemia and prolonging survival time (Makinde et al., 1988, 1990). The chloroform extract showed particularly strong activity comparable to control treatments.

Computational Studies: Recent research using computational modeling identified four phytoconstituents from flower extracts—notably 1,2-ethanediol monobenzoate, 4-hydroxy benzoic acid, and methyl-β-D-galactopyranoside—with high binding affinity to antimalarial targets (Geevarghese et al., 2024).

3.2 Other Medicinal Applications: Limited Evidence

Antidiabetic Activity: A decoction of stem bark showed hypoglycemic activity in mice, though without influencing insulin levels (Niyonzima et al., 1999). This suggests potential for blood sugar management but requires further investigation.

Wound Healing: Methanol extract of stem bark formulated into topical preparations demonstrated wound healing potential in laboratory studies (Ofori-Kwakye et al., 2011).

Antimicrobial Properties: Various extracts have shown antibacterial and antifungal activities against selected pathogens, though efficacy varies significantly (PROTA, 2021).

3.3 Critical Assessment: Medicinal Value Does Not Justify Ecological Risk

While the antimalarial properties of *S. campanulata* are scientifically validated, several critical factors must be considered:

Availability of Alternatives: Modern antimalarial drugs are widely available and more effective than plant-based remedies. The existence of ursolic acid in *Spathodea* does not necessitate cultivating an invasive species when pharmaceutical alternatives exist.

Extraction Inefficiency: Medicinal compounds are present in bark and flowers, requiring destructive harvesting. The low concentration of active compounds relative to biomass makes this an inefficient source compared to pharmaceutical synthesis.

Risk-Benefit Analysis: The potential medicinal benefits are vastly outweighed by the documented ecological damage. As noted in comprehensive reviews, "*S. campanulata* plant phytochemicals can be very useful as a first-aid treatment of malaria in remote areas of Africa and Asia where modern medicine is not easily accessible" (JAPSONLINE, 2021)—but the Nilgiris is not such an area, having access to modern healthcare facilities.

4. Timber and Economic Value: A Critical Evaluation

4.1 Wood Quality Assessment

Scientific assessments universally characterize *S. campanulata* wood as inferior for most commercial applications:

Physical Properties:

- Air-dry density: 350-470 kg/m³ (PROTA, 2021)
- Color: Brownish-white to dirty white
- Texture: Soft, fibrous, and weak
- Durability: Susceptible to butt and heart rot; rots quickly when in contact with ground

Structural Limitations: The wood is "too weak for construction use" and unsuitable for structural timber applications (Wikipedia, 2025). The tree's tendency to become hollow with age, dropping large branches as it matures, further limits its utility (Tropical Plants Database, 2025). The soft, brittle wood is "easily broken by high winds" (University of Florida IFAS, 2019).

4.2 Limited Commercial Applications

Plywood: The only widespread commercial use is plywood production in the Philippines, where the species is grown as a plantation crop specifically for this purpose (PROTA, 2021). However, this application has not been replicated successfully in India or other regions.

Minor Uses: The wood finds limited application in:

- Boxes and crates (rough carpentry)
- Toothpicks
- Carving (though considered inferior)
- Blacksmith bellows (because it is difficult to burn)
- Firewood and charcoal (low quality)

4.3 Economic Analysis: Negative Net Value

A rigorous economic assessment must consider not only potential revenue from timber but also:

Costs of Ecological Damage:

- Loss of native biodiversity
- Pollinator mortality and reduced pollination services
- Agricultural productivity losses
- Forest ecosystem service degradation
- Tourism impacts in a region dependent on natural beauty

Management Costs:

- Removal and control expenses
- Monitoring programs
- Restoration of native vegetation

Studies in Fiji quantified these economic dimensions, demonstrating that even the "less costly current approach" to management yields monetized benefits of $2.7 for each $1 spent, clearly showing that "managing African tulip tree is cost effective, even without explicitly considering biodiversity, culture, and other non-monetized benefits of control" (ScienceDirect, 2014).

Conclusion on Economic Value: The negligible timber value of *S. campanulata* cannot justify its presence in the Nilgiris. The species generates minimal economic benefit while imposing substantial ecological and economic costs.

5. The Pollinator Crisis: Toxic Threat to Native Bees

5.1 Scientific Evidence of Toxicity

Perhaps the most alarming ecological impact of *S. campanulata* is its devastating effect on native pollinators, particularly stingless bees. Multiple peer-reviewed studies have documented this phenomenon:

Brazilian Studies: Research at the Federal University of Bahia examined 86 flowers over a 15-day flowering period and found that 98.1% of dead floral visitors were bees (Apidae and Meliponini) (SciELO, 2024). The flowers contain toxic compounds with insecticidal properties, leading to increased mortality among *Melipona* species, *Trigona spinipes* (50% of deaths), and *Partamona helleri* (24% of deaths).

Amazonian Bee Studies: Controlled experiments on *Melipona fasciculata* and *M. seminigra* workers demonstrated that both nectar and pollen from *S. campanulata* significantly reduced worker survival compared to control groups (Sociobiology, 2014). The toxic effects prevented collected pollen from reaching hives, as bees died before returning.

Australian Documentation: In Australia, *S. campanulata* is known to be toxic to native stingless bees such as *Lipotriches (Austronomia) flavoviridis*, contributing to its classification as a declared Class 3 pest species (Wikipedia, 2025).

5.2 Mechanism of Toxicity

The nectar and pollen contain toxic secondary metabolites that evolved to protect the flowers from pollen thieves. In Africa, the natural pollinators are bats and birds that visit later when the tree releases copious nectar. The toxic compounds kill early-arriving stingless bees that would otherwise steal pollen (Bob the Beeman, 2025).

5.3 Implications for the Nilgiris Ecosystem

The toxicity to pollinators has profound implications for the Nilgiris:

Native Bee Diversity: The Western Ghats harbor exceptional bee diversity, including numerous endemic species. The region is "a herpetological heavyweight with several endemic frog species" and similarly rich in invertebrate diversity (Mongabay, 2016).

Pollination Services: Native bees provide critical pollination services for native flora and agricultural crops. Loss of pollinator populations threatens both natural ecosystem function and agricultural productivity.

Cascade Effects: Pollinator decline can trigger cascading effects throughout the food web, affecting plant reproduction, seed production, and ultimately the entire ecosystem structure.

Recommendation: Given the damage to native biodiversity, experts strongly advise avoiding cultivation of *S. campanulata* "in public squares, gardens, or in proximity to bee hives" (SciELO, 2024).

6. Threat to Nilgiris Biodiversity: Context and Evidence

6.1 The Nilgiris Crisis: 80% Habitat Loss

The Nilgiris represents a microcosm of the broader Western Ghats conservation challenge. As a "sky island"—an isolated mountain ecosystem radically different from surrounding lowlands—the region harbors unique species found nowhere else. The high-altitude forests of the Nilgiris are "some of the few sky islands in the Indian subcontinent," acting as "hotbeds of evolution, harboring unique species" (Mongabay, 2016).

However, the last 200 years have witnessed catastrophic transformation:

Native Vegetation Loss: Approximately 80% of native shola-grassland ecosystems have been replaced by:

- Tea estates
- Coffee plantations
- Exotic tree plantations (Eucalyptus, Wattle/Acacia, Pine)
- Invasive species of grass and plants

Endemic Species Under Threat:

- **Nilgiri Tahr** (*Hemitragus hylocrius*): Vulnerable mountain ungulate whose grassland habitat has been devastated by exotic plantations
- **Nilgiri Langur** and **Lion-tailed Macaque**: Threatened primates dependent on native forest
- **Nilgiri Marten**: Endangered carnivore
- Multiple endemic bird species, amphibians, and insects

6.2 The Invasive Species Epidemic in the Nilgiris

The Western Ghats face a severe invasive species crisis. A 2019 petition before the Madras High Court highlighted that 65-75% of the region's plants were invasive. The court judgment noted: "The standing trees on the first blush might give the impression of a healthy forest, but they actually deliver the sad story of aging and dying. The weaker they become, the greater the

spreading of invasive species. The crisis is impending and looming" (The Swaddle, 2020).

Major Invasive Species in the Nilgiris:

- **Lantana** (*Lantana camara*): Creates mat-like structures leading to biodiversity degradation
- **Eucalyptus**: Banned from planting since 1987 but still widespread
- **Wattle** (Acacia species): Colonized grasslands extensively, encroaching on shola forests
- **Prosopis juliflora**: Competes with native species regeneration
- **Eupatorium odoratum** and **Parthenium hysterophorus**: Lower slope invasives

Ecological Impacts:

- Acidification of soil through resin-like substances
- Prevention of native plant growth
- Creation of impenetrable thickets blocking wildlife movement
- Depletion of food sources for herbivores (Gaur, Chital, Sambar)
- Consequent impacts on predators (tigers, leopards)

6.3 Forest Department Response and Policy Framework

In recent years, the Forest Department has initiated measures to combat invasive species:

Current Initiatives:

- Removal of eucalyptus and wattle in Reserve Forests of Nilgiris and Kodaikanal
- Planting of native floral species
- Attempts to eradicate *Prosopis juliflora* and *Lantana camara*

Expert Committee Recommendations (2019): Following the Madras High Court petition, an expert committee recommended:

- Mass mapping of invasive species in each forest division
- Systematic removal for "ecological restoration of weed-free landscapes"
- Recognition that "The Shola vegetation has become relict in Ooty Nilgiris and may vanish soon as a result of exotics and tea plantations"

National Policy Framework: India has adopted Aichi Target 9 as National Biodiversity Target 4, committing to "identify invasive alien species and their pathways of introduction, and to develop strategies to manage prioritised invasive alien species by 2020" (The Wire, 2016).

6.4 *Spathodea campanulata* in the Nilgiris Context

While *S. campanulata* has not yet reached the same level of proliferation as Lantana or Eucalyptus in the Nilgiris, the global evidence and local conditions suggest high invasion risk:

Risk Factors:

1. **Climate Suitability:** Nilgiris elevation (up to 2,637m) and climate match the species' tolerance range
2. **Habitat Disturbance:** Extensive disturbed areas from tea/coffee cultivation provide ideal invasion sites
3. **Moisture Availability:** Adequate rainfall supports rapid growth
4. **Lack of Natural Enemies:** No natural predators or pathogens in India to limit population growth
5. **Existing Propagule Pressure:** Widespread ornamental planting provides seed sources

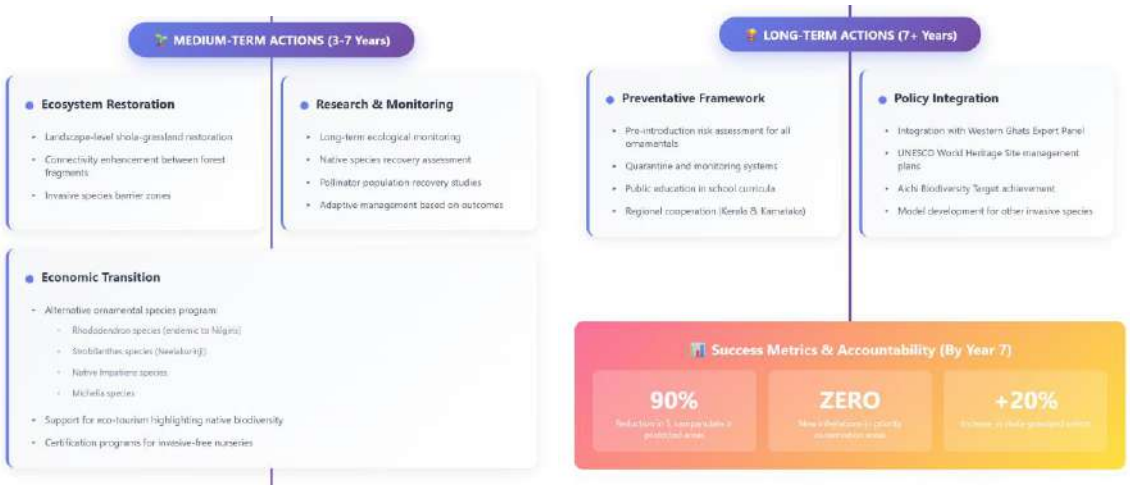
Evidence of Presence: The species is documented in "All districts" of Tamil Nadu (India Biodiversity Portal, 2016) and specimens are held in the Western Ghats collection at the Indian Institute of Science herbarium.

Potential Trajectory: Without intervention, *S. campanulata* could follow the pattern observed in Cuba, where densities reached 12,000 plants/hectare, or Fiji, where it became the "prevailing tree" in invaded areas.

7. Policy Recommendations: A Call for Immediate Action

Based on comprehensive scientific evidence, we propose the following tiered policy framework for managing *Spathodea campanulata* in the Nilgiris:







8. Comparative Analysis: Native Alternatives

To facilitate the transition away from *S. campanulata*, we recommend native and non-invasive ornamental alternatives:

8.1 Native Flowering Trees of Nilgiris

For Red/Orange Flowers:

- *Rhododendron arboreum* (Tree Rhododendron): Native, spectacular red flowers, supports native pollinators
- *Butea monosperma* (Flame of the Forest): Native to India, similar color palette, culturally significant

For Year-round Interest:

- *Michelia nilagirica* (Nilgiri Champak): Endemic, fragrant white/yellow flowers
- *Magnolia champaca*: Native to Western Ghats, aromatic
- *Strobilanthes* species: Endemic, purple mass flowering (every 12 years)

For Ecological Value:

- *Terminalia* species: Native, support diverse wildlife
- *Artocarpus* species: Native, provide food for wildlife
- *Syzygium* species: Endemic to Western Ghats, year-round interest

8.2 Benefits of Native Species

Ecological:

- Co-evolved with native pollinators (support native bee populations)
- Provide appropriate food sources for endemic wildlife
- Contribute to ecosystem function and resilience
- No invasion risk

Economic:

- Eco-tourism value (unique to region)
- Non-timber forest products
- Potential for endemic species conservation tourism
- Long-term ecosystem service provision

Cultural:

- Connection to indigenous traditions
- Regional identity and pride
- Educational value for biodiversity awareness

9. Conclusion: The Verdict is Clear

The comprehensive evidence assembled in this review leads to an unequivocal conclusion: *the African Tulip Tree (Spathodea campanulata) represents a net negative for the Nilgiris ecosystem and must be managed as a serious invasive threat, not celebrated as an ornamental asset.*

9.1 Summary of Findings

Invasive Status: Recognized globally as one of the "World's 100 Worst" invasive species, with documented catastrophic impacts across Pacific Islands, Caribbean, Africa, and Australia.

Medicinal Value: While antimalarial properties are scientifically validated, they do not justify cultivation in a region with access to modern medicine, especially given the availability of pharmaceutical alternatives and the species' ecological costs.

Economic Value: Timber quality is poor, with the only significant commercial application being low-grade plywood. The negligible economic benefit is vastly outweighed by ecological damage costs.

Pollinator Toxicity: Causes 98% mortality in visiting native bees, threatening pollination services critical to both natural ecosystems and agriculture.

Ecosystem Threat: In a region that has already lost 80% of native vegetation, introduction of additional invasive species accelerates biodiversity loss and threatens endemic species survival.

9.2 The Path Forward

The Nilgiris stands at a critical juncture. The region has witnessed two centuries of ecological transformation, with shola-grassland ecosystems reduced to fragments. The 2019 Madras High Court recognition that "The Shola vegetation has become relict in Ooty Nilgiris and may vanish soon" underscores the urgency of action.

Spathodea campanulata may appear less threatening than Lantana or Eucalyptus simply because it has not yet reached equivalent densities. However, the global evidence demonstrates that without intervention, it will follow the same trajectory, achieving densities that exclude native vegetation and fundamentally alter ecosystem function.

The question is not whether to act, but how quickly we can mobilize resources to prevent another invasive species catastrophe.

9.3 A Call to Action

We call upon:

Tamil Nadu Forest Department to immediately designate *S. campanulata* as a prohibited

invasive species and implement the removal protocols outlined herein.

Tamil Nadu Biodiversity Board to prioritize *S. campanulata* management in state biodiversity action plans and allocate appropriate resources.

Nilgiri Biosphere Reserve Administration to eliminate the species from all protected areas within the Reserve and establish buffer zones preventing re-invasion.

Municipal Authorities in Ooty, Coonoor, Kotagiri, and other Nilgiris towns to remove *S. campanulata* from public spaces and replace with native alternatives.

Research Institutions to establish long-term monitoring programs assessing removal effectiveness and ecosystem recovery.

Civil Society Organizations to raise public awareness about invasive species threats and mobilize community participation in restoration.

Individual Citizens to voluntarily remove *S. campanulata* from private properties and plant native species instead.

9.4 Final Reflection

The African Tulip Tree's spectacular orange blooms have captivated generations, earning it a place in gardens worldwide. But beauty, however striking, cannot justify ecological destruction. In the Nilgiris—a global biodiversity treasure facing existential threats—every decision about land use and species introduction carries profound consequences.

The choice before us is clear: we can continue to admire the ornamental appeal of an African invader while our native ecosystems crumble, or we can make the difficult but necessary decision to protect what remains of the Nilgiris' irreplaceable biodiversity heritage.

The Nilgiri Tahr, climbing diminishing grasslands. The endemic frogs, calling from vanishing streams. The stingless bees, dying in toxic flowers. The shola forests, retreating before advancing exotics. They cannot speak for themselves. But the scientific evidence speaks volumes.

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SYSTEM OF MATING IN CROP IMPROVEMENT

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Introduction

Mating system always referred by which individuals are paired for crossing. Selection and mating system were the two basic tools to manipulate the genetic nature of a population. Random mating involves that each of female gamete has equal chance to unite with any male gamete attributing the rate of reproduction of each genotype is equal without any mode of selection. Worthwhile, the random mating may be practiced in plant breeding in several ways, e.g., progeny testing, production and maintenance of synthetic and composite varieties and production of polycross progeny.

In this condition, the gene frequencies and variance for the trait remain constant besides the correlation between relatives or prepotency also does not change. However, in crop breeding certain mode of selection is always followed which is called as random mating with selection.

Genetic constitution of random mating

Random mating with selection changes the mean of the character and increases the frequency of alleles for which selection has been practiced. Further, random mating may increase the variance when the selection is in favour of a rare allele whereas tend to reduce it when a predominant allele is selected for. These changes are more effective when the trait is highly heritable and is governed by one or a few genes. Random mating in small population often unable to prevent an increase in homozygosity due to inbreeding and genetic drift attributing to a chance fixation of alleles. In case of polygenic traits with moderate heritability, the effect of expression due to selection is relatively small.

Genotypic Assortative Mating

In genetic assortative mating, the mating is between individuals that are more closely related by ancestry than in random mating. Genetic assortative mating is useful in the development of inbreds both partial and complete. Hence, the genotype of the plants selected for mating has been clearly defined to be closely related. When the mating system is more common, it is known as **inbreeding**.

1. Genetic assortative mating increases homozygosity and reduces heterozygosity.
2. Alleles and the traits become fixed based on the number of genes controlled and their heritability for the trait, except for the variation produced by environment.
3. Intense inbreeding lead to increase in the number of non-interbreeding groups and thereby selection must be done to keep the population size manageable.
4. The total genetic variability of the population increases rapidly. The genetic variability within interbreeding group. i.e., families or line, decreases rapidly and is ultimately reduced to zero.
5. Genetic variability of the population decreases rapidly under selection,. In cases where only one line is selected the genetic variability is very small or zero.
6. Continuous inbreeding may lead to increase under inbreeding**.**
7. **Prepotency** referred to an individual to produce progeny which are similar to each other and to the parent. Prepotency has been influenced by homozygosity, dominance, epitasis and linkage.

Genotypic Disassortative mating

It involves mating between individuals which are less closely related by ancestry than would be under random mating. Examples of such a mating are inter varietal and inter specific crosses. The effects of genetic dis assortative mating are similar to those of migration which facilitate decrease in homozygosity and increase heterozygosity.

Phenotypic Assortative Mating

Phenotypic assortative mating involves mating between individuals, which are phenotypically more similar than would be expected under random mating. It involves

1. Division of the population into two extreme phenotypes.
2. Increase in homozygosity.

3. Increase in genetic variability provided both the extreme phenotypes are kept in the population.
4. The prepotency of individuals also increases due to an increase in their homozygosity.

Restoration of random mating reduce the effects of this mating stystem. The effect of phenotypic assortative mating become quickly obvious in case of those characters that are governed by one gene, but the effects are slower to appear in the case of those governed by two genes. In the case of polygenic traits, effects are much slower to realize, and the intermediate types are seldom eliminated. Gene actions *viz.*, dominance and non-additive reduce the effects of phenotypic assortative mating. Since heritability is always less than 100 per cent for most of the quantitative traits, the effectiveness of this mating is further reduced. Therefore, the increase in homozygosity etc. is much slower than that expected with 100 per cent heritability. This mating system is useful in the isolation of extreme phenotypes and is exploited in recurrent selection.

Phenotypic Disassortative Mating

Mating between phenotypically dissimilar individuals belonging to the same population is referred to as phenotypic disassortative mating. The consequences of this mating are.

1. Increase in heterozygosity and reduction of population varance leading intermediate genotypes.
2. Reduction in correlation between relatives or in prepotency due to the increase in heterozygosity.

Phenotypic disassortative mating system ensure population stability on expression of biometric traits therefore help to maintain the genetic variability. Selection of ideal parents rests on strength and weakness. The mating system is also useful when desirable type is an intermediate one and the available parents have the extreme phenotypes.

Control of Mating system

Gene number and quantum of heritability decide the effect of different systems of mating on the genetic composition of populations. Random mating changes neither gene frequency, variability of the population, nor the genetic correlation between close relatives. Random mating with selection change gene frequencies and so the mean of the population, whereas it has little effect on homozygosity, the population variance or the genetic correlation between relatives.

Continuous inbreeding breaks populations up into numerous non-inter breeding groups thereby lead fixation of like alleles with an increased prepotency constituting increased

homozygousity. But inbreeding with selection favour only one type of homozygote reduces genetic variance to zero as the type becomes fixed. Close inbreeding is the only effective method of bringing to light hereditary differences in traits as decided by nature of gene controlled besides heritability. Phenotypic assortative mating tends to concentrate the population toward the two extremes but is inefficient fixation of type or in changing prepotency. Phenotypic assortative mating produces most of its effect in a few generations after it is begun, and its effects are likely to disappear almost immediately upon resumption of random mating.

Conclusion

Different mating systems has their own advantages and disadvantages on referred utility. If the option is concerned to increased homozygousity, inbreeding is the obvious choice; even through it will almost certainly less than optimum performance. To develop an extreme phenotype, progeny testing would be the best hand to proceed with the phenotypic assortative mating. Random mating with selection through progeny testing has its credible role in crop improvement. Also, genotypic and phenotypic disassortative mating ensure the genetic stability among the source population.

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KEY INSECT PESTS AFFECTING WHEAT CULTIVATION IN KOSI REGION OF BIHAR

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Introduction

Wheat (*Triticum aestivum L.*) ranks as the second most significant cereal crop following rice in Bihar and serves as a crucial element of the agricultural economy in the Kosi region. It is the most extensively cultivated food crop globally and serves as an essential staple, especially in India following rice. As per the Economic Survey 2023–24, India's wheat production during the 2023–24 agricultural year was a record 113.292 million tonnes (1132.92 LMT). The Kosi belt, which mainly includes districts such as Saharsa, Supaul and Madhepura is recognized for its rich alluvial soils deposited by the Kosi River. However, despite this fertility, the area is susceptible to recurrent floods and droughts, which foster conditions conducive to insect pest outbreaks. The sandy loam soils, along with considerable variations in soil moisture, create an optimal setting for both soil-dwelling and foliar pests that target wheat at various growth stages**.** Different arthropods inflict significant harm on wheat crops during their entire lifecycle, and no phase of the crop is exempt from damage. Wheat pests can be classified as either polyphagous or oligophagous.

Major Insect Pests infesting the wheat crop are-

1. **Aphid**- Aphids are regarded as notorious for the direct and indirect losses they cause. They feed on the sap of wheat plants, leading to direct damage through nutrient depletion, which results in stunted growth, yellowing, and diminished vigor. Adult aphids measure approximately 1/8 inch in length, and they may possess two pairs of nearly transparent

wings. Aphid infestations generally rise in warm, dry conditions, and their high reproduction enables populations to expand rapidly. Aphid outbreak during the early growth stages of wheat is particularly concerning. Furthermore, these pests are significant as they can transmit diseases to the plant, such as the barley yellow dwarf virus.

2. **Pink Stem Borer-** The pink stem borer is a polyphagous pest. Caterpillars exhibit a range of colors, starting as brown and later transitioning to a greenish with darker broken lines along the sides of their bodies. The moth is stout and medium-sized, characterized by brownish or greyish forewings that feature a dark crossband near the outer margin and dark spots near the costal margins. Young larvae initially feed on the leaves for a period before moving on to attack the earheads. The internal tissues are severely consumed, resulting in complete hollowing out. During feeding, the caterpillar inserts its head inside while leaving the remainder of its body exposed.

   The larvae represent the destructive stage of this insect. Clusters of eggs are deposited on the leaf sheaths close to the base of the plant. The eggs, which are initially creamy white upon being laid, gradually change to yellow as they develop prior to hatching. After hatching, the larvae penetrate the stem of a wheat plant. The larvae burrow into the stem, which can be sufficiently damaging to eliminate the central growing point of the plant, although the outer leaves may still appear green. In young wheat plants, this results in a condition known as dead heart, where the central shoot becomes desiccated and perishes.



Aphid



Pink stem boree



Grasshopper

3.Grasshopper- These grasshoppers are polyphagous, consuming various cultivated crops. Grasshoppers inflict significant economic damage by damaging young wheat plants, especially in rain-fed and dryland agriculturalDamage to cereal crops typically occurs near the edges of fields, primarily due to hatchling grasshoppers migrating from their egg beds to these margins; in contrast, damage to grasslands is usually more uniformly spread. The harm inflicted on cereal crops encompasses leaf notching and stripping, but the most significant losses arise when stems are cut just below the heads of either maturing or fully mature crops

Conclusion

The Kosi area in Bihar, while blessed with rich soils, continually confronts challenges posed by insect pests in wheat farming. The major insect pests include aphids, armyworms and pink stem borers whereas minor insect like armyworm and ghujia weevil each possessing distinct life cycles that enable them to flourish within the region's ecosystem. By gaining insights into pest biology and employing a combination of management strategies, farmers can reduce yield losses and promote sustainable wheat production in this crucial agricultural region.

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INSECT PESTS OF GARLIC AND THEIR MANAGEMENT

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Introduction

Common insect and mite pests of garlic include onion thrips, onion maggot, aphids, and red spider mites. These pests can damage garlic by feeding on leaves, stems, and bulbs, leading to stunting, yellowing, and reduced yield. Management strategies involve integrated pest management (IPM) practices, including cultural controls, biological controls, and the use of targeted insecticides when necessary. Among the pests attacking garlic, onion thrips requires attention as it is the most destructive.

1. Onion thrips, *Thrips tabaci* Lindeman (Thysanoptera: Thripidae)

Pest description and identification:

Nymphs: White to pale yellow, elongate, slender body, resembling adults but without wings.

Pupae: Pale yellow to brown.

Adults: Slender, yellowish-brown, about 1 mm long. Males are wingless; females have long narrow fringed wings.



Fig 1: Thrips damage in garlic



Fig 2: Yellow nymphs of thrips

Symptoms of damage:

Nymphs and adults feed on leaves causing curling, twisting, and white or silvery patches.

Entire plant appears blemished and turns white.

2. Red spider mite, *Tetranychus* sp (Acari: Tetranychidae)

Pest description and identification:

Adult females: Elliptical, reddish in color.

Eggs: Laid singly on leaf undersides or attached to silky webs.

Larvae: Pinkish, with four pairs of legs, slightly larger than eggs.

Nymphs: Reddish or greenish with four pairs of legs.



Fig 3: Red spider mites (larva, nymphs, and adults)

Symptoms of damage:

Nymphs and adults feed mainly on leaf undersides.

Feeding punctures appear as small stippled spots on leaf tops.

An infested plant shows silk webbing on the leaves.

Leaves become bleached, discolored, and may eventually fall off.

3. Eriophyid mite, *Aceria tulipae* Keifer (Acari: Eriophyoidea)



Fig 4: Eriophyid-infested garlic plant

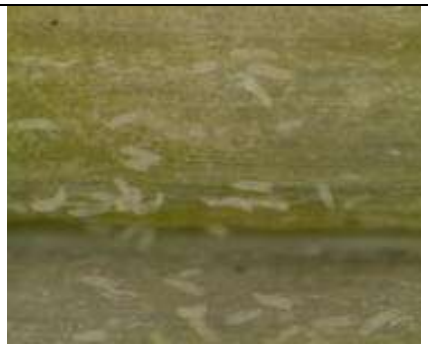


Fig 5: Eriophyid mites

Pest description and identification:

Cylindrical/cigar-shaped, translucent white, microscopic.

Only two pairs of legs near the head.

Adult size: 200–250 µm length; 36–52 µm width

Symptoms of damage:

Feed on young leaves causing stunting, twisting, curling, discoloration.

Leaves do not open fully; yellow mottling at leaf edges.

Mites acts as vector viral diseases in garlic.

4. Aphids *Aphis* sp. and *Myzus* sp. (Hemiptera: Aphididae)

Pest description and identification:

Myzus nymphs: Green to yellow.

Winged aphids: Black head and thorax, green abdomen with dark dorsal patch.

Aphis nymphs: Tan, grey, or green with dark head and distal abdomen.

Adults: Light to dark green.

Symptoms of damage:

Nymphs and adults suck sap causing leaves to roll, twist, and yellow.Transmit viral diseases.

 Adult zigzag beetle	 Eggs of coccinellid	 *Aeolothrips*
 *Adults Orius*	 Lacewing egg	 Adult *Ceranisus* sp

Fig 6. Natural enemies of garlic pests

Management strategies

- Avoid late planting; early sowing reduces thrips population.
- Avoid successive onion and garlic planting to reduce pest buildup.
- Destroy crop residues, weeds (e.g., parthenium, amaranthus) to prevent thrips overwintering.
- Use blue/yellow sticky cards for monitoring and mass trapping adults.
- Spray neem based formulation 2-3 ml/lit and entomopathogens like *Lecanicillium lecanii* @ 5g/lit.
- The use of neem based or botanical and microbial insecticide formulations or products, and following ETL as well as need based application of insecticides can help in retaining the existing predators like zigzag ladybird beetle *Cheilomenes sexmaculata*, predatory thrips, *Aeolothrips mongolicus*; minute pirate bug, *Orius* sp; Anthacorid bug, *Blaptostethus pallescens*; Green lacewing, *Chrysoperla* sp and thrips parasitoid, *Ceranisus* sp populations in garlic production system.
- Spray insecticides when thrips exceed economic threshold (30 thrips/plant): Profenofos @ 1 or ml/lit or Carbosulfan @ 2 ml/lit or Fipronil @ 1 ml/lit or Spinosad @ 0.4 ml/lit
- Spray Profenofos @ 1 ml/lit against aphids.
- Apply wettable sulfur @ 2 g/lit for mite infestations; repeat after 15 days for control.

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Volume: 05 Issue No: 10

ANALYSING WORLD MARINE FISHERIES AND AQUACULTURE TRENDS (2012-2022)

Article ID: AG-VO5-I10-33

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Abstract

Aquaculture and fishing are essential to nutrition, livelihoods, and global food security, especially in developing nations. FAO SOFIA data from 2012–2022 are used in this study to analyse worldwide production and use patterns, with a focus on 2020–2022. Climate fluctuation, overfishing, and disturbances like the COVID-19 pandemic caused sea fisheries to fluctuate while inland production remained consistent in capture fisheries. By contrast, aquaculture, which surpassed capture fisheries as the primary source of fish supply, showed consistent growth, increasing from 66.6 million tonnes in 2012 to 94.4 million tonnes in 2022. Fish consumption by humans rose steadily due to population growth and increased demand, while non-food applications varied, with per capita consumption reaching 20.7 kg in 2022. The results highlight how important aquaculture is to supplying the world's seafood needs while easing the strain on wild stocks. To strike a balance between increasing productivity and protecting ecosystems, sustainable aquaculture growth must be combined with efficient catch fisheries management.

Keywords: Fisheries, aquaculture, production trends, sustainability, consumption.

Introduction:

The global economy, livelihoods, and food security are all significantly impacted by the fisheries and aquaculture industries. Since fish is the main source of protein for billions of people, there is a considerable increase in demand for fish and seafood. Particularly in coastal and developing areas, fisheries and aquaculture provide jobs in addition to nutrition. However,

there are several issues facing this industry, including habitat deterioration, overfishing, and climate change. To guarantee the industry's longevity and comprehend its changing dynamics, these tendencies need to be examined. Advances in aquaculture, or the growing of fish and other aquatic organisms, have resulted in record global fish production. Aquaculture is presently the fastest-growing food production sector, accounting for approximately half of the global fish supply. Countries like China, India, and Vietnam have emerged as leaders in this field. This increase in aquaculture has helped supply the expanding worldwide demand for seafood while also reducing strain on wild fish supplies. Despite its benefits, aquaculture must handle environmental concerns, disease outbreaks, and resource utilization. Marine capture fisheries, which gather fish from the oceans, remain a cornerstone of the fishing business.

The North Atlantic, Pacific, and Indian Oceans contribute significantly to global catches. However, the viability of these fisheries is jeopardized due to overfishing and illicit fishing techniques. International agreements such as the United Nations Sustainable Development Goals (SDGs) and regional fishery management organizations seek to address these concerns and promote sustainable practices. Inland fisheries, which entail capturing fish from rivers, lakes, and reservoirs, are also quite important. These fisheries are critical for millions who live in landlocked areas, particularly in Africa and Asia. However, they face obstacles such as water pollution, dam development, and decreased water supply as a result of climate change. To ensure the continued productivity of freshwater ecosystems, efforts are being made to integrate inland fisheries management with conservation. The worldwide fish trade has grown significantly, with seafood now one of the most traded commodities in the world. Fish exports are an important source of income for millions of people in developing countries. However, this trade is susceptible to changes in international markets, tariff obstacles, and certification requirements. Sustainable sourcing and certification regimes, such as the Marine Stewardship Council (MSC), play an important role in ensuring these countries' market access.

Materials and Methods:

The data for this analysis were collected from the FAO SOFIA (State of World Fisheries and Aquaculture) report, which provides comprehensive statistics on global fisheries and aquaculture trends. The data span the years 2020 to 2022, covering various categories such as production, utilization, exports, and employment.

Data Collection: The production data for both capture fisheries (inland and marine) and aquaculture (inland and marine) were recorded for the years 2020, 2021, and 2022. Additional data on total fisheries production, world fisheries and aquaculture, human consumption, non-food uses, and per capita apparent consumption were also collected.

Data Visualization: To analyze trends and patterns, the data were visualized using several graphical representations such as: Line Graph, Pie Chart and Bar Chart.

Data Analysis: The data were analyzed to identify patterns, evaluate growth trends, and assess how utilization categories (human consumption vs. non-food uses) evolved. The analysis focused on identifying the contribution of aquaculture vs. capture fisheries to global fisheries production growth.

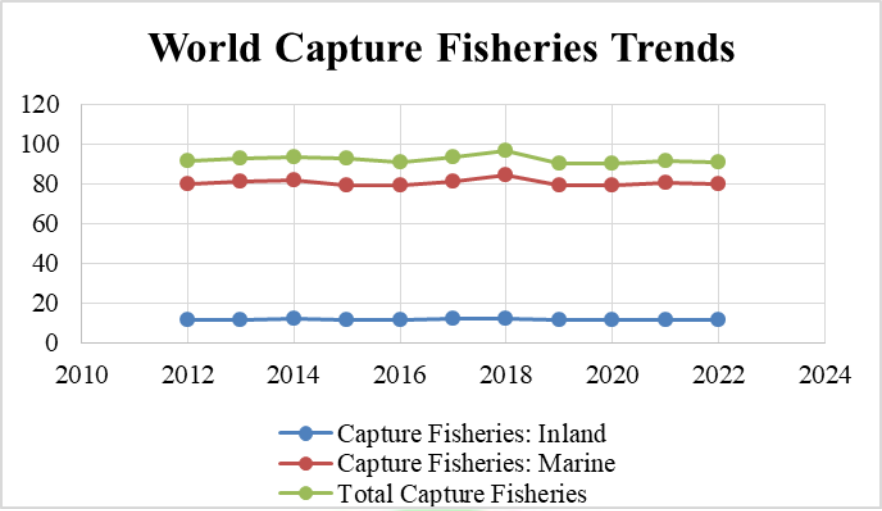
Results and Discussion:

World Capture Fisheries Trends:

The production trends in capture fisheries, encompassing both inland and marine sectors, were analyzed for the period 2012–2022. The total capture production exhibited significant annual variations, ranging from 90.3 million tonnes (2019 and 2020) to a peak of 96.4 million tonnes in 2018. Inland capture fisheries showed relatively stable production throughout the period, fluctuating slightly between 11.3 million tonnes (2022) and 12.0 million tonnes (2018). The peak in 2018 was primarily attributed to a substantial increase in anchoveta landings in the Southeast Pacific, driven by favorable oceanographic conditions such as nutrient-rich upwelling. In subsequent years, production declined due to the El Niño–Southern Oscillation (ENSO) events, which disrupted fish availability, and the COVID-19 pandemic, which significantly impacted global fishing operations and supply chains (Chen, Xinjun. (2022). Effects of Global Climate Changes on Marine Fishery Resources. 10.1007/978-981-19-2956-4_7.).

In contrast, marine capture fisheries displayed more pronounced variations. Production peaked at 84.4 million tonnes in 2018 but declined sharply to 78.8 million tonnes in 2020, likely due to unforeseen disruptions or environmental factors. This sharp decline in 2020 was primarily caused by the impacts of the COVID-19 pandemic, which severely disrupted global fishing activities, labor availability, and market access. This stark reduction was followed by a recovery in 2022, as global fishing operations resumed post-pandemic and favorable oceanic conditions improved fish availability, with production rising to 79.7 million tonnes. The analysis highlights that while inland fisheries maintained a consistent contribution to total capture fisheries, marine

fisheries experienced significant fluctuations, influencing the overall trends.



World Fish Resources Utilization Trends:

The global utilization of fish products from 2012 to 2022 reveals significant trends in human consumption, non-food uses, and per capita apparent consumption.

Human Consumption:

Fish utilization for human consumption exhibited a steady increase over the study period, rising from 136.2 million tonnes in 2012 to 164.6 million tonnes in 2022. The growth is attributed to rising demand for aquatic protein, advancements in aquaculture, and improvements in supply chain logistics. This growth was primarily driven by the growing global population, rising incomes, and increased consumer demand for seafood, coupled with the expansion of aquaculture production, which ensured a stable supply of fish to meet the rising demand. Notably, the most significant increase occurred between 2020 and 2022, with an increment of 7.2 million tonnes.

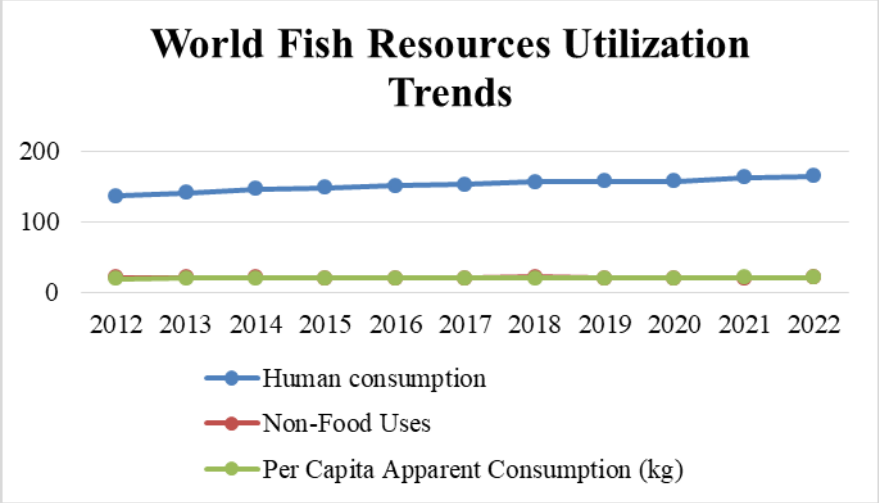
Non-Food Uses:

The utilization of fish for non-food purposes displayed a fluctuating trend. Starting at 20.7 million tonnes in 2012, it peaked at 22.2 million tonnes in 2018 before decreasing and stabilizing around 20.3-20.8 million tonnes during the later years of the study. This fluctuation indicates a shifting balance between fishmeal production and other industrial uses.

Per Capita Apparent Consumption:

Per capita apparent fish consumption increased marginally over the study period, reflecting global population growth and dietary shifts. Starting at 19.2 kg in 2012, it rose to 20.7 kg in

2022. A notable plateau was observed from 2015 to 2019, where consumption hovered around 20.2-20.5 kg, suggesting temporary stabilization influenced by economic or production factors.



Capture Fisheries Vs Aquaculture:

The analysis of global fisheries production from 2012 to 2022 highlights significant differences between capture fisheries and aquaculture. Total capture fisheries production showed stagnation, ranging from 91.3 million tonnes in 2012 to 91.0 million tonnes in 2022, with minor annual fluctuations. Stagnation in capture fisheries production may be due to overfishing, leading to depleted fish stocks, and environmental changes such as climate impacts that disrupt marine ecosystems and fish distribution (Zhang *et al.* 2022). Inland capture fisheries remained stable, averaging around 11.5 million tonnes annually, while marine capture fisheries experienced variability, peaking at 84.4 million tonnes in 2018 but declining thereafter.

In contrast, aquaculture demonstrated consistent growth over the decade, with total production increasing from 66.6 million tonnes in 2012 to 94.4 million tonnes in 2022. Inland aquaculture grew by ~41%, while marine aquaculture expanded by ~43%, reflecting technological advancements and improved management practices. By 2022, aquaculture surpassed capture fisheries, contributing more than 50% to global fish production.

These trends emphasize the critical role of aquaculture in sustaining global fish supply and the need for conservation measures to maintain capture fisheries' viability amidst environmental and resource constraints.

Category	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Production (million tonnes)											
Capture Fisheries: Inland	11.6	11.7	11.9	11.4	11.6	11.9	12	11.5	11.5	11.4	11.3
Capture Fisheries: Marine	79.7	81.1	81.5	79.3	79.3	81.2	84.4	78.8	78.8	80.3	79.7
Total Capture Fisheries	91.3	92.7	93.4	92.7	90.9	93.1	96.4	90.3	90.3	91.6	91.0
Aquaculture: Inland	41.9	44.8	47.1	48.6	51.4	49.6	51.3	54.4	54.4	56.4	59.1
Aquaculture: Marine	24.7	25.5	26.7	27.5	28.7	30	30.8	33.1	33.1	34.7	35.3
Total Aquaculture	66.6	70.3	73.8	76.1	80.0	79.5	82.1	87.5	87.5	91.1	94.4
Total World Fisheries and Aquaculture	158.0	162.9	167.2	168.7	170.9	172.7	178.5	177.8	177.8	182.8	185.4
Utilization (million tonnes)											
Human consumption	136.2	141.5	146.3	148.4	151.2	152.9	156.4	157.4	157.4	162.5	164.6
Non-Food Uses	20.7	21.4	20.9	20.3	19.7	19.7	22.2	20.4	20.4	20.3	20.8
Per Capita Apparent Consumption (kg)	19.2	19.7	20.1	20.2	20.3	20.3	20.5	20.2	20.2	20.6	20.7

Conclusion

Fisheries and aquaculture are essential to global food security and livelihoods. Capture fisheries have stagnated due to overfishing, climate change, and environmental issues, but aquaculture has been growing quickly and is expected to surpass capture fisheries as the world's

main source of fish by 2022. Human consumption of fish is rising, which suggests that fish is becoming more and more important in diets. Sustainable aquaculture growth, together with effective management and conservation of wild stocks, will be crucial to meeting future seafood demand while protecting aquatic ecosystems.

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BOTANICA OF BRINJAL

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1. Introduction

Brinjal is one of the few cultivated Solanaceous species originating in the Old World. It is known as brinjal in India, where it was domesticated long ago and, where the greatest diversity is found. It is a major vegetable crop in several countries like China, India, Egypt, Turkey, Iran, Indonesia, Japan, Italy Philippines, Bulgaria, France, the USA and several African countries. Brinjal cultivation in India is estimated to cover about 8.14% vegetable area with a contribution of 9.0 per cent to total vegetable production. The crop is largely grown in small plots or as inter crop both for cash and domestic consumption by farmers all over India. The major brinjal producing states are West Bengal, Orissa, Bihar, Gujarat, Maharashtra, Karnataka, Uttar Pradesh and Andhra Pradesh. It is not a tropical crop but can grow well in the low tropics. The best temperature for tuberization is 60-80 ^{0}F, Long day cultivars should be avoided in the tropics.

2. ORIGIN OF BRINJAL

Daunay (2008) has covered eggplant breeding quite extensively. According to his compilation, there are reports that *S. incannum*, a wild form of *S. melongena* is found in Southern India. *S. incannum* differentiated progressively, in South East Asia into a closely related species, the wild *S. melongena* which is still found growing in natural conditions in large areas from Southern and Eastern India to Southern China, Philippines and Indonesia and this has been described by former botanists as *S. cumingii*. In “Origin of cultivated plants” published in 1886, De Candolle, stated that the species S. melongena has been known in India from ancient times and regarded it as a native of Asia. According to N. I. Vavilov, the eggplant originated in the

Indo-Burma region. Under domestication process, this wild form gave rise to *S. ovigerum* (small round/oblong fruits with white, green or violet colour) which evolved progressively into advanced cultivars with large fruits. *S. insanum*, widespread in India is probably a form of *S. ovigerum* which reversed to the wild state with strong prickliness.

According to Zeven and Zhukovsky, 1975, it originated in India but spread eastward and by the 5th century B.C. was in China, which became a secondary centre of variation. Thus, it has been known for the last 1500 years in China. Arabic traders were responsible for subsequent movement to Africa and Spain. Brinjal cultivation in the Mediterranean region is relatively recent. Portuguese colonies took it to Brazil. It is now widely cultivated for its fruits in the tropical, subtropical and warm temperate zones, especially in Southern Europe and the Southern United States. Sampson, 1936 suggested the African origin of this crop, but there is no evidence that S. melongena is native there though there are spiny African brinjal plants.

3. TAXONOMY OF BRINJAL

Brinjal belongs to the family Solanaceae and is known under the botanical name *Solanum melongena* L. The family contains 75 genera and over 2000 species, out of which, about 150-200 are tuber bearing and belong to section Tuberarium. The majority of species (about 1800) are non tuber bearing. Cytological studies have indicated that basic chromosomal number 2n = 24 is same in almost all the varieties and species.

Rank	**Classification**
Kingdom	Plantae
Subkingdom	Tracheobionta
Division	Magnoliophyta
Class	Magnoliopsida
Order	Solanales
Family	Solanaceae (Nightshade family)
Genus	*Solanum*
Species	*Solanum melongena* L.

4. PLANT MORPHOLOGY

Brinjal or eggplant is a delicate herbaceous annual with erect or semi spreading habits.

It is a perennial plant but cultivated as annual. It develops into bushy plants with large, fuzzy leaves that grow to a height of about 60 to 120 cm. The plant is erect, compact, and well branched. It has tap root with a mass of fine fibrous adventitious root or lignified root system. The leaves are large, simple, lobed and alternate on the stems.

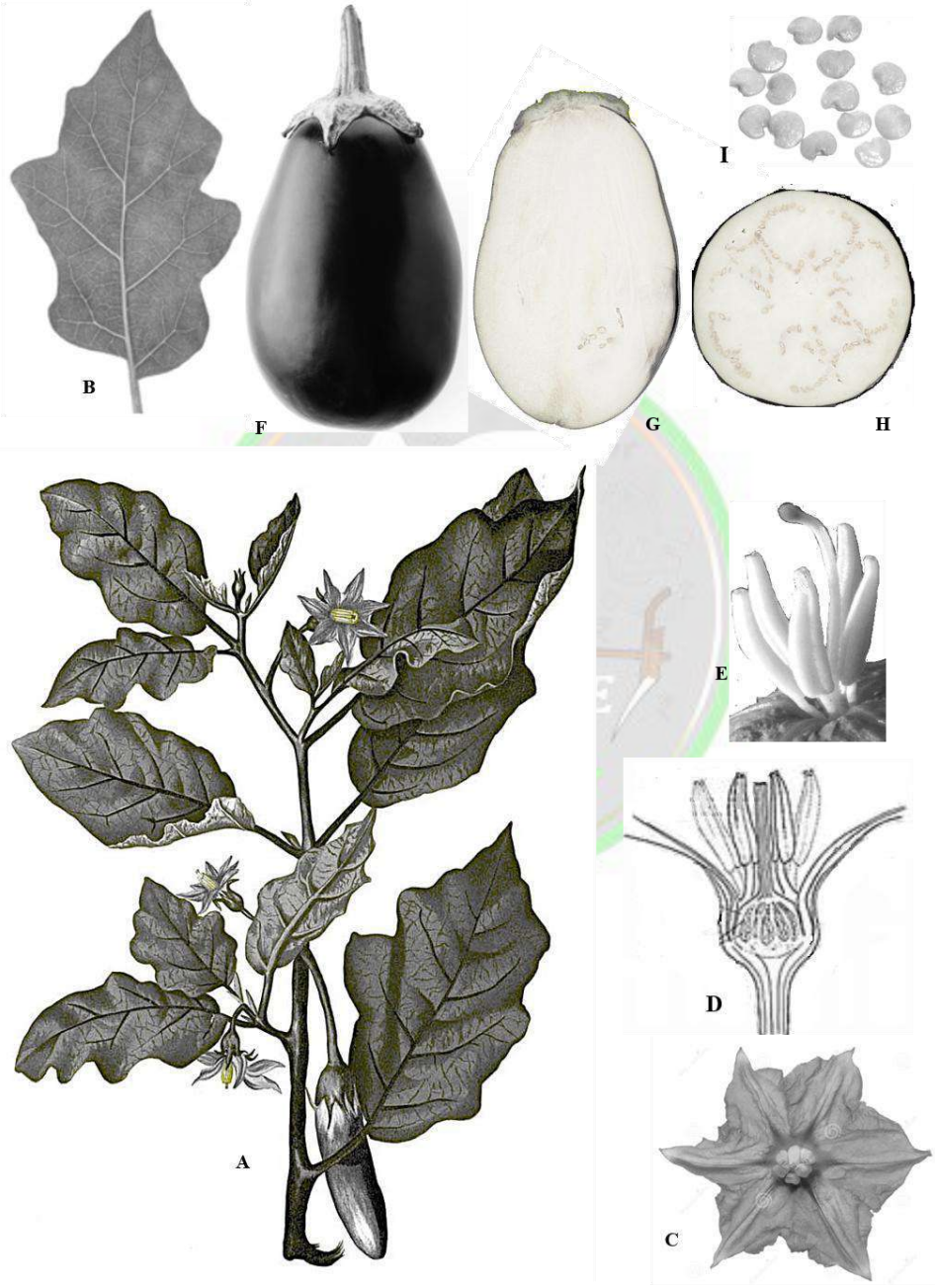


Fig. 1. Botanical illustration of Brinjal or Eggplant (*Solanum mrlongena* L.) A. Flowering and fruiting branch, B. Single leaf, C. Single flower in top view, D. Flower in longitudinal section, E. Androecium and Gynoecium, F. Fruit, G. Fruit in Longitudinal section, H. Fruit in cross section, I. Seeds

The stems, leaves, and calyx of some cultivars are spined Stem is erect, herbaceous that becomes woody latter; sometimes spiny. Leaves simple leaf with large coarsely lobes; 10 to 20 cm long and 5 to 10 cm broad. The leaf pattern is mostly opposite, large, single lobed and the underside of the most cultivars is covered with dense wool-like hairs. The leaves may be with or without spines at the midrib portions. The leaf blade and tip angle is very acute to very obtuse. Inflorescence is often solitary cyme, but sometimes it constitutes a cluster of 2-5 flowers. Solitary or clustering nature of inflorescence is a varietal character. Flower is complete, actinomorphic and hermaphrodite. Calyx is five lobed, gamosepalous and persistent. It forms a cup-like structure at the base. Corolla is five lobed gamopetalous with margins of lobes incurved. There are five stamens which are free and inserted at the throat of corolla. Anthers are cone-shaped, free and with apical dehiscence.

Ovary is hypogynous, bicarpellary, syncarpous and with basal placentation. The fruit is pendent and is fleshy berry borne singly or in clusters. The shape of fruit varies from ovoid, oblong, obovoid, or long cylindrical. The colour of the mature fruit varies from monocoloured purple, purple black, yellowish, white, green and variegated types of purple with white stripes, green with light green/white stripes or even combination of three colours. The seeds are borne on the fleshy placenta and the placentae with the seeds completely fill the locular cavity. The number of seeds per fruit varies from few (50) to many. The seed colour is white, light yellow, brownish yellow, brown to black brown for different varieties.

5. FLORAL BIOLOGY OF BRINJAL

Brinjal exhibits heterostyly, which encourages cross-pollination through variation in style and anther position. Four types of flowers have been reported depending upon the length of style. **These are:**

a**. Long styled with large ovary**

b. Medium styled with medium size ovary

c. Pseudo-styled with rudimentary ovary and

d. True short styled with very rudimentary ovary

In long-styled flowers, the stigma is positioned well above the anther cone, favoring cross-pollination. In medium-styled flowers, the stigma is at the same level as the anther cone and thus more suited for self-pollination. Short-styled flowers have the stigma located below the anther cone and are often sterile or exhibit poor seed set. The distribution of these morphs varies

by cultivar and environment, influencing the degree of natural outcrossing. Fruit setting in long styled flowers normally, varies from 70 to 85% and that in medium styled flowers from 12 to 55 per cent The non-fruit setting flowers consist of short styled flowers in which androecium is fertile but stigma is smaller with underdeveloped papillae.

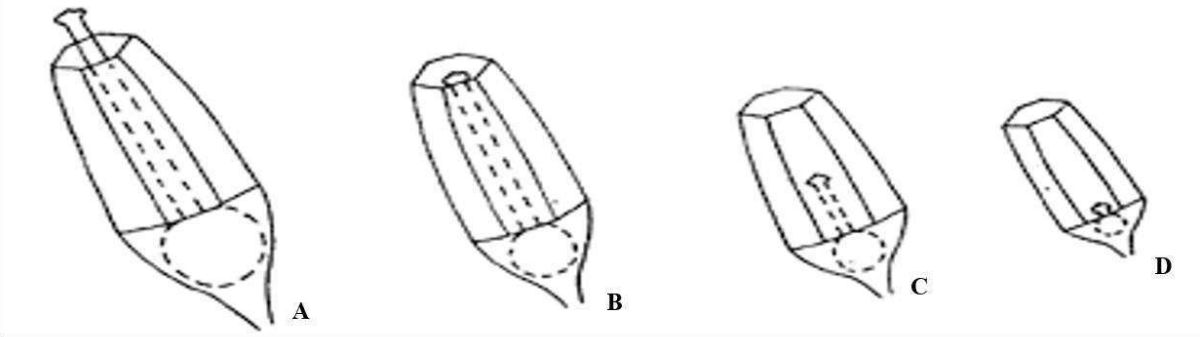


Fig. 2. Four different types of heterostyly in Brinjal. A. Long styled with large ovary, B. Medium styled with medium ovary, C. Pseudo-styled with rudimentary ovary, and D. True styled with very rudimentary ovary

Pollination

Eggplant is an often-cross pollinated crop. Basically, it is self-pollinated but the extent of cross-pollination has been reported as high as 29% and hence, it is classified as often cross-pollinated or facultative cross-pollinator. The cone-like formation of anthers favours self-pollination; but since the stigma ultimately projects beyond the anthers, there is an ample opportunity for crosspollination. The rates of natural cross-pollination may vary depending on genotype, location and insect activity. Out-crossing takes place with the help of insects.

Anthesis

Flowers generally emerge 40-45 days after transplanting. Anthesis occurs at about 6-8 a.m. in August-September and usually between 9.30 to 11.15 a.m. during winter (December-January). Stigma receptivity is highest during anthesis, i.e. flower opening. Anthers usually dehisce 15 to 20 minutes after the flowers have opened. The receptivity of the stigma can be observed from its plump and shiny appearance which gradually becomes brown with the loss of receptivity. The period of effective receptivity ranges from a day prior to flower opening until about four days after opening. Pollen usually remains viable for a day during summer and 2-3 days in winter under field conditions.

6. SELFING AND CROSSING TECHNIQUES

Selfing: Select a panicle before anthesis, cover it with a paper cover for 10 days or till anthesis is over in all the spikelet.



Fig. 3. Emasculation and crossing in Brinjal. A. Selection flower bud for emasculation. B. Cut opening of flower by forceps, C. Opening of corolla, D. Removal of anthers, E. Emasculated flower, F. Covering the emasculated flower with red paper cover, G. Dusting the stigma with anthers of male flower and H. Covering the pollinated flower with white paper bag

Emasculation and crossing: For emasculation, a healthy long or medium styled, well-developed bud from the central portion of the plant is selected. The bud is opened gently with the help of fine pointed forceps one or two days before the opening of the bud and all the five anthers are carefully removed. For pollination, freshly dehiscing anthers are picked up and are slit vertically with fine needle to get sufficient pollen at the tip of the needle.

Pollen are applied on the stigma of the emasculated flower bud. It is labelled and covered with small pollination bag. Emasculation is done in afternoons followed by pollination in next morning. Emasculated buds are covered with pollination paper bags and bags are secured with U clip. The pollinated buds are covered with the same bag but now bags are stappled.

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EXPLOITING UNDERUTILIZED VEGETABLES

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1. Introduction

India is one of the most populous countries in the world, making up about one-fifth of the global population, with over 70% of households relying on farming for their livelihood. While the annual population growth rate is roughly 1.8%, food demand is expected to increase by at least 3% per year in the near future. As a result, food production must grow at an annual rate of about 3.5% to meet this demand. Achieving this will require a combination of advanced technologies, strong institutional support, favourable policies, and other enabling factors to enhance agricultural and horticultural productivity, governmental policies and awakening among the farmers are necessary to tackle the various issues. Moreover, malnutrition is a widespread issue in India, which could be significantly alleviated through greater availability of vegetables.

Vegetables are essential to a balanced human diet and play a vital role in ensuring global nutritional security, as they provide essential nutrients, vitamins and minerals. However, this remarkable production was contributed by only few major vegetables. Although, diverse agroclimatic conditions of India permit to grow more than 60 cultivated and about 30 lesser-known vegetable crops, not much attention has been given on underutilized vegetables known. Underutilized crops/plant species as “those species with underutilized potential for contributing to food security, health (nutritional/medicinal), income generation and environmental services”. Currently, only a quarter of vegetables are grown as major crops, while the rest are considered minor or underutilized, or wild vegetables. These lesser-known vegetables are often found only in certain regions and are mostly grown in rural areas.

2. POTENTIAL ROLE OF UNDERUTILIZED VEGETABLES

Many neglected and underutilized vegetables are highly nutritious and well-suited for low-input agriculture. The loss of these species—whether wild, cultivated, or managed—can have serious impacts on food security and the well-being of vulnerable populations. Increasing their use can lead to better nutrition, as many of these vegetables contain higher levels of vitamin C and pro-vitamin A compared to commonly grown commercial crops. By focusing on underutilized vegetables, we can support a more diverse and nutritious diet, helping to combat micronutrient deficiencies, or "hidden hunger," especially among rural communities and vulnerable groups in developing countries.

3. INCREASED INCOME FOR RURAL POOR

The rising demand for diverse and novel foods from consumers in both developed and developing countries is creating new market opportunities for neglected and underutilized vegetables. These emerging markets can provide additional income for farmers in disadvantaged regions where these crops have distinct advantages over major staples or commercial crops. Moreover, modern technologies that enhance crop processing and extend shelf-life offer new avenues for developing innovative products. This not only helps in promoting these vegetables but also opens up opportunities for their commercialization ultimately benefiting farmers with higher incomes.

4. ECOSYSTEM STABILITY

Climate change and the degradation of land and water resources have increased interest in crops and species that thrive in challenging environments, such as desert margins, poor soils, degraded landscapes, or areas prone to drought. Underutilized vegetables, being naturally adapted to harsh conditions, they contribute to maintain eco-stability by supporting agricultural diversity and resilience in the face of environmental stress.

5. CULTURAL BIODIVERSITY

Plants have long been an integral part of local cultures and traditions. Many neglected and underutilized vegetables help preserve cultural diversity by playing a significant role in food habits, health practices, religious rituals and social interactions. These vegetables contribute to maintaining cultural identities and traditions particularly in rural and indigenous communities where they form an essential part of local heritage and cuisine.

6. CONSTRAINTS FOR THE DEVELOPMENT OF UNDERUTILIZED VEGETABLE CROPS

i. Lack of awareness among the farming community about the nutritional and medicinal value of underutilized Vegetable crops.

ii. Lack of researches in underutilized vegetables

iii. Lack of desirable seeds and planting material.

iv. Limited application of advance on-farm agro-techniques.

v. Lack of application of innovative and novel technologies such as biotechnology, plasticulture for enhancement of productivity.

vi. Lack of about post-harvest management practices.

vii. Limited and inadequate marketing supports and infrastructure facilities for transportation, storage and processing.

viii. Poor recognition of these crops in horticulture promotion programmes.

ix. Improper institutional arrangements and limited role played by financial Institutions in setting up of agro-industrial and horticulture based industrial Units.

7. DEVELOPMENT STRATEGIES FOR UNDERUTILIZED VEGETABLE CROPS

Underutilized vegetable crops have a potential in the improvement of food security. Following measure can be taken into consideration to improve production of underutilized vegetable crops:

i. Afforestation and forest rejuvenation could be done to augment and enrich the biodiversity of underutilized vegetable crops.

ii. Domestication of potential wild species through household cultivation should be encouraged to avoid overexploitation of natural resources. Support is needed for the multiplication and distribution of planting materials, as well as market access for perishable vegetables.

iii. More research and development is necessary to improve the production of underutilized vegetable crops because they are nutritionally rich and suited to low-input farming that helps to sustain human nutrition and food safety.

iv. Underutilized vegetable crops are cultivated mainly by different ethnic communities under traditional farming systems. An increase in focus is required for the documentation of indigenous knowledge, such as ethnobotany. This stress will help tap value add-ons as a

multipurpose of indigenous diversity.

v. n particular, strategies must be developed at national and regional levels to build and deliver promising selections/varieties, overcoming production restrictions on good seeds or planting materials, in vitro and tissue-cultured materials, *etc*. This would boost production, meet local needs, foster domestic markets, and improve smallholder farmers' incomes.

vi. There should be systematic local special planning after agroclimatic appropriateness of the area.

vii. The rapid expansion of infrastructure with a focus on market development, transport and communication must be achieved.

viii. Export-oriented production programs, border trade with high-value products such as off-season vegetables, should be emphasized in particular.

ix. These crops' yields and quality are poor that interfere with productivity. The criteria such as high productivity, demand on the market, the absence of severe insect and disease insects, easier management after harvest, a high nutrient value, the availability of production technologies, etc. for the commercial exploitation of these crops need to be developed.

x. The organization of micro and macro awareness camps/campaigns, exhibitions, multimedia applications such as radio, TV, the press and other imprints helps the farming community to recognize the nutritional significance of underutilized vegetable crops. The organization should also emphasize the development of processing units in this area for appropriate exploitation and improved economic returns from underutilized vegetable plants. It would also employ the rural people.

xi. Genetic erosion is a significant problem and will extinguish many land areas unless they are soon preserved. Commercial cultivation of nontraditional vegetable crops feasible by efficient production technologies and postharvest management is also required. The availability of nontraditional vegetable crops will help overcome the malnutrition of rural people.

8. FUTURISTIC CHALLENGES

To feed the world's estimated 9 billion people by 2050, agriculture is increasingly pressurized on limited agricultural resources to produce more food, feed and bio-fuel. To cope with a projected 40% rise in global population by 2050, agricultural production will need to

expand by 70%. Approximately 90% of this increase is expected to be achieved through increase in crop yield and intensity, the rest on the land that is not currently used for agriculture. Underutilized vegetables are important at the local or regional level, but they are seldom recognized or valued nationally or internationally. Public awareness can help boost the popularity of these crops. Underutilized vegetables offer many benefits they are easy to grow, hardy and can thrive in poor soil and challenging climate conditions. Certain underutilized legumes, such as adzuki bean, African yam bean, horse gram, and winged bean can also improve soil health by increasing fertility. Most of these vegetables are naturally resistant to pests and diseases, reducing the need for pesticides and fungicides. They require minimal inputs and can adapt well to harsh conditions, making them suitable for marginal lands.

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CLASSIFICATION OF CULTIVATED BRINJAL

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1. INTRODUCTION

Brinjal in tender stage isa popular vegetable crop all over India. It is cultivated in the tropics and it is a speciality of Indian vegetable crop. Brinjal or eggplant *(Solanum melongena* L.) is an important solanaceous crop of sub-tropics and tropics. The name brinjal is popular in Indian subcontinents and is derived from Arabic and Sanskrit whereas the name eggplant has been derived from the shape of the fruit of some varieties, which are white and resemble in shape to chicken eggs. It is also called *Aubergine* (French word) in Europe. It finds place in many of the Indian curries as a most common vegetable in Indian cooking. Brinjal is proved to have originated in India with many diversified forms and China is the secondary centre of diversity. In the south East Asian Countries, the crop finds a place in native medicine besides its versatility in consumption as vegetable as it is simple and delicious. In addition to bringing in a unique texture and mild flavour to recipes brinjal brings a load of health benefits. It is a nutrient dense food as it contains considerable amount of Vit.C, Vit. K folate, Manganese and Potassium. It is high in fibre and polyphenols, solasodine which helps in fighting against a type of cancer. Rich anthocyanin content also contributes to this quality.

A. Based on botanical species

Brinjal, also known as eggplant or aubergine, belongs to the Solanaceae family and the Solanum genus. There are various species and cultivars of brinjal, with different shapes, sizes and colours of fruit. Here are a few common species within the Solanum genus that are often cultivated as brinjals:

a. *Solanum melongena*- Common eggplant*:* This is the most common species of brinjal that is widely cultivated for its edible fruit. It includes various cultivars with different shapes, sizes and colours of fruit, ranging from small and round to long and elongated. Different regions around the world have their own preferred cultivars of *Solanum melongena.* This cultivated species had three varieties *viz.*,

i. *Solanum melongena* var. *esculentum* - common eggplant: Produces oval (egg-shaped) or round fruits

ii. *Solanum melongena* var. *serpentium* - snake eggplant: Produces long slender fruits

iii. *Solanum melongena* var. *depressum* - dwarf eggplant: Produces smaller sized fruits that usually annuals

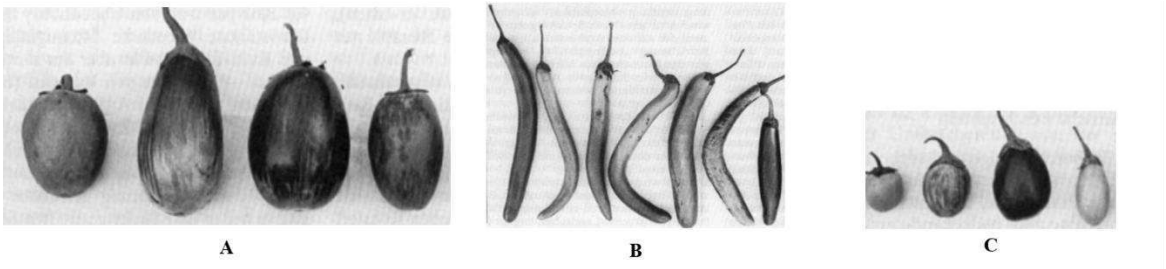


Fig. 1. Three different varieties *Solanum melongena* species. A. var. *esculenta*, B. var. *serpentium* and C. var. *depressum*

b. *Solanum incanum*- Wild Eggplant: This species is less commonly cultivated for its fruit. It produces smaller, round and often spiny fruits. It is not as widely consumed as the cultivated varieties and is sometimes considered to have potential medicinal uses.

c. *Solanum aethiopicum*- Scarlet or Garden Eggplant: They are typically smaller and rounder than the common eggplant and come in various colors, including shades of white, green and red. These varieties are popular in certain African regions.

d. *Solanum torvum*-Bitter apple or Pea Eggplant: This species produces small, round and green fruits that are often used in culinary dishes in some tropical regions. They have a bitter taste and are used in various traditional recipes.

e. *Solanum macrocarpum*-Gilo or Jilo Eggplant: Similar to *Solanum torvum,* it produces small, green and bitter fruits that are consumed in various dishes in some tropical countries.

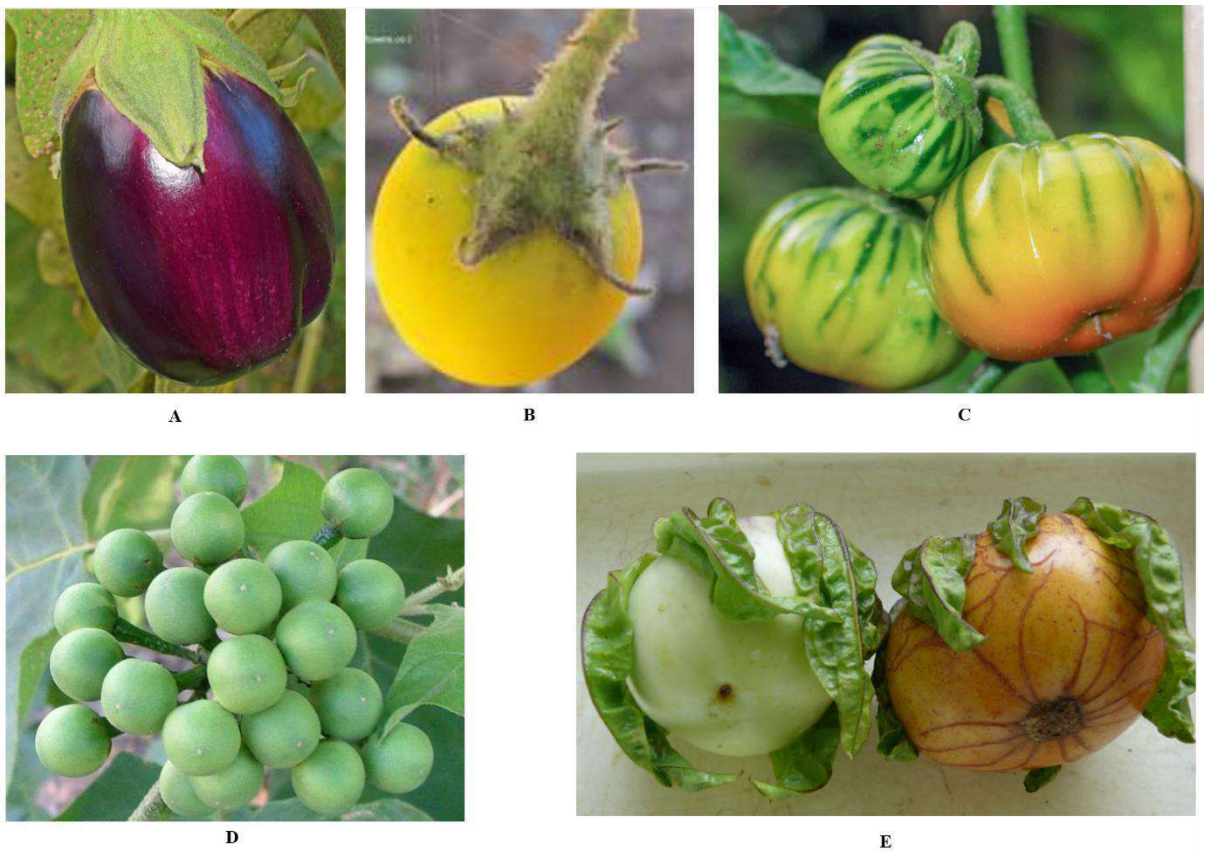


Fig. 2. Different cultivated species of Brinjal or Eggplant. : A. *Solanum melongena* - Common Eggplant, B. *Solanum incannum* - Wild Eggplant, C. *Solanum aethiopicum* – Scarlet Eggplant or Garden Eggplant, D. *Solanum torvum* – Bitter Apple or Pea Eggplant and E. *Solanum macrocarpum* – Gilo or Jilo Eggplant.

B. Based on Geographic origin

a. American Eggplant: These are large, round to slightly oval, with deep purple and glossy skin, meaty texture with mild flavor, and slightly bitter in taste.

b. Chinese Eggplant: These are longer and thinner than Japanese eggplants, with a delicate lavender colour that sets them apart. They have a sweet, tender flesh with fewer seeds, making them less bitter and easy to cook with.

c. Indian Eggplant: These are small, round to oval, with dark purple skin and green calyx. They are slightly crunchy when young but become tender as they mature.

d. Italian Eggplant: These are globose, teardrop shaped and deep purple in colour. It is sweeter and more tender, with a delicate flesh that cooks quickly with good flavors.

e. Japanese Eggplant: These are long, slender, and dark purple, with a thinner skin and fewer seeds than other varieties. They are less bitter and develop a creamy, smooth texture when cooked.

f. Mediterranean or Santorini Eggplant: These are long and slender, with lighter purple skin that is sometimes variegated. They have a creamy texture and a mild, sweet taste, especially when cooked.



Fig. 3. Classification of Eggplants based on Geographic origin. A. American Eggplant, B. Chinese Eggplant, C. Indian Eggplant, D. Italian Eggplant, E. Japanese Eggplant, F. Mediterranean or Santorini Eggplant, G. Sicilian Eggplant, H. Tai Eggplant and I. Turkish Orange Eggplant

g. Sicilian Eggplant: These are medium-sized, elongated oval in shape with eye-catching purple and white stripes. They have sweet flesh and thin skin, with a mild flavour that's never overly bitter.

h. Tai Eggplant: These are small and round, often green, purple or white. They have a crisp texture when raw but can be slightly bitter, especially if the seeds are not removed.

i. Turkish Orange Eggplant: These are small to medium in size, round to slightly oval, with bright orange skin when fully mature. They are sweet with a dense, creamy texture when cooked.

C. Based on shape of the fruit

a. Oval or egg shaped

b. Round shaped

c. Globose shaped

d. Long or Elongated shape

e. Slim and slightly pendulous shape

f. Large or giant shaped

g. Miniature or Baigan shaped

D. Based on colour of the fruit

a. Light purple coloured fruit

b. Dark purple coloured fruit

c. Black or deep purple coloured fruit

d. Green coloured fruit

e. Apple green coloured

f. White coloured fruit

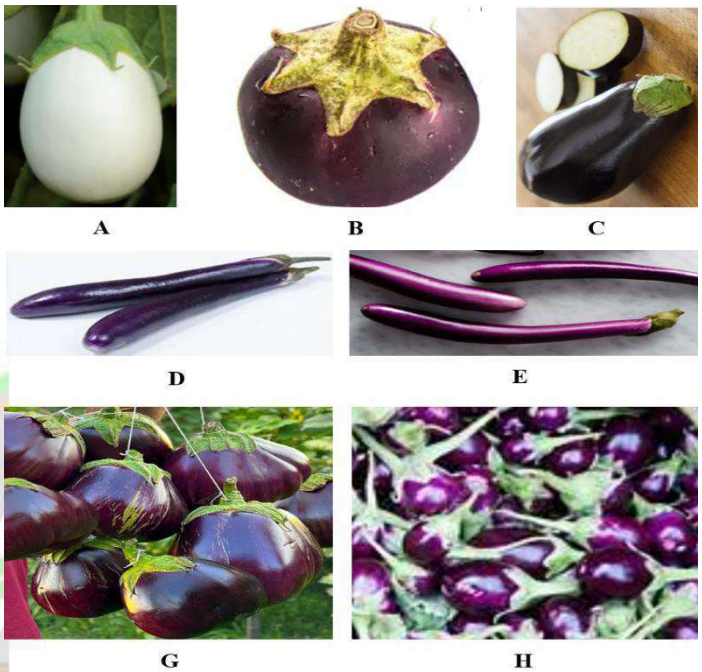


Fig. 4. Classification of Eggplants based on Shape of fruit. A. Oval or Egg shaped, B. Round shaped, C. Globose shaped, D. Long or elongated shaped, E. Narrow and slightly pendulous shaped, F. Large or Giant shaped and G. Miniature or Baigan shaped

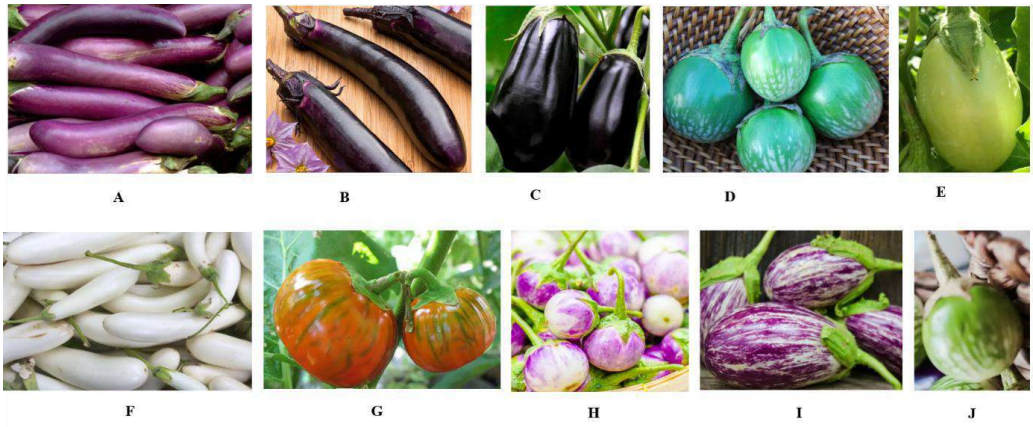


Fig. 5. Different types of Tomatoes based on fruit skin colour. A. Light purple, B. Dark purple, C. Black or deep purple, D. Green, E. *Apple* green, F. White, G. Orange, H. Bicolour with colour gradient, I. Bicoloured –purple with white stripes and J. Bicoloured-green with white stripes

g. Orange/red coloured fruit

h. Bicoloured fruits with colour gradient

i. Bicoloured-purple with white stripes

j. Bicoloured- green with white stripes

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COMMERCIAL APPLICATION OF BIOACTIVE COMPOUNDS FROM MARINE ALGAE

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Introduction

Marine group of algae has large divisions and contains huge no of known and unknown genus. Each algae has its own advantage *viz*., pharmaceutical, antifungal, antibacterial, antiviral, human and animal feed. Microalgae are a huge group of photoautotrophic microorganisms, including species from different phyla such as Cyanophyta (bluegreen algae, cyanoprokaryotes, cyanobacteria), Chlorophyta (green algae), Rhodophyta (red algae), Cryptophyta, Haptophyta, Pyrrophyta, Streptophyta, Heterokontophyta. Microalgae displays a significant ecological plasticity, by the ability to adapt to changing extreme environmental conditions such as temperature, light, pH, salinity and moisture, which describes their worldwide distribution. Microalgae are a diverse group of photosynthetic microorganisms that convert carbon dioxide into valuable compounds including biologically active compounds such as biofuels, foods, feed and pharmaceuticals.



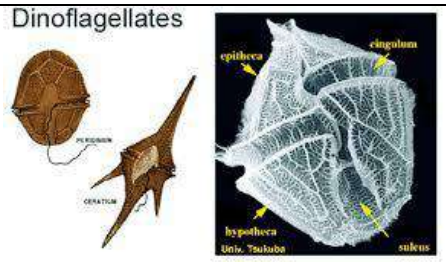
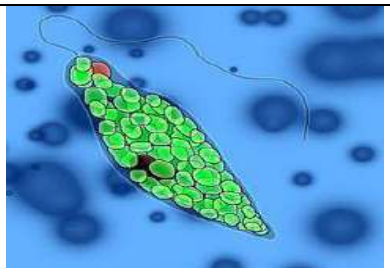
Rhodophyta



Chlorophyta



Phaeophya

 Bacillariophyta	 Dinoflagellata	 Euglenophyta

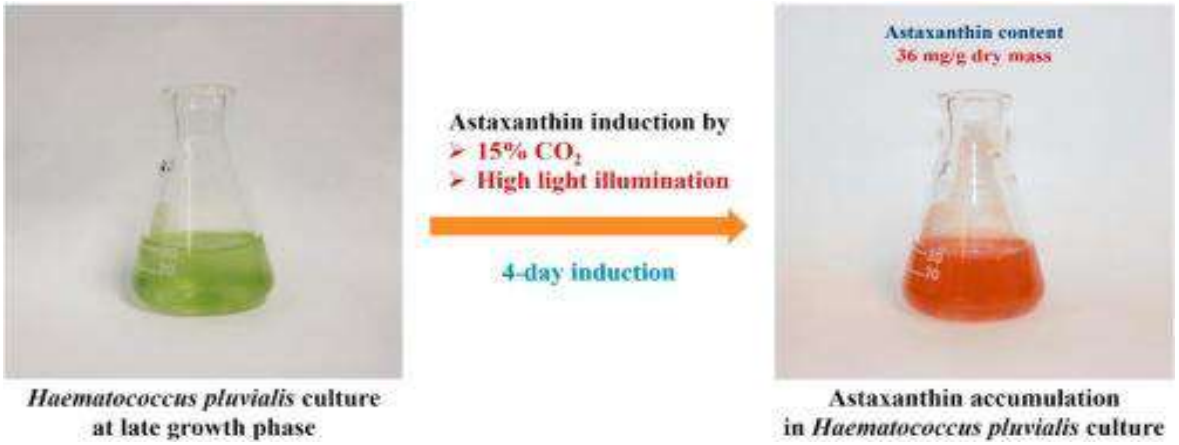
Algae are considered as a sustainable source of biodiesel which have the ability to synthesize and accumulate significant quantities of lipids as they are sunlight driven oil factories (Chisti, 2007). Earlier researches have shown that, compared to oil crops microalgae have 20–40 times more productivity whereas some of them can accumulate up to 80% of dry lipid biomass weight. Hence, microalgae have greater potential to be a major source for renewable energy production in terms of biofuel. Many algal strains are able to accumulate lipids when they are subjected to stress these strains have the potential to grow in mass culture (Rodolfi *et al*., 2009).

Key words

Carotenoids, proteins and vitamins, Biofuel, carragenan, agar agar, proteins and enzymes, sterols

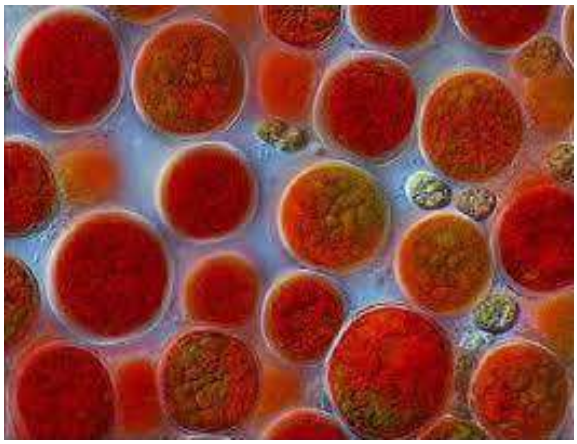
Carotenoids

In photosynthetic organisms, including algae and plants, during the light phase of photosynthesis carotenoids act as accessory pigments in light harvesting and are also able to photoprotect the photosynthetic machinery from surplus light by scavenging reactive oxygen species with singlet oxygen and other free radicals. Almost all carotenoids are involved in quenching singlet oxygen and trapping peroxyl radicals.



Haematococcus pluvialis culture at late growth phase

Astaxanthin accumulation in *Haematococcus pluvialis* culture



Astaxanthin

The bioactivities of astaxanthin including UV-light protection and anti-inflammatory activity have been reported to effect human health conditions because of their stronger antioxidant activity (Guerin *et al*., 2003). The wide use of carotenoids as colorants has been found in natural foods including egg yolk, chicken, and fish. More than 750 carotenoids have been identified; still, only a few have been used commercially available such as astaxanthin, canthaxanthin, lutein, lycopene and β carotene are the most common.

As many other antioxidant compounds are present in algal cells, the main advantages of the using microalgae as a carrier of carotenoids is their positive impact on human health. Astaxanthin is synthesized by Chlorophyceae family namely *Chlorella*, *Chlamydomonas*, *Dunaliella*, and *Haematococcus* spp. Though, a few green microalgae such as *Haematococcus* sp. can accumulate xanthophylls in oil bodies outside the plastids in the cytoplasm (Lemoine and Schoefs, 2010). Formation of xanthophylls in algal cells can be influenced by nitrogen-limitation, temperature, oxidation, light intensity, metal ions and salts. β-carotene β-Carotene is a provitamin A carotenoid and therefore is able to be converted into retinol. Vitamin A has been revealed to reduce the risk of macular degeneration.

Proposed mechanisms of action for β-carotene in cancer prevention include inhibiting the growth of cancer, induction of differentiation by modulation of cell cycle regulatory proteins, modifications in insulin like growth factor-1, hindrance of oxidative DNA damage, and possible augmentation of carcinogen-metabolizing enzymes. Explicitly, β-carotene has been shown to condense cell growth and induce apoptosis in a variety of cancer cell lines, may be through caveolin-1 expression. Lycopene referred as a non-provitamin A carotenoid, lycopene possesses

a variety of biological activities. These include antioxidant activity via singlet oxygen quenching and peroxyl radical scavenging, cancer prevention through inhibition of cancer growth, and induction of differentiation by modulation of cell cycle regulatory proteins. Additional reported properties of lycopene includes alterations in insulin like growth factor-1 or vascular endothet al growth factor levels, preventing the oxidative DNA damage, and possible development of carcinogen-metabolizing enzymes, reduced risk for some types of cancers, and some cardiovascular events.

Astaxanthin

Astaxanthin, another non-provitamin A carotenoid, has recently gained attention due to its antioxidant activity and is also traditionally used to pigment the flesh of salmon and trout through dietary supplementation. Astaxanthin scavenges free radicals, provides protection against cancer and an implicated role in inflammatory processes, ocular health, and diabetes. Latest studies on astaxanthin have shown its effectiveness against colon cancer cell proliferation, possibly through inhibition of the cell growth and increased apoptosis of human colon cancer cells.

β-Carotene

The value of the world wide carotenoid market was found to be nearly $1.2 billion in 2010 and is planned to reach over $1.4 billion by 2018. β-Carotene has the leading share of the market. Valued at $250 million in 2007, this part is expected to be worth $309 million by 2018. Red algae and cyanobacteria and show valuable fluorescent properties and accessory pigments. Some of the common phycobiliproteins include phycoerythrin (PE), phycocyanin (PC), and allophycocyanin (APC). These pigments are hetero-oligomers consisting of a grouping of subunits within producing cells (Cyanophyta) or chloroplasts (Rhodophyta) that are organized into complexes called “phycobilisomes”. Phycobiliproteins have been used as natural dyes; moreover, they are extensively being used as nutraceuticals or in other biotechnological applications.

Secondary Metabolites

The ecological function of secondary metabolites in microalgae or cyanobacteria is not well understood; however, several possible roles have been intended with recent researches carried out. For example, the brevetoxins responsible for neurotoxic shellfish poisoning (NSP) are generated by marine dinoflagellates which are considered to have an ecological role as a

feeding deterrent. Swimmer's itch caused by the molecule Lyngbyatoxin is thought to have an ecological role as a defense against grazing. Some secondary metabolites are said to play roles in sexual communication or symbiotic signals (Maschek and Baker, 2009). Secondary metabolites can be represented in all classes of molecules including isoprenoids, polyketides, peptides, and macromolecules such as nucleic acids, carbohydrates, proteins, and lipids. This level of chemical diversity associates with the huge number of environments inhabited by algae and cyanobacteria. Secondary metabolites signify unique adaptations to these diverse environments.

Filamentous cyanobacteria growing on a shallow tropical reef, and would expect unique chemical structures with exclusive biological properties to be produced. With more richness in chemical and biological diversity, the algae and cyanobacteria are gaining more value as commercial products. For example, the unique structures produced by algal species possess rich value as components in human food, cosmetics, and various pharmaceuticals.

Polyunsaturated fatty acids (PUFA)

It is very well known that, some of the ω-3 and ω-6 fatty acids are required for humans needs but cannot synthesize this is the reason why some PUFA are called essential fatty acids. The illness, smoking or alcohol intake can cause inability to synthesize some fatty acids. Essential fatty acids, particularly ω-3 and ω-6, are important for the reliability of tissues where they are incorporated. Linoleic acid is used as formulations for treatment of skin hyperplasias. Arachidonic acid can be obtained from linoleic acid. DHA and EPA showed an ability to reduce problems associated to cardiovascular strokes and arthritis, and also to lower hypertension. Furthermore, DHA and EPA play essential roles in lowering lipid content by reducing triglycerides, augmenting HDL levels and as anti-inflammatory agents. Although it is poorly synthesized, the breast milk contains high amount thus, newborns, fed with artificial milk, should be given ω-3 DHA as an additive.

Proteins and enzymes

Proteins are biopolymers of amino acids, are essential for human beings, as they cannot be obtained without feeding, because of some deficiency in synthesizing them in enough amount. In addition, besides nutritional benefits some proteins, smaller peptides and amino acids have functions that contribute to a few health benefits. As microalgal species *Arthrospira* and *Chlorella* are rich in protein and amino acid they may be used as nutraceuticals or be included in functional foods to prevent tissue damage and diseases.

Vitamins

Marennine, a blue pigment responsible for greening of oysters, diatom *Haslea* (Navicula) *ostrearia* is particularly rich in vitamin E. Another microalgae named *Porphyridium cruentum* is rich in vitamins C, E (tocopherols) and provitamin A (β-carotene). In addition, *Dunali ellasalina* besides producing β-carotene (provitamin A), it also produces thiamine, pyridoxine, riboflavin, nicotinic acid, biotin and tocopherol.

Biofuel

The natural source of renewable energy such as microalgae, can be formed from natural resources such as sunlight, water and O_2/CO_2.The production of biodiesel and bioethanol from microalgae that have potential to replace fossil fuels being in an economic sustainable way and leading reduction of GHG emissions. Microalgae are considered to be an outstanding candidate for biomass production (nearly 77% of dry cell mass), photosynthesis process for lipid fabrication, and production of biofuel.

Biocontrol activity of algae

Approximately 30,000 freshwater and marine algal species have been studied and identified (Mata *et al*., 2010). They are able to produce a wide range of bioactive substances with antibacterial, antiviral, antifungal, immunostimulant and antiplasmodial activities (Borowitzka, 1995; Angulo-Preckler *et al*., 2015). Most of the isolated bioactive substances belong to groups of polyketides, amides, alkaloids, peptides, and fatty acids (Ghasemi *et al*., 2007; Feng *et al*., 2013). Research to identify bioactive compounds produced by microalgae has recently received considerable attention as a new source of novel antifouling substances. Marine dinoflagellates could produce diverse bioactive compounds, exemplified by okadaic acid, ciguatoxin, and maitotoxin (Yasumoto and Murata, 1993).

The genus Amphidinium was also a rich source of bioactive compounds which showed certain biological activity, such as anti-fungal, anti-tumor, and hemolytic properties (Gopal *et al*., 1997). For marine dinoflagellate *Amphidiniumcarterae*, the toxic and red-tide microalgae, numerous efforts had been made to isolate pharmaceuticals and other biologically active compounds. However, the reports about its antifouling potential have not been found by now. So the present study was undertaken to explore the antifouling potential of *Amphidiniumcarterae carterae* at low temperature of 35. Secondly, the concentrate was purified by a C18 solid-phase extraction (SPE) column and eluted with 10 mL MeOH. Then, the methanol eluent was dried by

nitrogen blowing, solubilized in 20 mLCHCl$_3$, and partitioned with NaOH (0.1 mol L^{-1}) three times. The aqueous partition is equivalent to a saponification, as described in lipidic extraction procedures, and the non polar compounds were discarded (Bursali *et al*., 2006). Thirdly, the aqueous phases were combined, acidized by H_2SO_4 (1.0 mol L^{-1}) and extracted three times withCHCl$_3$/MeOH (2:1). Finally, the organic phases were combined, concentrated under vacuum at the low temperature of 30, and dried by nitrogen blowing (the organic extract C). The organic extract C contained lipophilic compounds that were moderately polar and saponifiable.

Fatty Acids

Fatty acid with two or more methylene interrupted double bonds is good for normal cell function, and now has been entered in different areas like biomedical and nutraceutical. As a result of understanding the biological use of fatty acid it is most commonly used in western society against obesity and cardiovascular problem. Moreover PUFAs play an important role in cellular and tissue metabolism, PUFAs is stand for polyunsaturated fatty acids, it also play an important role in the regulation of membrane fluidity, oxygen and electron transport, as well as thermal adaptation (Funk, 2011). In addition, people show more attention towards healthy food in their busy life style (Napier, 1999).

In particular, people show increasing interest towards PUFAs family, namely EPA (5, 8, 11, 14, 17- eicosapentaenoic acid). EPA is a fatty acid of 20 carbon chain with having five double bonds located at the carboxy terminus or with the last double bond located at the third carbon from methyl terminus. EPA is normally esterified to form a complex lipid molecule inside the cell and play an important role in higher plants and animals as a precursor of a group of eicosanoids, hormone like substance such as prostaglandins, thromboxanes are crucial in regulating developmental and regulating physiology. Fish oil is seems to be conventional source of EPA.

EPA is passed up by food chain *via* consumption by omnivores fish and then by carnivores fish and then finally by human (Wen and Chen, 2003). The biosynthesis of fatty acid occur in two steps, first step is the *de novo* synthesis of oleic acid from acetate followed by converting to linolenic acid and α-linolenic acid. The stepwise saturation and elongation form a ω-3 PUFA. Fish oil is a conventional source of EPA but fish do not synthesize EPA *de novo*, they derived this compound from the marine microorganisms they consumed, thus EPA passed through the food chain and ultimately reach to the human being. EPA from the marine fish oil is

refined for pharmaceuticals, this oil having a very complex fatty acid varying with chain length and unsaturation degrees (Gill and Valivety, 1997). EPA has been found in wide variety of marine algae class but only some of them have the potential to demonstrated industrial production, mainly due to the fact that majority of marine algae have low specific growth rates and low cell densities when grow in autotrophic condition (Wen and Chen, 2003).

Sterols

Some species of microalgae have been used for promoting growth of juveniles, especially oysters for their content in sterols. Cholesterol is rarely being found in phytoplankton species such as Chaetoceros and Skeletonema that were reported to produce up to 27.7 and 2.0 µg sterols/g dry weight cholesterol being the major sterol. Other microalgae, such as Thalassiosira and Pavlova also show high amounts of sterols. *Pavlova lutheri* contains other uncommon sterols such as brassicasterol, campesterol, stigmasterol and sitosterol apart from cholesterol. Its is well familiar that high levels of cholestrol and cholesterol lowering of plant sterols are of high risk for heart and coronary diseases.

Sterols are the major nutritional component found in seaweed, they are the most important chemical constituent of microalgae. Mainly sterols are present in plant, animal and fungi, with the most famous animal sterol known as “cholesterol”. Cholesterol is vital to cellular function and affects the fluidity of animal cell membrane. Cholesterol is a precursor to fat soluble vitamins and steroid hormones. Various species of seaweeds have different sterols, like green seaweeds contain 28 is of ucocholesterol, cholesterol, 24 methylene cholesterol and *β*-sitosterol while brown seaweeds contain fucosterol, cholesterol and brassicasterol. Red seaweeds contain sterols like desmosterol, cholesterol, sitosterol, fucosterol and chalinasterol (Sanchez *et al*., 2004). Brown seaweeds (*Laminaria* and *Undaria*) contain 83% - 97% of fucosterol in total sterol content (662 - 2320 µg/g dry weight) and desmosterol of red seaweeds (*Palmaria* and *Porphyra*) contain 87% - 93% of total sterol content (87 - 337 µg/g dry weight). However red seaweeds of *C. crispus* has cholesterol as major sterol. It is reported that plant sterol like *β*-sitosterol and fucosterol leads to the decrease in the concentration of cholesterol in the serum experimentation in animals and human (Whittaker *et al*., 2000).

Polysaccharide

Marine algae contain huge amount of polysaccharides mainly cell wall structure and also myco polysaccharides and storage polysaccharides (Kumar *et al*., 2008). Polysaccharides are the

polymer of simple chain monosaccharide or simple sugar that is linked together by glycosidic bond. They have many applications like they are use in food, beverages, stabilizers, emulsifiers, thickeners, feed. The green seaweed species contain high content of polysaccharide like *Ulva* contain 65% of dry weight. The other seaweeds species contain high amount polysaccharide are *Ascophyllum*, *Porphyra* and *Palmaria*. Mainly the seaweeds contain polysaccharide concentration in the range from 4% - 76%. According to the nutritional perspective, seaweeds are low lipid content and having high carbohydrate most of this is dietary fibers even though they are not taken up by the human body.

However dietary fibers are good for human bodye. The polysaccharide cell wall mainly consists of cellulose, hemicelluloses, and neutral polysaccharides. The content of cellulose and hemicellulose of seaweeds species of interest is 2% - 10% and 9% of dry weight. *Chlorophyceae* or green algae contain sulphated galactans, sulphuric acid polysaccharide whereas the *Pheophyceae* also known brown algae contain alginic acid, fucoidan or sulphated fucose, laminarian or *β*-1, 3 glucan. *Sargassan* and *Rhodophyceae*or red algae contain carrageenans, amylopectin like sugar also known as floridean starch, water soluble sulphated galactan, as well as porhyran as mucopolysaccharide that is present in the intracellular spaces (Kumar *et al*., 2008).

Agar

Agar is a mixture of polysaccharide mainly composed of agarose and agro pectin, which having structure and function properties as similar as carrageenan. Agar is the sulphated polysaccharides mainly extracted from Phaeophyceae, it is also extracted from red seaweeds such as *Gelidium* sp. and *Gracilaria sp*. The use of this compound is mainly in commercial and scientific areas because of its gelling emulsify and viscosity property. Agar is a generic name of seaweeds galactans containing *α* (1-4)-3, 6-anhydro-L-galactose and *β*9 (1-3)-D-galactose residues with having esterification of sulphatein small amount which is up to 6% (w/w) (Hemmingson, 1996). The low quality agar is used in food products like candies, fruit juice, frozen foods, bakery icing, meringues and desert gels. Agar also has an industrial application include paper coating, adhesives, textile printing dyeing, impressions, casting. The medium quality agar is used in biological culture media as the gel substrate. They are also important and used in the field of medical and pharmaceutical as a bulking agents, anticoagulant agent, laxatives, capsules and tablets. The high quality of agar or highly purified agar (agarose) is used

in intermolecular biology for separation techniques like electrophoresis, immune diffusion and gel chromatography. Agar-agar is used for cooking & as a food source in Japan. It is known for the manufacturing of capsules for industrial application & also used as medium for cell culture. Agar structural and functional property is same as carrageenan.

Agar Agar	
	 Red algae -Gelidiumgelidium

agar affects the absorption of ultraviolet rays (Murata, M. and Nakazoe, 2001), it can decrease the blood glucose level and also exerts an anti-aggregation effect on red blood cell. Agar-oligosaccharide has also been shown that it suppresses the production of a pro-inflammatory cytokine and also suppresses the enzyme associated with production of nitric oxide. Agar type polysaccharide which is extracted from cold water extraction of another *Gracilaria* species shows anti-tumor activity. If agar is hydrosylates then it result to form agaro-oligosaccharides with activity against glycosidase and antioxidant ability (Fernandez, 1989). The agar quality and its content is totally depend upon the physiochemical property as well as closely related to environmental parameters, growth and reproductive cycle. Although agar is also used in commercial level outside the hydrocolloid industry, the recently used this in medicinal, pharmaceutical areas for the treatment against the cancer cell, since it can be induce the apoptosis of these cell *in vitro* (Chen, 2005).

Alginate

Alginate is first discovered by British pharmacist, ECC Stanford in 1880, its first industrial production began in California in 1929. Alginate is a common name for a family of linear polysaccharide containing 1, 4 linked β-D-mannuronic and α-L-guluronic acid residues which is arrange in a non-regular block wise order (Andrade *et al*., 2004). Alginate is produced from brown algae and it mainly used in food and pharmaceutical industry, because of its ability

to chelate metal ion and to form high viscous solution. It is also used in the textile industry the sizing cotton yarn and also used as a gelling agent. Alginate is available in both forms that is acid and salt, the acid form of alginate is a linear polyuronic acid and it is called asalginic acid, whereas the salt form is an important cell wall component of brown seaweeds, consisting of 40% - 47% dry weight of algal biomas. It has been reported that alginate is play an important role as a dietary fiber in human and animal both. It is used for decrease the concentration of cholesterol, exerts hypertension effect, can prevent absorption of toxic chemical substance (Kim and Lee, 2008). This dietary fiber is not present in any land plant, they help protect against the potential carcinogen, and they protect the surface membranes of the stomach and intestine, and they also clear the digestive system. They also have a property to absorb substance such as cholesterol and then eliminated from intestine (Burtin, 2003) and they result in hypocholesterolemic and hypolipidimic responses (Panlasigui *et al*., 2003).



Alginate



Alginate producing algae

Carrageenan

It is the generic name for the family of natural water soluble sulphated galactans, having alternative backbone consisting of α (1-4)-3, 6-anhydro-D-galactose and β (1-3)-D-galactose (Goncalves *et al*., 2002). Carrageenan is widely used then agar as emulsifiers and stabilizer in numerous foods especially milk based product. κ- and ι-carrageenan are very importantly used in milk products like chocolate, pudding, deserts gels, ice creams, jellies, jams, evaporated milk, because of its thick and suspension property. Carrageenan commercially divided into five of the following λ-carrageenan, ι-carrageenan, κ-carrageenan, μ-carrageenan, ν-carrageenan. In sulphate level large difference that is 20% (w/w) in κ-carrageenan and 40% (w/w) in λ-carrageenan is due to the difference in the seaweeds species and their extraction condition. The

μ-carrageenan and *ν*-carrageenan biologically are the precursor of *κ*-and *ι*-carrageenan, can be transfer into sulfotransferase and sulfohydrolase (Van de Velde *et al*., 2005). Carrageenan can also be used as a potential pharmaceutical as anti-tumor, anti-viral, anti-coagulant and immunomodulation activity (Zhou *et al*., 2004). Carrageenan can dissolve in water because of the biomolecules group that composed of linear polysaccharide chain with sulphate half esters attached to the sugar unit. Other medical use of carrageenans are asan anti-coagulant in blood products and also for the treatment of bowel problems, constipation and dysentery. They also used for making internal poultices to control stomach ulcers. New research from biocide properties shows that carrageenan gel from *Chondrus crispus* may block the transmission of HIV virus as well as other STD viruses such as gonorrhoea, genital warts and the herpes simplex viruses (HSV) (Luescher -Mattli, 2003).

Antiviral Activity

It has been reported that some sulphated polysaccharide from red algae show antiviral activity against viruses that are responsible for human infection. Most notable are *Aghardhiellatenera* and *Nothogeniafastigiate* (Kolender *et al*., 1995). It was tested that galactan sulphate (from *Aghardhiellatenera*) and xylomannan sulphate (from *Nothogeniafastigiata*) show antiviral activity against the most infectious viruses like human immune deficiency virus or HIV, herpes simplex viruses types 1, 2, respiratory syncytial virus or RSV. The polysaccharide present in these seaweeds are active during the first stage of RNA replication, when it adsorbs onto the surface of the cells. The most important requirement of antiviral polysaccharide is that it has to be very low cytotoxic effect towards the mammalian cell and most of the seaweeds fulfill this requirement especially *Aghardhiellatenera* and *Nothogenia fastigiata*. Carrageenan is a potential that show *invitro* antiviral activity. There are many types of carrageenan like *μ*-carrageenan, *λ*-carrageenan, *κ*-carrageenan *and ι*-carrageenan.

It was also reported that some carrageenan also show potent antiviral activity against different strain HSV 1 and 2. Carragaurd is a carrageenan based on microbicide, is an undergoing phase 3 trials, it is used for blocking of HIV and other sexually transmitted disease. A sulphated polysaccharide from *Schizymeni apacifica* inhibits the HIV reverse transcriptase *in vitro*, which is a later stage in HIV replication (Nakashima, 1987), they don't have any effect or minimal effect on DNA and RNA polymerase activity. Some high molecular weight galactan sulphate also known agaroids from *Gracilaria corticata* show antiviral property against HSV

type 1 and 2, this is because of the inhibition of initial virus attachment to the host cell (Wu *et al*., 2012). Fucoidan has potent antiviral activity against HSV type 1 and 2, human cytomegalovirus (Malhotra, 2003) and HIV. Fucoidan show antiviral property by inhibiting the binding of viral particle to host cell (Baba, 1988). It also has the property to inhibit the binding of sperm to the zona pellucid (Oehninger, 1991).

Antibiotic Activity

Macro algae have many compounds that show antibiotic activity. The interesting list of compounds present in macro algae are halogenated compound such as halogenated alkanes, haloforms, alkenes, alcohol, aldehyde, hydroquinone and ketone (Lincoln *et al*., 1991). Compounds such as sterols, heterocyclic and phenolic compounds show antibiotic property. Many of these compounds show antiseptics as well as cleansing property, but their antibiotic activity *in vivo* is often only achieved at toxic concentration (Lincoln *et al*., 1991). A halogenated furanone also known as fimbrolide which is a promising antibacterial agent, belong to class of lactones from *Delis eapulchara*. It has been exam in edas effective result on bacterial anti-fouling (Kjelleberg and Steinberg, 2001) and also used as treatment for chronic *Pseudomonas aeruginosa* infection.

Pseudomonas aeruginosa infection mainly cause by the production of mucoid alginate and formation of biofilm in the lungs of patients suffering from cystic fibrosis (Hoiby, 2002). Bacterial inhibition mainly occur by inhibiting the furanone on the quorum sensing mechanism by functioning as intracellular signal antagonist, as a result disruption of intra and inter cellular cell-cell communication occur (Rasmussen, 2000). This effect mainly occur in gram negative bacteria. Compounds like sterols heterocyclic and phenolic compounds sometimes shows antibiotic property. These properties may be developed into antiseptics and cleansing agent but the antibiotic property *in vivo* is only achieved at toxic concentration.

Anti-Cancer Activity

Fucoidans obtained from brown algae *Eclonia cava*, *Sargassum hornery* and *Costaria costalla*, widely spread in the sea of the South Korea, play an inhibitory role in colony formation in human melanoma and colon cancer cells. Hence these fucoidans may be effective anti tumour agents (Ermakova *et al*., 2011). Hydrolyzed fucoidan from sporophyll of *Unda riapinnnatifida* were used to determine the molecular weight and hydrolysis condition on cancer cell growth. Native fucoidan showed anti-cancer effect. A test showed that anti-cancer activity of fucoidan

could besignificantly enhanced by lowering the molecular weight, only when they are depolymerized by mild condition (Yang *et al*., 2008).

Conclusion

Algae has multifunctional compounds *viz*., carotenoids, astaxanthin, β carotene, secondary metabolites, PUFA, proteins and enzymes, vitamins, biofuel, biocontrol activity of algae, fatty acids, polysaccharide, agar, alginate, carrageenan, antiviral activity, antibiotic activity and anticancer activity. All the compounds are very essential for human health and well being. Hence for the sustainability of algae availability and its growth we have to preserve the marine ecosystem.

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THE PERFORMANCE OF INDIGENOUS AZOSPIRILLUM OF THE PLANT GROWTH UNDER POT CULTURE FROM MADURAI DISTRICT

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Abstract

Azospirillum is the foremost common plant growth-promoting rhizobacteria (PGPR) that are generally associated with fibrous root containing plants viz., rice, wheat and Ragi. ***Azospirillum*** is a nitrogen fixing bacterium and secretes plant growth hormone like IAA, Gibberellin which helps in plant root growth. The performance of *Azospirillum* will be varying for different location due to its adaptability to the particular environment. In this experiment, the indigenous strains were isolated from rice. The isolates were purified, characterized, screened and massmultiplied on N free malic acid (Dobreiner, et.al, 1976). The screened isolates were subjected to pot culture condition. The effect of the isolates on plant root length, shoot length, dry weight, no of main and lateral roots were examined at 10, 20 and 30 DAS. Among the isolates isolate AI_7 gave better performance towards root length (18 cm), shoot length (35 cm), root volume (0.19 cc), number of main root (16) and number of lateral root (15.64) and dry weight (0.64g/plant).

Keywords: ***Azospirillum***, IAA, Pot culture experiment, plant root growth.

Introduction

Azospirillum is a microbe belonging to the class of Plant Growth Promoting Rhizobacteria (PGPR).***Azospirillum***is a smaller scale aerophilic, gram negative, rod shaped, plant growth promoting bacteria, which grows well in Nitrogen free semi-solid malate medium.Azospirillum species are found in the rhizosphere of most important crop plants and are able to fix N under the conditions of microaerophilic. The isolation and use of Azospirillum was initiated from 1970 (Steenhoudt and Vanderleyden, 2000). Azospirillum consists of 10 species,

including **Azospirillumbrasilense, Azospirillumamazonense, Azospirillumirakense, Azospirillumlipoferum, Azospirillumlargimobile, Azospirillumhalopraeferens, Azospirillumoryzae, Azospirillumcanadensis, Azospirillumdoebereinerae, and Azospirillumme*linis*** (Tarrand et al., 1978; Magalhães et al., 1983; Dekhil et al., 1997; Peng et al., 2006; Mehnaz et al., 2007; Saharan and Nehra, 2011).The first individuals who indicated the production of ABA by Azospirillum in defined culture were Kolb and Martin (1985). Here, ***Azospirillum*** strain was isolated from AC & RI, Madurai and studied for the plant growth under pot culture conditions. The biochemical tests and estimation of IAA production were conducted to examine further about ***Azospirillum***. This article briefly explains about the foresaid experiments in a well-organized manner.

Materials and Methods

In order to evaluate the growth performance of ***Azospirillum***, initially the microbe has to be isolated and then purified. After that broth cultures are developed. Then finally, mass production is started using Fermentors.

ISOLATION

To begin with isolation, the medium used is N-free Malic Acid semi solid medium (Malic Acid (5g), Potassium Hydroxide (4g), Dipotassium Hydrogen Orthophosphate (0.5g), Magnesium Sulphate (0.2g), Sodium Chloride (0.1g), Calcium Chloride (0.2g), Agar (1.75g), Iron EDTA (4 ml), trace element solution (2ml), Bromothymol blue (0.5%)) .Fresh roots of graminaceous plants like rice are collected and are inoculated into the fresh N-free Malic acid semi solid medium and kept for incubation under 30 ± 1 ºC. It nearly takes a week (5-7 days) for proper growth of the microbe. By this way the colonies are isolated and their growth is simultaneously observed.

PURIFICATION

Purification process is followed by isolation. This process helps to isolate a pure individual cell from isolated colonies. Slants are used to check the purity of ***Azospirillum***. Slants are prepared using N-free Malic acid medium and the isolated ***Azospirillum*** colonies are streaked in the slants. These are incubated under 30 ± 1 ºC for 5-7 days. Purification process is followed by

BIOCHEMICAL CHARACTERIZATION

Biochemical Characterization utilizing different biochemical tests. Carbon source utilization test,

Glucose production from acid test and Biotin Requirement test are performed. Characterization was also performed using Gram Staining.

IAA ESTIMATION

Azospirillum microbe produces visible quantities of Indole Acetic Acid (IAA) and this is estimated using the foresaid procedure. It requires the preparation of Glucose yeast extract peptone broth (250 ml) and L-Tryptophan solution (100 ppm). 100 ppm of L-Tryptophan is prepared and added to the glucose yeast extract peptone broth. Finally the culture is inoculated into this broth and incubated under dark for 7-10 days. After this, the extraction procedure gets started and initially 25 ml broth culture is centrifuged at 10,000 ppm for 5-10 mins to palletize the cells. The cell free extract is collected using decantation and acidified using 0.1N HCl to pH 2.8. This extract is mixed with Diethyl etherin a separating funnel and kept in refrigerator at 4ºC. After 4 hrs, the solvent phase is withdrawn and evaporated to dryness in a beaker. The residue is then dissolved in 2 ml methanol for quantitative estimation of Indole Acetic Acid. Here, the sample is mixed with 4ml Salpher's reagent and incubated under dark for 1 hr. Then, the color intensity is read usingspectrophotometer at 535 nm and the quantity of IAA produced is calculated using the standard curve.

MASS PRODUCTION

Finally, the broth culture of 3litres capacity was developed with the help of starter culture. After the complete growth of ***Azospirillum*** in broth, mass production gets started in fermenters. The evaluation of this indigenous ***Azospirillum*** was performed using Pot Cultures. Rice seeds were soaked overnight and were sown in pots. As soon as the seedlings start to emerge the ***Azospirillum*** was inoculated into these pots. Two controls and three replications/treatments were maintained. The root lengths of the ***Azospirillum*** treated seedlings as well as control seedlings were compared and their growth was recorded.

Results and Discussion

The results of the above foresaid experiments like isolation, purification, Biochemical characterization, IAA production are categorized below,

ISOLATION AND PURIFICATION

Isolation of ***Azospirillum*** was made from rhizoplane of Paddy root samples obtained from Agricultural College and Research Institute Campus, Madurai district. Nearly, six***Azospirillum*** isolates were obtained byadopting enrichment culture technique. Thecolony

morphology of isolates on N-free malate medium wassmall to medium, pale white dense, spindle and transparentpale shiny white in color. All the isolates formed subsurfacepellicles in NFBTB medium and turned olive green color ofBromoThymol Blue (BTB) to brilliant blue.Formation of pellicle in NFBTB indicates the isolates seem tobe ***Azospirillum spp***. The pellicleformation may be considered as one of the criteria foridentification.The morphological characteristics of the isolates in thepresent study were appeared similar to the description of***Azospirillum spp.*** given by Krieg and Dobereiner (1984) and Tarrand et al. (1978).Slants are used to check the purity of ***Azospirillum***. The results show that the streaked slants visually show the color change from olive green to blue.



Fig.1 Isolated plate



Fig.2 Azospirillum Slants

BIOCHEMICAL CHARACTERIZATION

All the isolates were tested for biochemical characteristics. Undercarbon source utilization test, thetest tubes showed the appearance of turbidity whichindicated utilization of glucose. Biotin requirement test shows Biotin free medium favored the growth of ***Azospirillumbrasilense***, ***Azospirillumlipoferum*** required biotin for growth.The change in color of BTBfrom green to yellow was recorded in the Glucose production from acid test.

IAA PRODUCTION

This study began with the isolation of bacteria type strain ***Azospirillum sp.*** and developed the investigation to a screening of their ability in IAA production. This screening conducted a selection of only bacteria that was capable of the production of IAA with its content of over 28 mg mL-1 for sequencing.Various factors that influence ***Azospirillum sp.***in biosynthesizing IAA such as temperature, pH, nitrogen presence and concentration of tryptophan in the culture medium were examined. The results indicated that the culture conditions were suitable for IAA biosynthesis at pH 6.5, 30 °C, culture media with nitrogen, and 0.1% tryptophan.

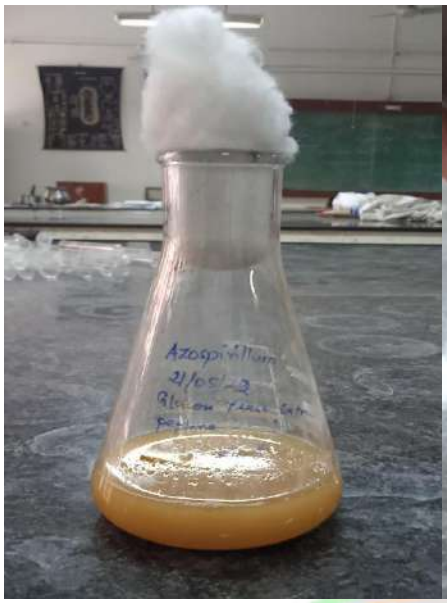


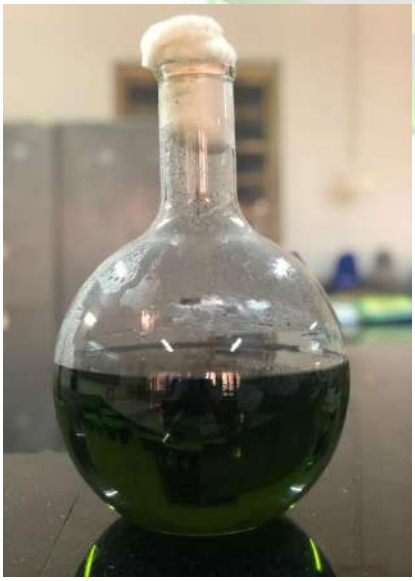


Fig.3 Glucose peptone broth

Fig.4 Centrifuged broth containing Azospirillum

MASS PRODUCTION

The isolated strains were used for mass inoculums production. The isolates were stored in the refrigerator under lowtemperature. These strains are called starterculture. These cultures were then transferredinto 100 mL, 250 mL conical flask containing N- free malic acid semisolid medium incubated into for28±20ºC for one week. Then the motherinoculums were transferred into 500mL,1000mL conical flask containing N- free Malic acid liquidbroth (without agar).



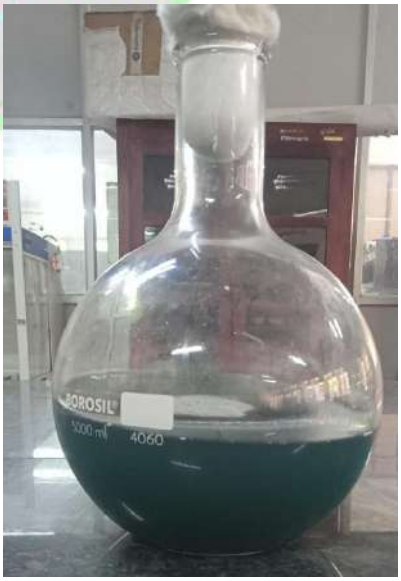


Fig.5 Broth initially after inoculation

Fig.6 Broth after incubation and growth

These flasks wereplaced in the shaker using occasional shakingfor 7 days for proper aeration and agitation.After 7 days, the liquid culturecontaining ***Azospirillum***were mixed withcarrier material. Lignite powder was used ascarrier. The carrier material 4 kg was mixedwith 1 liter of culture broth with 2% CaCO3was mixed and then the mixture is placed in apolythene sheet and covered with polythenesheet for 24 hrs for curing. Then the mixturewas pocketed into polythene bags and sealedit. The polythene bags were stored into thestore room at 28±20ºC. These culture pocketswere used for field application

POT CULTURE EVALUATION

Pot culture is a method of growing treatments of biofertilizer treated seedlings and observing their root as well as shoot length. This evaluation is performed using rice seedlings. Rice seeds (ADT 45 Variety) were soaked overnight and were sown in pots. As soon as the seedlings start to emerge the ***Azospirillum*** was inoculated into these pots. Two controls and three replications/treatments were maintained. Under these two controls, no azospirillum was inoculated. In replications, T1 was inoculated with 50 ml of ***Azospirillum***, T2 with 100 ml and T3 with 150 ml. After few days of their growth, the root as well as shoot lengths were measured which is given below in table.1

Sample	Root length (cm)	Shoot length (cm)	Root volume (cc)	No. of Main roots	No .of lateral roots
INITIALLY BIOMETRIC OBSERVATION (10 DAS)					
Control -1	9.5 cm	17 cm	0.10	5	4.56
Control -2	4.5 cm	13 cm	0.20	7	4.43
T1 (50 ml)	8.5 cm	21.5 cm	0.10	10	5.10
T2 (100 ml)	4.8 cm	13 cm	0.38	9	5.02
T3 (150 ml)	3.5 cm	26 cm	0.28	10	4.08
AFTER 20 DAYS OF OBSERVATION					
Control -1	11 cm	25 cm	0.15	7	7.45
Control -2	7 cm	27 cm	0.10	8	7.50
T1 (50 ml)	9 cm	24 cm	0.20	9	12.75

T2 (100 ml)	6.5 cm	23 cm	0.25	11	12.45
T3 (150 ml)	3.5 cm	16.5 cm	0.22	13	11.09
AFTER 30 DAYS OF OBSERVATION					
Control -1	12 cm	30 cm	0.18	9	10.0
Control -2	9 cm	32 cm	0.15	8	9.0
T1 (50 ml)	15 cm	28 cm	0.20	15	16.94
T2 (100 ml)	18 cm	35 cm	0.19	16	15.64
T3 (150 ml)	14 cm	38 cm	0.25	19	14.55

Table.1 Root and Shoot Lengths of Pot Culture Plants



Fig.7 Azospirillium inoculated Rice seedlings under Pot Culture Conditions



Fig.8 Biometric Observation of Azospirillum treated Rice seedlings

Conclusion

Azospirillum is currently one of the most broadly studiedand commercially employed PGPB.Nitrogen is available in abundance in gaseous form in the atmosphere but it is unavailable to plants unless it is reduced to ammonia. The process of reduction of atmospheric nitrogen to ammonia is carried out by prokaryotic microorganisms. ***Azospirillum*** has potential use as biofertilizers in agriculture mainly as a nitrogen fixer.The capability of the ***Azospirillum*** to extend within therhizosphere of crop recommends its capacity to get waybetter the supplement accessibility to the plants and beable to improvement the costly inorganic and organicfertilizers. Shifting to biofertilizers paves the way for a better organic environment.

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META ANALYSIS OF YIELD IN INTEGRATED NUTRIENT MANAGEMENT ON MAIZE CULTIVATION

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Abstract

Maize were grown at four different combinations comprising four levels of enriched FYM with fertilizers viz., conventional (FYM @ 10 t/ha+100% RDF), enriched FYM+50% RDF, enriched FYM+100% RDF and enriched FYM+150% RDF and four biofertilizer levels viz., control, *Azotobacter*, PSB and *Azotobacter*+PSB were laid out factorial concept in randomized block design with three replications. The application of FYM @ 10 t/ha enriched with 150% RDF recorded significantly increased grain yield (4449.52 kg/ha), stover yield (8026.52 kg/ha), The experimental soil was clay loam, slightly alkaline in reaction (pH 7.8), medium in available nitrogen (260.40 kg/ ha) and available phosphorus (18.26 kg/ha) (Gajendra singh *et al* .,2012).Among fertilizer levels, application of 100 per cent RDF recorded significantly higher maize equivalent yield (10986kg/ha) compared to 75 per cent (10416kg/ha) and 50 per cent RDF (9720kg/ha), this is due to nutrient exhaustive nature of maize crop. Chandrashekara *et al.* (2000) conducted the field experiment in Arabhavi, Karnataka during the *kharif* season of 1996 and reported that the application of poultry manure (10 t/ha) with recommended rate of fertilizers(RRF 150 kg N/ha in three split doses) produced longer cobs (14.35 cm) with bigger diameter (15.6 cm) and heavier cob weight (170.5 g/cob) than application with control. The per cent increase in cob length, cob girth, and grain weight per plant with the application of poultry manures was 13.1, 23.8 and 53.2 %, respectively, compared with control. Nanjappa *et al.* (2001)

conducted an experiment on maize to study effect of integrated nutrient management at Bangalore, Karnataka. The grains per row were recorded maximum with 75% RDF + FYM 6 t/ha, which was at par with RDF (150 : 75 : 40 kg NPK/ha) alone and significantly superior over 50% RDF + 12 t FYM/ha and FYM 24 t/ha treatments. The grain weight per plant was recorded maximum with 75% RDF + FYM 6 t/ha, which was at par with RDF alone and both these treatments were significantly superior over rest of the treatments.

Key words: FYM, enriched FYM, fertilizers, RDF, Manure, Maize, yield

Introduction

Maize is the queen of cereals, occupies a pride place among cereal crops in India. It has emerged as third most important food crop after rice and wheat as it represents 24% of total cereal production. It is a staple food for vast rural population of our country. The integrated plant nutrient supply envisages conjunctive use of inorganic and organic sources of plant nutrients and use of biofertilizers for crop productivity besides sustaining soil health. FYM is traditional source of organic manure. Out of total utilizable nutrient content of FYM, only one third N and two-third P are available in the current season crop and rest in the succeeding crop in the recent years (Gajendra singh *et al.,* 2012).The productivity of the system mainly depends on proper nutrient and moisture management practices. Low organic matter content in vertisols coupled with low and imbalanced application of macro and micro nutrients to the crop limits the full potential of yield and is the main yield barrier for crops (Ghosh *et al.* 2003).

Integrating chemical fertilizers with organic manures was quite promising, not only in maintaining higher productivity but also in providing greater stability in crop production (Nambiar and Abrol 1992). Among fertilizer levels, application of 100 per cent RDF recorded significantly higher maize equivalent yield (10986kg/ha) compared to 75 per cent (10416kg/ha) and per cent RDF (9720kg/ha), this is due to nutrient exhaustive nature of maize crop (UK Shanwad 2010). Whereas judicious uses of organic manures and inorganic fertilizers are essential to safeguard soil health and augment productivity and input use efficiency which can sustain a highly intensive production system. The positive effect of judicious use of FYM and inorganic fertilizers on productivity of crops has been reported by many workers (Bandyopadhyay *et al*., 2003; Hati *et al*., 2006; Bhattacharyya *et al*., 2008). Today, for the country of India's dimension, with no scope for horizontal expansion and complexity of problems and challenges, there is no alternative but continue to improve productivity without

further degrading its natural resources that too in a sustainable manner (Narayanswamy *et al.*, 1994). In this contest we will have to adopt a rationalist organic farming approach to have an 'Evergreen Revolution'. This has led to the concept of integrated nutrient management (INM) gain momentum in recent years to improve and maintain the soil health. Besides this, with escalating cost of energy based fertilizer material, limited fossil fuels, INM approach combines the use of organic sources along with fertilizers, which would be remunerative for getting higher yields with considerable fertilizer economy (Subbian and Palaniappan, 1992)

Discussion

The productivity of the crop in terms of grain and stover yield tended to increase with application of FYM integrated with chemical fertilizers.(Fig.1.) Application of FYM @ 10 t/ ha enriched with 150% RDF recorded significantly the highest grain yield (4449.52 kg/ha) which represented increase of 363.75, 383.25 and 570 kg/ha over application of FYM 10 t/ha enriched with 100% RDF, conventional practice and FYM 10 t/ha enriched with 50% RDF, respectively. The highest stover yield (8026.52 kg/ha) was recorded when the crop was supplied with FYM @ 10 t/ha enriched with 150% RDF, which represented significant increase of 705 kg/ha over FYM @ 10 t/ha enriched with 50% RDF but was found at par with conventional practice and FYM @ 10 t/ha enriched with 100% RDF. Similar trend was also observed in harvest index. Application of FYM @ 10 t/ha enriched with 150% RDF recorded significantly highest protein content in grain (Gajendra singh *et al.,* 2012). Uptake of nitrogen and phosphorus by grain, stover and the total uptake by the crop were significantly the highest with application of FYM enriched with 150% RDF. Application of FYM @ 10 t/ha enriched with 150% RDF significantly increased available nitrogen and phosphorus in soil over control and FYM @ 10 t/ha enriched with 50% RDF.

However, it remained at par with FYM @ 10 t/ ha enriched with 100% RDF. Nutrient uptake is product key of yield and nutrient content, considerable increase in either nutrient content or in yield may increase the uptake. The results are in confirmation with the findings of Dadarwal *et al*. (2009) and Balai *et al*. (2011). Application of 100 per cent RDF produced significantly higher yield of maize (5578kg/ha) and bengal gram (1495kg/ha) thereby maize equivalent yield (10986kg/ha). Increase in the levels of NPK from 50 to 100% resulted in significant increase in the yield of both the crops. Similar results have been reported by Channabasavanna *et al.* (2007). Application of 100 per cent NPK recorded 13.0 and 5.4 per cent

higher maize equivalent yield over 50 and 75 per cent NPK, respectively, This might be due to higher supply of plant nutrients by application of organic and/or chemical fertilizers to both the crops where initial soil was low in available nutrients and organic C content (Ramachandran & Biswas., 2020).

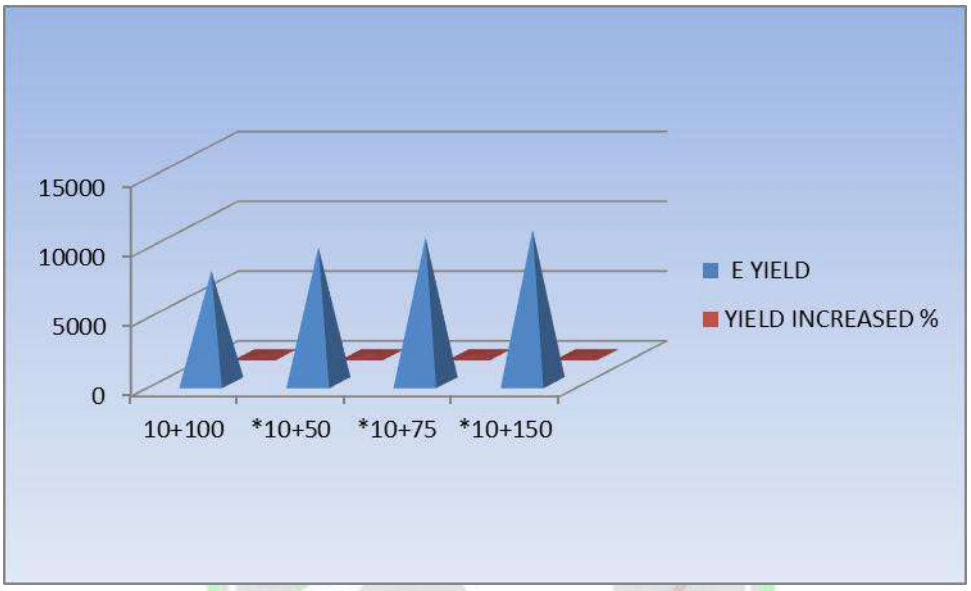


Fig.1.Yield in integrated nutrient management on maize

Conclusion

From the Meta analysis yield is influenced by Integrated nutrient methods and quantity, manures, enriched manures and recommended dose of fertilizers. Here 36% of yield increase through 150 percentage of recommended dose of fertilizers with INM . 75 percentage of recommended dose of fertilizers with INM involved then yield factors 29% influenced and compared to these two with enriched FYM, 50 percentage of recommended dose of fertilizers with INM of Agronomic practices increased yield 21% increased through INM involved for yield and yield parameters impact development.

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POTENTIAL BIOPRODUCTS FROM OIL PALM RESIDUES

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1. Introduction

Oil palm cultivation is common throughout the world, while substantial production is primarily concentrated in Southeast Asia, Africa, and South America. Indonesia and Malaysia are the principal producers of oil palm in Southeast Asia, represent 84 percent of global palm oil production due to favourable climatic conditions, and substantial government supports. Oil Palm (*Elaeis guineensis*) is widely recognized as a versatile oil crop due to its high productivity and the numerous applications linked with the various parts of oil palm. Oil palm farming and processing produce substantial bio-residues in both fields and mills and about 10-15% is being used as alternative raw materials, and the remaining is left untapped which poses serious environmental challenges. By exploiting the potential of oil palm residue for biofuels production using innovative technologies, the palm oil trade aids in environmental sustainability, resource conservation, and the shift towards renewable energy sources.

2. Oil palm residues

Global demand for palm oil significantly contributes to economic development, driven by its use in vegetable oils. This demand prompts countries to accelerate oil palm plantation development, which results in increased mill effluents from palm oil industries. However, only a minimum fraction of the oil palm tree is utilized for oil production and a maximum fraction is resulted as lignocellulosic bio-wastes.

Oil palm residues include oil palm trunk (OPT), oil palm fronds (OPF), empty fruit bunch (EFB), mesocarp fibre (MF), palm kernel shell (PKS) and palm oil mill effluent (POME). OPT, OPF and EFB contribute 5%, 10% and 70% of total oil palm residues. While these wastes are organic and environmentally degradable, their large quantities pose a potential for environmental pollution

3. Sustainable bioproducts from Oil palm residues

Exploring oil palm residues for tapping bioenergy, presents a significant opportunity for increased energy production. Biooil, one of the renewable biofuels obtained through fast pyrolysis of biomass, is being explored as a substitute for petroleum. Oil palm residues rich in cellulose, hemicellulose, and lignin are subjected to anaerobic thermal treatment at higher temperatures (500-600°C) to produce a brown viscous liquid fuel called bio-oil (60-70% wt. yield) rich in organics. It offers advantages such as ease of use, storage, and transport, contributing to the reduction of fossil fuel use and GHG emissions. Along with bio-oil, biochar and syngas of around 15-30% is also obtained as co-products. Bio-oil has potential applications to be used as fuel for burning in boilers or engines. Biochar, a stable carbon compound, is produced from oil palm residue through carbonization processes. Biochar has greater potential for carbon sequestration in soils and soil amendment property.



Research has also been directed toward green hydrogen synthesis from oil palm wastes through gasification, although this remains in the early stages of research exploration. Renewable options of using oil palm wastes to produce steam and electricity by cogeneration is being

adopted in practice worldwide which significantly reduces CO_2 emissions associated with its conventional open burning practice. Apart from this, superior bio-products like activated carbon and carbon molecular sieve (CMS) from wastes has also been investigated for its suitable applications in wastewater treatment, gas and liquid adsorption. Various research on co-firing application of bio-oil in boilers, engines or furnaces.

3.1 Biochar from Empty Fruit Bunches

As a residue from palm fruit processing, EFB, comprising 20% of fresh fruit weight, is a major residue from palm oil mills post-oil extraction. Previously, EFB was incinerated at mills for steam generation, with resulting ash used as fertilizer. However, this practice was discouraged due to excessive white smoke emission, largely from high moisture content. Utilizing EFB to produce value added bioproducts offers a solution to both the issue of EFB disposal and the associated environmental problems. EFB has the potential to be transformed into biofuels via thermochemical processes. Among thermochemical methods, pyrolysis excels in generating biochar, reflects a growing recognition of biochar's benefits, including soil enhancement and carbon sequestration, alongside its potential as a renewable energy source through gasification processes.

3.2 Biooil from Empty Fruit Bunches

With a high volatile matter content and fixed carbon, EFB showed notable characteristics favoring volatility and reactivity, especially beneficial for liquid fuel production. When high cellulosic biomass undergoes conversion processes, the resulting liquid products, biooil, termed as pyrolytic oil, contain a varied range of chemical constituents. These include acids, alcohols, aldehydes, ketones, esters, heterocyclic derivatives, and phenolic compounds. This diverse array of compounds underscores the complexity of biomass conversion and highlights the potential for EFB and similar materials in sustainable energy applications.

3.3 Bioethanol from Empty Fruit Bunches

Production of bioethanol from oil palm Empty Fruit Bunches is gaining momentum as a promising pathway for sustainable energy generation. Various research endeavors and pilot projects have been undertaken to assess the viability and scalability of this technology. However, several hurdles persist, including the need to optimize the efficiency of pretreatment and enzymatic hydrolysis methods to maximize sugar extraction from EFB. Though significant strides have been made in recent years, advancements in pretreatment techniques, such as acid

hydrolysis and steam explosion, have enhanced the efficiency of sugar extraction from EFB. Additionally, the development of robust fermentation strains capable of effectively converting EFB sugars into ethanol is essential for improving overall ethanol yields. The exploration of genetically modified microorganisms with enhanced fermentation capabilities holds promise for boosting ethanol production rates. Moreover, integrating bioethanol production with existing palm oil mills presents opportunities for synergy, such as leveraging waste heat and water streams for process optimization, thereby bolstering the overall sustainability of the production process.

3.4 Carbon Molecular sieves from Palm shell

Carbon Molecular Sieves (CMS) constitute a specialized category within active carbons, distinguished by their small pore sizes and precise micropore distribution. Sourced from diverse carbonaceous materials such as lignocellulosic biomass and coal, CMS is generated through two primary methods: controlled pyrolysis of carbon precursors and alteration of existing porosity via carbon deposition. In controlled pyrolysis, precursor materials undergo specific pyrolytic conditions to gradually augment adsorption capacity by forming micropores, while preventing excessive widening that may compromise selectivity. However, CMS produced by this method often displays diminished adsorption capabilities. In contrast, CMS crafted by modifying existing porosity through carbon deposition is favored, offering heightened adsorption and selectivity. This approach strategically introduces carbon deposits to amplify porosity, yielding a superior-quality product. Such differentiation underscores the significance of production techniques in optimizing CMS properties for diverse industrial applications.

Conclusion

Oil palm residues can be converted into a variety of useful bio-products using cutting-edge technologies, supporting rural development and protecting the environment. Another byproduct of biomass conversion is biogas, which may be used as fuel for generating electricity, cooking and lighting giving rural communities access to inexpensive, clean energy. Additionally, oil palm residues can be converted into pellets and briquettes, effective and sustainable substitutes for conventional fuels like coal, which helps to improve air quality and lessen deforestation. The economic feasibility and sustainability of rural palm oil mills can be further improved by directly integrating oil palm residues-based electricity generation through gasification technology.

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PREPARATION AND NUTRIENT ANALYSIS OF LABORATORY-MADE RAW UNCOOKED FISH-PASTA FOR HEALTH BENEFITS

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Abstract

In the modern day and age , people are becoming more conscious of the importance of eating healthy foods and incorporating in their diet the required amount of protein. With the advent of the blue revolution all over the globe the requirement of protein security is fulfilled by fish contributing to around 15 % of the global protein supply from animals. Fish is becoming more popular due to its unique nutritional and practical qualities. Adding the benefits of fish into a food like pasta is a necessity of ensuring food security especially in the tastiest of ways possible. Using basic processing instruments, fish enriched pasta was created with refine flour, semolina, gram flour, cheese, and fish mince (*Labeo rohita*). A panel of judges used a 5-point hedonic scale to conduct acceptability studies on the pasta both at the beginning and at the end of the storage period, which is four months, at the laboratory level. Proximate principles and cooking quality were evaluated. The study's findings demonstrated that preparing pasta with added fish mince can produce pasta of acceptable quality.

Keywords: Fish mince, omega-3-fatty acids, nutrition analysis, pasta, sensory evaluation.

Introduction

Pasta is one of the most globally popular food items in the world. The origin is frequently associated with Italian cuisine and it offers versatility and convenience. Each country has its own version of pasta where there are hints of native traditional evolution in the Italian preparation of the same. However, pasta in its original form is made of flour(maida) or semolina(suji) and thus it traditionally lacks substantial protein and essential fatty acids. Pasta is considered by many to be a junk food especially in countries like India where it is sold in a plethora of restaurants and outlets ranging from rich fancy restaurants to cheap roadside stalls. But there is a way to nutritionally enhance the tasty pasta that we eat and thus fortify its existence in our food chain value. One such fortification in pasta is the addition of nutritionally rich fish meat into its composition. Fish is a good source of lipids that contain omega-3 fatty acids and high-nutrient-value protein, particularly, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) (Kris-Etherton *et al*., 2000); Kris-Etherton *et al*., 2002). In addition to being necessary for healthy growth and development, omega-3 fatty acids may prevent or lessen the risk of cancer, hypertension, diabetes, arthritis, coronary artery disease, and other autoimmune and inflammatory diseases (Simopoulos, 2000). It is interesting to note that fish is also an excellent source of certain minerals (such as iron, zinc, iodine, selenium, potassium, sodium, etc.) and vitamins such as A, D, B6, B12, etc. (Devi *et al*., 2013).

Incorporating fish mince in pasta preparation significantly enhances the nutritional value of pasta by boosting protein content and omega-3 fatty acids (Devi *et al*., 2013). Though it appears easy to incorporate fish mice into pasta making, it is a tedious process as a little bit of mistake in the preparation can lead to a severe alteration in the taste and thus the overall result of pasta making. There are ways to introduce fish into the pasta externally during final preparation, the benefits of it being incorporated in the raw pasta form is different from that in the nutritional context. There are different papers and works involving the different ways to do the same the steps and work flow here is quite simple and does not require the use of an extruder. This work plan provides an in-depth guide for preparing fish-enriched pasta, including its formulation, detailed preparation procedures, simplified proximate composition analysis, and assessments of sensory, quality, and microbiological parameters.

Ingredients for Pasta Preparation

To prepare 1 kg of raw fish pasta, the raw materials required for the preparation include Fish Mince (200 g), Refined Wheat Flour(Maida) – 325 g, Semolina (325 g), Gram Flour(100 g), and Grated Cheese (50 g). The use of raw materials is flexible and subject to availability.



Figure 1: Ingredients used to prepare raw fish pasta

Preparation of fish mince

The fish that we used for our purpose was Rohu(*Labeo rohita*) as shown in figure 2 due to its easy availability and low cost. The fish was bought fresh from the market and it weighed approximately 1.2 kg. It was prepared by discarding the head, fins, tail, viscera and washing with clean water (Devi *et al*., 2013) followed by descaling by the vendor itself. It was further deboned and flesh was separated. The final mince is displayed in figure number 3.



Figure 2: Rohu Fish used for the purpose



Figure 3: Raw fish mince after final mincing

The Equipment Required

The different equipment required for our work were a manual pasta maker, a cabinet drier, domestic grinder, deboning machine, automatic mincer, and a sieve. These were easily available at our disposal at the FPT lab of our college. All the equipment prior to their use were thoroughly washed and sanitized in order to avoid any microbial contamination during the process and to maintain proper hygiene.

Procedure

The work flow starts with the preparation of the fish flesh and further manual deboning of the

left-over fish carcass. Post preparing of the fish mince, the mince is thoroughly and repeatedly washed with clean distilled water. This was done to remove the soluble protein and impurities from the fish mince. The washing process continued until a clear white flesh mince was obtained. This mince was then sieved out and separated from water using a thin and light muslin cloth. This process required utmost care and precaution so as to avoid losing any further amount of flesh obtained. The amount of flesh mince that was obtained after through washing was a mere 30% of the original quantity of mice used. The initial mince weighed around 500g shown in the figure 3 above, whereas the final white mince obtained was 200g.

Drying: The clear white mince obtained after sieving is evenly spread in a steel tray and is taken to be dried to in a cabinet dryer at 60°C for 24 hours. The time of the starting of the drying process is carefully noted down, and right after 24 hours the product is taken out of the drier. Drying reduces the amount of moisture in the mince resulting in a further reduction of the weight of the mince. The wet weight of the mince was 200g and the final dry weight was a mere 120g. This 120 g dry fish mince obtained as shown in figure 4 is further used in the preparation of the final product.



Figure 4: Setting the Cabinet Dryer for drying the minced fish



Figure 5: Dried Fish Mince

Grinding and Sieving: The dry fish mince obtained post 24-hour drying is grounded and made into a fine powder using a domestic mixer grinder available at the lab. The powder obtained is the further passes through a 44 mm fine mesh sieve to remove or filer out any larger granules or impurities and the dried powder as shown in figure 6 is taken out to be used in the further steps.

Storage: The fish powder obtained post grinding and manual sieving is further stored in an airtight container



Figure 6: Dried fish mince powder

Pasta Dough Preparation

For the preparation of dough, the first step involves the mixing of the refined flour and semolina together in the required amounts as stated earlier. To this mixture lukewarm water is added while mixing to achieve a dough with 31% moisture content (Devi *et al*., 2013). Before kneading the dough is added with gram flour, grated cheese and dry fish powder obtained in the previous steps in the stated amounts and further kneaded to form a uniform homogenous mixture. The dough is finally ready to be used as shown in figure 7 below and shaped into pasta. The shaping of the pasta is obtained using a manual pasta maker available at the lab of COF, Dholi. Long pasta dough is prepared using the manual pasta maker which is further cut into small sizeable pieces by hand.



Figure 7: The final dough for the pasta



Figure 8: Long Pasta threads

Drying of the final product

The long thin pasta shape is further cut into small shaped pasta as shown in figure 9 and is then kept back again in the cabinet drier at around at 80°C for 4 hours to lower moisture content and improve shelf life of the final product.



Figure 9: Dried Pasta

Packaging

The final pasta product obatined is stored in polyethylene pouches as shown in figure 10, and around 5 such batches of 100 g each is finally . These are kept and stored in a dry place away from sunlight to protect against moisture and extend shelf life. The final product obtained need not be refrigerated. In our study the pasta was stored for a period of 4 months.



Figure 15: Storing the dried pasta in polyethylene pouches

Proximate Composition Calculation

In order to measure the moisture content of the pasta we use AOAC (1990) method. 5 g of pasta is weighed and further dried in a *Hot-air oven* at 105°C. (Zaman, 2024). The final moisture content is determined using the formula:

Moisture (%) = {(Initial weight - Final weight) / Initial weight} × 100

For protein estimation we use the Kjeldahl method for nitrogen estimation. (Zaman, 2024) AOAC (1990) procedure and calculated as the product of percent nitrogen and a multiplication factor of 6.25 to calculate the final crude protein content. The steps involved in protein estimation are Digestion, neutralization, distillation, titration, and final nitrogen content calculation. To measure the quantity of fat in the sample we Extract fat using the *Soxhlet extraction method AOAC (1990)* with ether as the solvent. (Zaman, 2024). To calculate the ash content sample was estimated by AOAC (1990) method where the sample is incinerated in a *muffle furnace* at 550°C until only ash remains. (Zaman, 2024).

Sensory Evaluation

To Conduct a sensory evaluation of our product we conducted evaluation at both initial and 60-day storage periods. (Devi *et al*., 2013). For this we use the help of untrained 3 students and a 5-point *Hedonic scale* to assess colour, texture, flavour, aroma, and overall acceptability both at the beginning and at the end of the 4 months period. (Devi *et al*., 2013)

Results and final analysis

- **Cooking Time:** This was estimated to assess the hydration properties of the pasta prepared(Martinez, 2007). The typical cooking time was 10–15 minutes. An increase in cooking time was observed for experimental samples compared to the studies on wheat based composite flour for pasta products by Shanti *et al*., (2005) that showed that cooking time of pasta products ranged from 8.13 to 9.27 min.
- **Water Absorption:** This is determined using standard procedures and higher absorption reflects good hydration. (Martinez, 2007). The hydration is our tests ranged from 40-45% in contrast to the 42.46 to 53.57 of Devi et al., 2013, due to incorporation of different materials as stated in the ingredients list.
- **Nutrient content analysis:** The outcomes of nutrient analysis are arranged in Table below. The moisture levels in the 100g samples varied from 2.13 to 3.06 grams. The level of moisture was greater in the initial sample and less in final sample. The amount of

carbohydrates in the experimental products showed a decreased level after 4 months compared to the initial checked sample. The levels of protein and fat were greatest in initial sample items compared to the post 4-month analysis. The energy content of the items varied from 356.9 to 375.4 calories.

Table:

Nutrients(per 100g)	Initial sample	Post 4 months sample
Moisture (g)	2.13±0.01	3.06±0.01
Ash (g)	1.38±0.02	1.56 ±0.04
Energy (kcal)	356.9±1.55	375.4±2.96
CHO (g)	71.14±1.39	76.2±0.28
Protein (g)	12.30±0.28	13.1±0.14
Fat (g)	3.20±0.02	3.7 ±0.2

Conclusion

Food products such as pasta, are widely consumed both as a fast food and snack all over the world. Typically, pasta is produced using flour which is deficient in certain essential amino acids and lacks the necessary amount of protein. Though being an extruded product, thus being comparatively low in calories compared top other fast-food items, in order to enhance the nutritional profile of everyday pasta, supplementation with protein-rich fish mince presents a better choice. The preparation of fish pasta incorporating both the goodness of cereals and fish mince, without compromising the quality of the final product, can improve nutritional value while imparting a unique flavour and taste. Additionally, the utilization of underexploited fish species especially those from bycatch and discard in product development can improve nutritional content and reduce the overall production costs. Fish-enriched pasta is superior product with enhanced and well available protein and omega-3 fatty acids. By following the same procedure as stated above one can produce high-quality pasta with appealing sensory attributes and extended shelf stability, creating an opportunity for commercialization and broader consumer appeal.

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FROM EVERY KITCHEN TO NOWHERE - THE RISE AND FALL OF DALDA: AN ENTREPRENEURIAL LENS

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Introduction

As a cheaper alternative to desi ghee, "DALDA" was once an indispensable component of Indian home kitchens. For more than half a century, the vanaspati brand has been more widely distributed and cheaper than desi ghee. However, today, it is only found in certain specialized B2B markets and has vanished from middle-class households. A cautionary tale about how health concerns, rising incomes, and policy changes can outpace even the strongest brand strategies is the lesson of its decline.

How Dalda Won the Kitchen: Product & Distribution



Figure 1. DALDA Brand from Lever

Image source: Brands India

Branding, positioning, and distribution were the lynchpins of Dalda's meteoric rise to fame. Although expensive, desi ghee was widely available and used as a culinary staple in many Indian households in the early 1900s. As a low-cost alternative to ghee, the Dutch-imported vanaspati brand "DADA." In 1937, when the Lever brothers entered the market, they came up with the clever name "DALDA" by keeping the "Dada" name but adding the "L" from Lever (Figure 1). Since then, hydrogenated vegetable oil has gone from being an imported product to a staple in Indian households owing to its prolific marketing. Dalda had a near monopoly for the next quarter of a century to a third of a century.

The "poor man's ghee" had the same flavor and texture as more expensive varieties, but it cost much less. It became a great equalizer for middle- and working-class families, enabling them to prepare festive dishes, sweets, and parathas without breaking the bank. The distribution process has also changed the game. Lever Brothers ensured that Dalda was available in ration depots, wholesale markets, and local grocery stores across the nation. The product was easily identifiable in its distinctive yellow-green tins and was available in pack sizes that catered to consumers in both urban and rural areas.

Its advertising campaign was equally effective. Among the earliest packaged food brands to employ mass media, Dalda had memorable radio jingles, film reels, and print advertisements. A remarkable achievement for any brand, Dalda eventually became so closely associated with vanaspati that the two terms were frequently used interchangeably in advertisements. In the middle of the twentieth century, Dalda had gone from being a cooking medium to a cultural icon; it was a model of how effective pricing, robust distribution, and dogged brand promotion could lead to near-monopoly dominance.

Edible Oils vs. Dairy Fats

The market for cooking fats in India has always been split between more expensive vegetable oils and traditional ghee. Edible oil consumption has skyrocketed in the last 20 years, going from 8.2 kg per capita in 2001 to about 23.5 kg today, which is nearly twice the amount recommended by the ICMR. The total demand now stands at 25-26 million tonnes annually, while domestic production is only 11 million tonnes, making the country heavily import-dependent (~60%). Projections suggest that per capita use may reach 12.7 kg by 2034, with overall consumption climbing to 26-27 million tonnes. Meanwhile, ghee (a concentrated form of dairy fat) has retained its premium and cultural positioning. In 2024, India’s ghee market was

valued at approximately INR 3,482 billion, with a projected growth to INR 7,179 billion by 2033 (8.4% CAGR). This disparity draws attention to a crucial business realization: ghee thrives on premium value and tradition, whereas edible oils dominate in terms of volume and affordability. Dalda and other brands initially benefited from the low cost of oil, but household preferences changed as a result of increased incomes and health consciousness, demonstrating how market dynamics can change more quickly than brand positioning.

Health & Regulation: The Trans-Fat Turning Point

By the early 2000s, a growing wave of health consciousness started to clash with the vanaspati story. An inevitable by-product of the hydrogenation process that gives vanaspati its ghee-like texture, industrially produced trans fats have been increasingly linked to diabetes, obesity, and heart disease in scientific studies. The headlines in the media became harsh. Vanaspati was bluntly referred to as a "slow poison" in a 2010 Times of India article. Soon after, the regulators intervened. In 2011, the Food Safety and Standards Authority of India (FSSAI) took the first significant action, limiting the amount of trans fat in oils and fats to 10%. In 2015, this was tightened to 5%, and in January 2022, India imposed a 2% limit in accordance with the WHO's global push for elimination. From Denmark's early restrictions to New York City's 2006 restaurant ban, similar actions worldwide established a universal consensus that trans fats had no place in contemporary diets.

Concurrently, consumer sentiment has changed. Vanaspati, which was once valued for its low cost and long shelf life, has been dismissed as a thing of the past. Health-conscious urban families began turning back to "natural" substitutes such as cold-pressed oils and desi ghee. Marketers reinforce this idea by positioning olive oil, rice bran, and sunflower as "heart-healthy" options. Even clarified butter, which was once disapproved of for being fattening, has reclaimed its culinary and cultural status as the "authentic" choice. More than just a change in regulations, the trans-fat turning point marked the end of Vanaspati culture. Once a staple, vanaspati struggled to find its place as health consciousness redefined kitchen fats.

Table 1. Impact on Vanaspati (Dalda) production over the years

Year	Event	Impact On Vanaspati Ghee (Dalda)
2010	Times of India calls Vanaspati a “Slow Poison.”	Media amplifies fears, accelerating negative public perception

2011	FSSAI caps Trans Fat at 10% in oils/fats	First regulatory squeeze; vanaspati makers forced to alter formulations
2015	Limit reduced to 5%	Regulatory pressure intensified that weakened the vanaspati's cost advantage
20220	India enforces 2% limit, aligned with WHO's Global elimination goals	Effectively ended traditional vanaspati production

Data Source: Times of India

Brand & Positioning Missteps

In addition to being a health issue, Vanaspati's decline was also a branding failure. Vanaspati has been a cheap, multipurpose, bulk-sold commodity for decades. However, the product never evolved into a contemporary, distinctive brand as Indian households became more aspirational. Its dual identity is a major source of confusion. Vanaspati is still used by industrial bakeries and snack manufacturers for its texture and affordability, but at the household level, it was anticipated that the same product would compete with branded refined oils and Desi ghee. Customers were left wondering if vanaspati was an industrial ingredient or something for the home kitchen because of its hazy positioning.

In contrast, the packaged ghee brands were successfully upgraded. A once-disregarded product was repositioned as high-end and aspirational by Amul's "Pure Ghee, Pure Goodness" campaigns and Patanjali's promotion of ghee as both traditional and Ayurvedic. Vanaspati's marketing, meanwhile, either avoided addressing growing health concerns or played defensive. Ads emphasizing affordability did not connect as well with a generation that values wellness, status, and lifestyle.

Supply-Side Pressures: Raw Materials, Costs & Imports

The story's raw materials are another structural flaw in Vanaspati's work. Vanaspati is largely dependent on imported palm and soybean oils, in contrast to ghee, which is made from locally accessible milk fat. Nearly 60% of India's edible oil needs are met by imports, making it one of the biggest importers globally (NITI Aayog, 2021). More than half of these imports are palm oil, with a large portion coming from Malaysia and Indonesia.

Vanaspati is extremely susceptible to fluctuations in global prices because of its reliance on imports. Manufacturers' input costs skyrocket overnight when weather-related disruptions or

export restrictions cause palm oil prices to spike. Vanaspati is facing a margin squeeze, in contrast to premium ghee, which maintains cultural loyalty and can support higher prices. While absorbing costs reduces profits, raising consumer prices risks alienating its core base of cost-conscious customers. Consequently, the business model is continuously strained, becoming less reliable and more vulnerable to commodity cycles.

Where Dalda Survived: B2B & Institutional Uses

Dalda found a second life in the B2B and institutional sectors but declined in Indian households. Vanaspati's practical advantages, such as its texture, flakiness, and cost-effectiveness, have kept industrial bakeries, confectioners, and snack producers using it. Dalda was able to stay relevant in these industries despite consumers abandoning it at home because price competitiveness and performance were more important than perceived health.

The ownership of the brand has also changed. Hindustan Unilever sold Dalda to Bunge, a major player in the global agribusiness sector, in 2003. This signalled Dalda's transition from being the quintessential household fat in India to a quiet but reliable supplier in the food processing sector. Dalda's name is still widely used in bakeries, institutional kitchens, and packaged snack brands today. Its narrative depicts repositioning rather than extinction of the species. A legacy brand is adjusting to markets where cost and tradition continue to outweigh consumer trends driven by health concerns.

SWOC Analysis

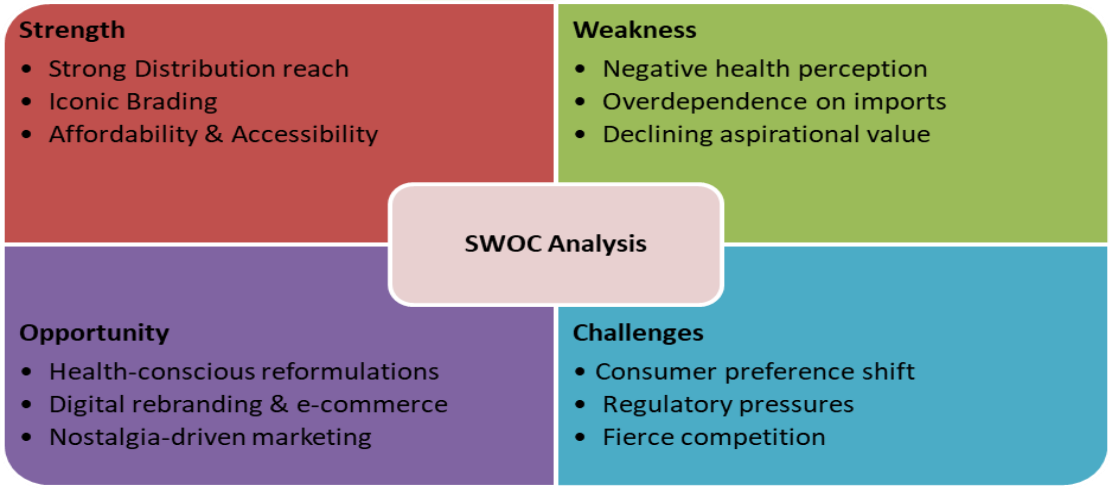


Figure 2: SWOC analysis of DALDA

Source: businesscasestudies.in

Conclusion

Markets outgrow models, as demonstrated by DALDA's journey from ubiquity to obscurity. Dalda benefited from scale, affordability, and ubiquity for fifty years. However, the brand failed to reinvent itself beyond its commodity roots as consumer aspirations changed, regulations tightened, and health consciousness increased. Ghee has been rebranded as "premium and authentic." Refined oils marketed themselves as "heart healthy." DALDA remained mired in the pricing logic of yesterday. However, its continued existence in institutional and B2B markets demonstrates that no brand dies if it can change course and continue to provide value. Dalda is still used subtly in bakeries, snacks, and industrial supply chains even though it isn't the main attraction in Indian kitchens anymore. The message for entrepreneurs is clear: distribution and price can capture markets, but only brand agility and vision can retain them in the long run. Reimagining relevance before the market abandons you is the true test, not achieving widespreadness.

"DALDA's fall demonstrates a timeless truth: in business, the most adaptable people survive, not the largest."

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KITCHEN GARDENS FOR NUTRITION AND WOMEN'S EMPOWERMENT IN SOUTHERN ODISHA

Article ID: AG-V05-I10-43

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Abstract

Kitchen gardens are small kitchen plots close to the household where vegetables, fruits, and herbs are grown by families for household consumption. In Southern Odisha, the gardens have been found to be an accessible and affordable means of enhancing family nutrition and empowering rural women. Families with kitchen gardens were reported to have improved access to fresh food and consuming a more balanced diet. Women, who typically oversaw the gardens, felt more empowered, made significant choices regarding food, and even earned additional money by selling excess produce. Kitchen gardens also motivated women to exchange information and assist one another within their villages. Therefore, kitchen gardens are not only contributing to preventing malnutrition but are also empowering women with additional strength and confidence within their homes and societies. With the right training and guidance, this humble concept can make a difference in rural life.

Keywords: Kitchen garden, Family nutrition, Women empowerment, Rural livelihood, Food security, Odisha

Introduction

Food and nutrition security remain urgent issues in much of rural Odisha, particularly in the tribal-majority southern districts. In spite of the richness in natural endowments, most

households are afflicted by dietary deficiencies that impact women's and children's health. Meanwhile, women find it difficult to access opportunities to engage in income-generating activities and make decisions in the household.

Against this background, the kitchen garden has proved to be a low-tech but potent intervention. Through the cultivation of small plots of land near the home, household members are able to produce a range of fruits, vegetables, and herbs that not only enhance nutrition but also give women more control over resources within the household. In Southern Odisha, kitchen gardens are now being seen as a weapon of nutritional security as well as women's empowerment, inducing changes that are sustainable, cost-effective, and community-led.

"Small Spaces, Big Changes"

In the green hills and valleys of Southern Odisha, small kitchen gardens are quietly transforming lives. What may look like a few rows of vegetables behind the house is, in reality, a powerful tool for nutrition, self-reliance, and women's empowerment.

Why Kitchen Garden?

In tribal and rural parts of Southern Odisha, households usually rely on markets or sporadic supplies for vegetables and fruits. This results in inadequate diets and concealed hunger, particularly among children and women. A kitchen garden solves these issues in a basic, home-oriented manner.

Affordable Nutrition – Diverse and fresh foods produced at home enhance diets without additional costs.

Self-Reliance – Families do away with market dependence and maintain vegetable availability throughout the year.

Empowering Women – Women are responsible for planning, farming, and consuming the produce, making them active decision-makers.

Safe Food – Home-grown produce with organic manure and fewer chemicals provide healthy consumption.

Sustainable Practice – Small land, recycled water, and local seeds make it eco-friendly.

REASON BEHIND KITCHEN GARDENS:

1. Nutritional Need:

Malnutrition and covert hunger remain widespread issues in tribal and rural parts of Southern Odisha. A lack of awareness regarding well-balanced diets and inadequate access to varied foods

results in nutrient deficiencies, particularly for women and children. Kitchen gardens enable families to produce a range of vegetables, fruits, and herbs that enhance diet diversity and provide year-round access to fresh, chemical-free produce.

2. Economic Need:

Rural households generally rely on unpredictable wages and endure volatile market prices. Home gardens save household money on vegetables and fruits by supplying a predictable quantity from one's own backyard. Moreover, excess yield can be marketed locally, which creates additional income to sustain the family.

3. Women's Empowerment

Women are usually the main caretakers of kitchen gardens in most homes. This increases their contribution to decision-making in the household in terms of food and nutrition. The activity enhances their confidence, enhances their capabilities, and offers them chances to make economic contributions. Taking care of kitchen gardens also offers women a sense of ownership and appreciation at the family and community levels.

4. Sustainability and Self-Reliance

Kitchen gardens encourage sustainable agriculture by recycling domestic waste, organic manure, and maintaining biodiversity. They minimize reliance on external markets and make the household more autonomous in fulfilling their daily nutritional requirements. In the long run, this practice helps to develop resilient rural communities with enhanced food and livelihood security.

Who Can Do Kitchen Garden?

The beauty of a kitchen garden is that anyone can have one, irrespective of landholding or resources.

a. Rural Families – Families can even grow seasonal vegetables and greens with a small backyard or front yard**.**

b. Urban Households – Town and city dwellers can use rooftops, balconies, or pots to form a garden.

c. Women and Self-Help Groups (SHGs) – Groups of women can collectively maintain kitchen gardens, balancing nutrition and income generation.

d. Schools and Institutions – School kitchen gardens can be used to supplement mid-day meals and educate children on the importance of healthy eating.

e. Resource-Limited Families – With recycled water, organic manure, and local seeds, even the poorest of homes can initiate and maintain a garden.

IMPORTANCE OF KITCHEN GARDEN:

i. A Garden of Health

Home kitchen gardens give households fresh fruits, vegetables, and herbs at their doorstep. For places such as Koraput, Rayagada, and Kandhamal—where malnourishment has been a long-term issue—such gardens improve dietary diversity. Leafy greens, fruits in season, and pulses produced within the home bring nutritious vitamins and minerals, thereby cutting down on anemia and under nutrition among women and children.

ii. Empowering Women

For women, kitchen gardens are not merely small plots of land but signs of confidence and freedom. In the past, women in Southern Odisha had minimal access to income and household control. With kitchen gardens, they become planners, gardeners, and decision-makers. Women get to choose what vegetables or fruits to plant based on family requirements and market demand. When surplus crop is sold on local markets, even their small earnings make them purchase some household needs or invest in education for the children. Most importantly, women earn respect and prestige in the family and society. Studies repeatedly affirm that when resources are controlled by women, they invest them in food, health, and education, which directly enhances family well-being. Therefore, kitchen gardens consolidate women's positions and enhance gender equality in rural homes.

iii. Sustainable and Low-Cost:

Kitchen gardens are extremely sustainable since they utilize locally accessible and cheap resources. Families reuse household wastewater for irrigation, produce compost from kitchen scraps and cow dung, and utilize saved seeds from earlier harvests. This minimizes reliance on chemical fertilizers and expensive external inputs. Additionally, the gardens promote growing local and climate-tolerant varieties that thrive in the soil and climate conditions of the region. These are environmentally friendly, build up the soil, and provide safe, chemical-free produce for the family. Women's self-help groups (SHGs) have been instrumental in propagating this model. Through example and peer support, they encourage other families to embrace.

iv. A Community Movement

The practice, making it a people's movement towards sustainability.

Kitchen gardening, which was previously an individual family practice, is slowly becoming a people's effort. Government programs and non-governmental organizations (NGOs) are encouraging it as part of nutrition-sensitive and livelihood programs. Training camps, demonstrations, and seed kit distribution are motivating families to initiate and sustain their gardens. SHGs and farmer clubs serve as hubs for knowledge sharing, where women share seeds, methods, and success stories. This collaborative method inculcates a sense of pride and ownership among the community. Villages in which kitchen gardens are extensively practised not only experience improved nutrition but also more cohesive communities. The movement encompasses self-reliance, food security, and empowerment—values deeply entrenched in Odisha's rural culture.

v. Growing a Better Future

The history of kitchen gardens in Southern Odisha is a straightforward but powerful one. What looks like a piece of land next to a house is actually a place of change. These gardens don't just raise fresh vegetables; they raise healthier families, empowered women, and healthier communities. They fill the gap between food insecurity and malnutrition, dependency and independence, silence and voice. Through such investments in home-based solutions, we sow the seeds of a future where women's empowerment and nutrition develop together.

KITCHEN GARDENS DURING THE COVID-19 PANDEMIC:

The COVID-19 pandemic disrupted food supply chains, limited market access, and caused income loss for millions of rural and urban households. During this crisis, kitchen gardens emerged as a lifeline for many families by ensuring a steady supply of fresh and nutritious food within the household premises. With mobility restrictions and increasing food prices, households who had kitchen gardens were less impacted by shortages of food and were able to preserve dietary diversity without relying heavily on extruded markets.

Kitchen gardens also mitigated psychological tension during lockdowns by keeping household members busy and active in meaningful work. Women, especially, were responsible for maintaining these gardens, which reinforced their agency in household decision-making and food provisioning under the crisis. Excess produce from kitchen gardens in some instances was distributed to neighbors or sold locally, producing solidarity in communities and small earnings.

Therefore, kitchen gardens not only protected families from nutritional vulnerability during the pandemic, but also underscored the value of self-sufficiency, resilience, and sustainable food systems in times of crisis.

CASE STUDY: KITCHEN GARDENS IN ODISHA DURING COVID-19

During the COVID-19 lockdown, Odisha's food supply chain was greatly affected, and it became challenging for rural families to get vegetables and fruits. The state government's Mo Upakari Bagicha (My Beneficial Garden) scheme, initiated under the Odisha Livelihoods Mission, was of great use in this time.

In areas such as Kandhamal and Koraput, self-help groups of women and households cultivated kitchen gardens with brinjal, okra, pumpkin, tomato, and leafy greens. The gardens provided household nutrition throughout the year when markets were shut down or transport became restricted. Most women indicated decreased household spending on vegetables and greater involvement in family food choices. Some households even exchanged excess produce with neighbors, enhancing support within the community during the crisis.

This experience also serves to show that kitchen gardens are not just a means of enhancing nutrition during regular times but are also a safety net in crisis situations, rendering families less vulnerable to shocks such as pandemics.

i. Odisha – Mo Upakari Bagicha initiative:

During COVID-19, Odisha's Mo Upakari Bagicha (My Beneficial Garden) initiative assisted thousands of rural families, particularly in tribal regions such as Kandhamal and Koraput, in having kitchen gardens. Households indicated improved availability of vegetables like pumpkin, brinjal, and leafy vegetables, making them less reliant on markets during time of restrictions on mobility. Women's groups were also actively involved in sustaining such gardens, providing family nutrition during lockdowns.

ii. Jharkhand – Nutrition Gardens:

The Jharkhand Government encouraged "Poshan Vatika" (nutrition gardens) during the pandemic from women self-help groups through the JSLPS. These gardens contributed to providing fresh vegetables to households and sustaining nutrition within the community when meal supply chains in anganwadis were affected.

iii. Chhattisgarh – Surplus Sharing

In Bastar district, women tended kitchen gardens that not only supported the food security of

their families but also enabled them to distribute excess produce to neighbors. This local support system reinforced solidarity during the pandemic crisis.

iv. Kerala – Kudumbashree Women's Collectives:

Kudumbashree units encouraged home/kitchen gardens throughout Kerala during lockdown. Household budgets were less strained in accessing vegetables if they had such gardens compared to families relying exclusively on markets. Women even sold surplus produce through local Kudumbashree networks.

v. FAO & Global Reports:

The Food and Agriculture Organization (FAO, 2020) emphasized that kitchen gardens were vital in most developing nations during the COVID-19 period, maintaining household resilience to supply dislocations and enhancing local food self-sufficiency.

Real-Life Success Stories from Odisha:

Laxmi from Koraput: A tribal woman of a small village in Koraput started with a handful of spinach and brinjal plants in her backyard. One year later, she diversified into tomatoes, chillies, and beans. Now her family has fresh vegetables to eat every day, and she earns approximately ₹1,500 per month by selling extra produce in the weekly market. "Before, I used to rely on the market for vegetables. Now the market relies on me," she proudly exclaims.

SHG Women in Rayagada: Self-Help Group (SHG) women from Rayagada collectively initiated kitchen gardens with training assistance from a local NGO. They cultivate leafy vegetables, gourds, and seasonal vegetables not only for their families but also to sell to the local school mid-day meal scheme. This has enhanced the nutrition of children and provided women with a community leadership status.

Sunita of Kandhamal: Being part of a poor family, Sunita herself suffered from anemia as she never had nutritious food. Now, with the initiation of a kitchen garden through seed kits provided under a government program, she cultivates amaranthus, pumpkin, and okra. Now her health is better, and she distributes seeds among neighbors. She boasts of her garden being her "green medicine box."

These narratives reveal that kitchen gardens are more about farming—about dignity, health, and hope. As more women embrace this activity, villages in Southern Odisha are seeing a quiet revolution based in soil, seeds, and confidence.

Conclusion

Kitchen gardens are a straightforward but effective strategy to deal with food and nutrition security in rural homes. Through providing access to a constant flow of fresh fruits and vegetables, they have the direct impact of improving health and dietary variety, as well as mitigating reliance on market food. Most importantly, they empower women by providing them with increased decision-making power, boosting their confidence, and opening doors to earning money. The practice also ensures that it is environmentally friendly by pursuing sustainability through organic farming and recycling of resources.

In Southern Odisha, where economic vulnerability and malnutrition are ongoing concerns, the kitchen garden is a low-cost and viable model of self-reliance. With effective training, input support, and extension linkages, the expansion of kitchen gardens can have far-reaching benefits for improving family nutrition and enhancing women's empowerment, opening the door to healthier and more resilient rural communities.

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SMART HARVESTING SOLUTIONS: ADVANCING PADDY FARMING PRACTICES

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Abstract

In order to address the ongoing issues of labour scarcity and the pressing need for timely harvesting, this article evaluates the mechanisation and operation of paddy harvesters in Tamilnadu. In comparison to conventional manual methods, it assesses the performance of mechanised systems, mainly combine harvesters, with an emphasis on important parameters like field capacity, efficiency, and operating costs. The results show that mechanisation increases farm profitability by drastically lowering post-harvest losses and human labour. Major limitations are noted in the study, though, such as the dispersed nature of land holdings and the high initial cost of machinery and supportive policies play in enabling the equitable use of these technologies.

Keyword : Paddy harvester, Mechanisation in agriculture, Combine harvester, Harvesting efficiency, Agricultural machinery, Farm profitability.

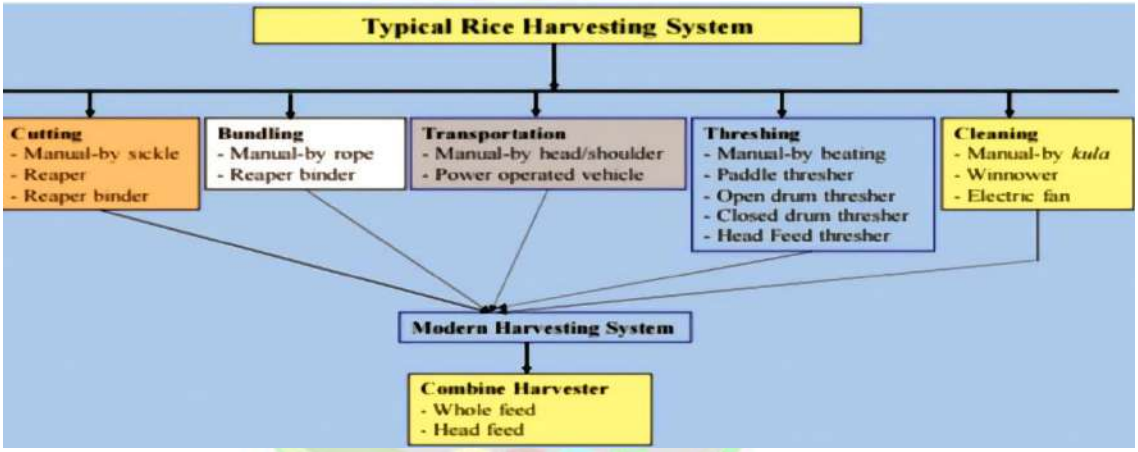
Introductions

Paddy harvesting is a crucial stage in rice production, yet traditional methods remain labour-intensive, time-consuming, and inefficient. With declining farm labour and rising food demand, smart harvesting solutions are emerging as a game changer. Modern harvesters and precision-based technologies not only save time and cost but also improve grain quality, reduce post-harvest losses, and support sustainable farming.

Advancing paddy farming through smart solutions ensures higher productivity and resilience for future food security.

Rice Harvesting System

On-time harvesting practice is the key factors to ensure sustainable production and confirm the quality of crops. Among the postharvest operations (threshing, transportation, harvesting, drying, storing and milling) of rice, harvesting is a significant activity to safeguard the crops from postharvest losses . In 2010, for example, recorded the average postharvest losses from harvesting to drying were 10%. in three rice-growing seasons . Therefore, mechanical intervention in rice postharvest operation, especially harvesting, is one of the strategic steps to ensuring Indians' food security



Traditional /manual method

Traditional techniques of harvesting rice without the use of sophisticated machinery, mostly utilising human labour and basic instruments, are referred to as manual harvesting practices in paddy. These methods are still widely used in small-scale farming and in places where mechanisation is not practical or affordable. Cutting the mature paddy crop with a hand sickle or knife is usually the first step in the manual harvesting procedure. To optimise crop output, farmers usually work in teams to chop



Cutting by sickle



Shoulder carry





Threshing

Winnowing the crop close to the ground. To make threshing easier, the paddy stalks are bundled after cutting and allowed to partially dry on the field.

Mechanical method

Paddy harvesting involves a series of mechanized operations that greatly improve efficiency and reduce labour requirements. The process begins with reaping, where machines such as self-propelled, tractor-operated, or pedal-operated reapers cut the standing crop close to the ground with minimal losses. Following reaping, threshing machines—including tangential flow and axial flow threshers—separate the grain from the straw and husk, significantly speeding up the process compared to manual methods.. After threshing, straw management machines such as straw choppers and balers handle the leftover straw, converting it into usable fodder or mulch. Supporting machinery like tractors, trailers, and dryers are essential for powering implements, transporting harvested paddy, and reducing grain moisture content to prevent spoilage.



Hand reaper



self propelled reaper.



Power tiller operated trolley



Open drum thresher



Closed drum thresher



Winnower

Together, these machines form a seamless mechanization process—reaping, threshing, winnowing, transporting, and drying—that has revolutionized paddy harvesting in modern agriculture.

Combined harvester

The combined harvester has become an essential machine in modern paddy cultivation, as it integrates the operations of cutting, threshing, separating, and cleaning grains in a single

pass. Traditional paddy harvesting is labour-intensive and time-consuming, but the use of combined harvesters ensures faster operations, reduced grain losses, and lower dependency on manual labour. These machines are especially valuable in regions facing acute labour shortages during peak harvesting seasons. Self-propelled and tractor-mounted paddy harvesters are widely used in India, helping farmers save both time and cost while increasing overall efficiency. By adopting combined harvesters, paddy farmers can achieve higher productivity, timely harvesting, and improved grain quality, making them a cornerstone of sustainable mechanized agriculture.

The assembly of the compact paddy harvester includes the petrol engine which is attached to the frame at the top position and the collecting unit is fixed at the bottom. The engine having a torque of 13N-m rotating at a speed of 8000rpm drives the pulley. The speed of the engine can be controlled by the accelerator with the help of handle control. This transmission of power from



the engine reciprocates the cutting blades causing the cutting down of crops.

Specification

1. Engine Power – Determines performance (typically 70–600 HP).
2. Fuel Tank Capacity – 300 L – 1500 L.
3. Cutting Width – 2 m – 13 m.
4. Threshing Drum Speed – 500 – 1200 rpm.
5. Grain Tank Capacity – 1000 L – 18000 L.

6. Transmission Type – 4–6 forward + 1 reverse gear.

7. Drive Type – 2 WD / 4 WD / Track drive.

8. Straw Management System – Chopper or spreader.

9. Cleaning System – Double sieve with blower.

10. Suitable Crops – Paddy, wheat, maize, barley, soybean**.**

11. Transmission – 4 to 6 forward + 1 reverse gear.

12. Drive Type – 2 WD or 4 WD / Track system for wet fields.

13. Dimensions – Length 8–12 m | Width 3–4 m | Height 3–4 m.

14. Weight – 8 to 25 tons (model-dependent).

t5. Tyres – Large rear tyres or rubber track type.

Operation of harvesting speed

The operation speed of paddy harvesters varies with machine type and field conditions. Walking-type harvesters work at 2–3 km/h with a field capacity of 0.15–0.3 ha/hr, making them suitable for small and wet fields. Tractor-mounted or reaper harvesters operate at 2.5–4 km/h with 0.3–0.5 ha/hr capacity, ideal for medium farms. Combine harvesters, commonly used in large fields, run at 4–6 km/h with a capacity of 0.8–1.5 ha/hr, offering harvesting, threshing, and cleaning in one operation. An optimal speed of around 5 km/h ensures efficiency and minimal grain loss.

Calculation of engine shaft speed

Taken engine speed=3000 RPM=11 Kmph on gear used

Wheel diameter D = 500mm

Circumference= pi^ * D = 1570mm = 1.57m

Wheel Speed=11 Kmph=11*1000/3600= 3.055m / s =3.055^ * 1000= 3055mm / s

RPS=Wheel Speed / circumference of wheel= 3055/1570= 1.94 per sec.

RPM=1.94*60=116.4

i.e. sprocket speed which is coupled with attached shaft of the wheel

N * 1 / N * 2 = D * 2 / D * 1

116.4 / N * 2 = 50/150

N2-349.2 RPM

D1 = Wheel sprocket diameter

D2 = Engine shaft sprocket diameter

N1 = Wheel sprocket speed

Harvesting process in traditional method

Labour charge per day Rs.400 per labour

Total labour required for harvesting 1-acre farm per day=7

Total amount paid to the labour=7×400= Rs.2800 per acre per day

So, total amount per day is Rs.2800.

Harvesting process made by harvester

Quantity of fuel needed for 1 acre=5L

Fuel price per litre=Rs.90

Estimated price of fuel for 1-acre land per day=5×90=Rs.450

Labour charge per day=Rs.400 per day

Total amount utilised

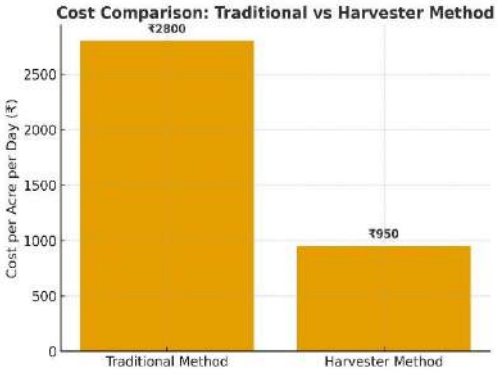
= Total cost of fuel+Labour charge per day+Maintenance

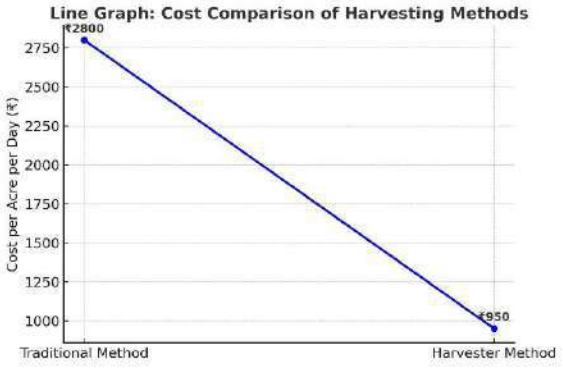
= 450+400+100= Rs.950.

Comparative table : Traditional Vs Modern Method

Parameters	Traditional Method	Harvester Method
Labour Charge per Labour (per day)	₹400	₹400
Total Labour Required (1-acre farm per day)	7	1
Total Labour Cost (per acre per day)	₹2800	₹450
Fuel Requirement (per acre)	-	5 L
Fuel Price per Litre	-	₹90
Fuel Cost (per acre per day)	-	₹450
Maintenance Cost	-	₹100
Total Cost (per acre per day)	₹2800	₹950

The analysis clearly shows that the traditional harvesting method costs ₹2800 per acre per day, whereas the harvester method reduces the cost to just ₹950 per acre per day. This demonstrates a cost saving of nearly 66% when mechanized harvesting is adopted, making it more economical, efficient, and sustainable compared to manual labour-intensive practices.





Conclusion

The adoption of paddy harvesters has transformed rice cultivation by reducing dependency on manual labour, saving time, and improving overall harvesting efficiency. By combining cutting, threshing, and cleaning operations, these machines ensure reduced grain loss and better quality produce. As farming practices continue to modernize, mechanized harvesters stand as a vital tool for achieving higher productivity and sustainability in paddy farming. Promoting their use not only strengthens food security but also supports farmers in meeting the growing demands of the agricultural

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ADVANCES IN THRESHING MECHANIZATION: EFFICIENCY GAINS, TECHNOLOGICAL INNOVATIONS, AND AGRICULTURAL PRODUCTIVITY

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Abstract

Threshing is one of the most essential post-harvest processes in agriculture, as it enables the separation of grains, seeds, and pulses from their husks, stalks, and chaff. Traditionally performed manually using wooden tools, animal trampling, or flails, the process was highly labour-intensive, time-consuming, and inefficient, leading to significant post-harvest losses. The advent of mechanization through threshers and combine harvesters has revolutionized this critical stage by improving speed, efficiency, and grain quality. Modern threshing technologies, including spike-tooth, rasp-bar, hammer mill, axial-flow, and multi-crop systems, offer higher threshing and cleaning efficiencies while minimizing grain damage and labor requirements. Comparative studies indicate that efficiency has advanced from 50–60% in traditional methods to nearly 99% in modern systems, with grain damage reduced to less than 1%. This paper reviews the technological evolution of threshing, the construction and working principles of modern threshers, and their role in enhancing agricultural productivity. Additionally, it highlights sustainability prospects through smart, eco-friendly mechanization aimed at improving food security and supporting smallholder farmers globally.

Keywords: Threshing, Mechanization, Post-harvest efficiency, Agricultural productivity

1. Introduction

Post-harvest processing represents a crucial stage in the agricultural value chain and forms the backbone of food security and rural livelihoods in many economies. Among these processes, threshing occupies a central role, as it facilitates the separation of grains and pulses such as rice, wheat, maize, sorghum, and millet from their husks, stalks, or pods. Without efficient threshing, grains cannot be adequately cleaned, stored, or marketed, leading to both economic and nutritional losses. The importance of threshing extends beyond food preparation; it directly affects the quality of produce, the efficiency of storage, and the profitability of agricultural enterprises.

Historically, threshing was performed through manual or animal-assisted techniques, such as beating bundles against a hard surface, trampling by cattle, or using simple wooden flails. While these methods were inexpensive and relied on locally available tools, they were also time-consuming, labour-intensive, and associated with high grain losses—often exceeding 10%. The low throughput and inefficiency of traditional systems constrained farmers' ability to scale production, especially as demand for cereals and pulses increased with population growth.

The advent of mechanized threshing marked a turning point in agricultural practices. Portable threshers, tractor-powered units, and later, integrated combine harvesters enabled rapid separation of grain with improved quality and reduced losses. These technological innovations significantly reduced human drudgery and improved the economic viability of farming, especially for small and medium-scale producers. Proper mechanized threshing ensures that grains are cleaner, less damaged, and free of foreign material, thus enhancing their market value. Conversely, delayed or poorly executed threshing can result in pest infestation, mold development, and spoilage, ultimately contributing to post-harvest losses that undermine food security.

In the context of rising global food demand, the modernization of threshing technology has become indispensable. Research and development in agricultural mechanization have focused on designing systems that are low-cost, durable, farmer-friendly, and energy-efficient. Increasingly, threshers are being adapted for multi-crop use, allowing farmers to process diverse cereals, pulses, and oilseeds with the same machine. Furthermore, the integration of threshing with harvesting operations through combine harvesters has revolutionized large-scale farming by enhancing throughput, improving efficiency, and reducing dependence on manual labor. This

paper explores both the historical evolution and the modern innovations in threshing mechanization, with particular attention to their implications for agricultural productivity, sustainability, and smallholder livelihoods.

2. Literature Review

The significance of threshing mechanization has been widely acknowledged in agricultural engineering and food security research. Early studies on post-harvest losses emphasized that manual and animal-assisted threshing resulted in substantial inefficiencies, often leading to 20–30% grain losses in developing economies (Hodges et al., 2011). These losses were not only due to incomplete separation but also the contamination of edible grains with husks, dust, and other impurities.

The transition to mechanized threshers has been shown to drastically improve both efficiency and grain quality. Prasad and Gupta (2020) highlighted that mechanized threshing reduced losses to below 5%, minimized grain breakage, and improved cleaning efficiency by 60–90%, depending on the machine type. They emphasized the role of multi-crop threshers in resource-limited regions, noting that adaptability across crops allows farmers to maximize returns on investment.

A growing body of literature has examined the technical performance of specific thresher designs. Sharma et al. (2018) conducted performance evaluations of axial-flow threshers and found that they provided 98–99% threshing efficiency, with less than 1% grain damage, outperforming traditional spike-tooth models. Similarly, Singh et al. (2019) reported that portable, tractor-operated threshers significantly reduced manual labor requirements while enabling farmers to process higher volumes of crops within shorter timeframes.

From a socio-economic perspective, mechanization has had far-reaching implications. Mrema et al. (2018) argued that threshing mechanization in sub-Saharan Africa and South Asia directly contributes to higher farm incomes, improved rural employment structures, and enhanced resilience against food insecurity. They also observed that mechanization plays a pivotal role in reducing gender disparities in agriculture, as women traditionally burdened with labor-intensive post-harvest activities benefit disproportionately from reduced workloads.

Beyond immediate productivity gains, the sustainability dimension of threshing mechanization has gained scholarly attention. Chandel et al. (2021) stressed the need for energy-efficient and environmentally friendly designs, particularly in regions where electricity access is

limited. The development of solar-powered threshers and machines that utilize renewable or locally available energy sources has been identified as a promising area of innovation. Similarly, Kumar and Singh (2021) discussed the integration of digital technologies, such as IoT-based monitoring systems, to optimize operational efficiency and predictive maintenance in modern threshers.

At the policy level, international organizations such as the FAO (2019) have emphasized that reducing post-harvest losses through mechanization is critical to achieving Sustainable Development Goal 2: Zero Hunger. Mechanization of threshing not only addresses quantitative food losses but also improves qualitative outcomes by ensuring grains remain pest- and contamination-free during storage and processing.

Recent works have also highlighted regional differences in the adoption and adaptation of threshing technologies. Mwangi et al. (2022) showed that smallholder farmers in Africa face barriers such as affordability, limited credit access, and lack of technical training. They advocated for public–private partnerships and government subsidies to accelerate mechanization adoption. Similarly, Yani and Raharjo (2025) documented the successful development of localized threshing technologies for cloves in Indonesia, emphasizing that tailoring designs to specific crop and regional needs improves both efficiency and adoption rates.

In summary, the literature establishes a clear progression in threshing efficiency—from 50–60% in traditional systems to nearly 99% in modern mechanized systems. Mechanization not only reduces crop losses but also enhances economic viability, labor efficiency, and sustainability. The convergence of engineering innovation, digital integration, and policy support underscores the transformative potential of threshing mechanization for modern agriculture.

WORKING AND CONSTRUCTION

A thresher is an agricultural machine designed to separate harvested crops into grains, husks, and straw residues. Its construction typically comprises a main frame, feeding chute, threshing cylinder, concave, blowers, sieves, and separate outlets for grains and straw. The frame provides structural stability, while the feeding chute directs harvested material into the threshing unit. At the heart of the system lies the threshing cylinder—commonly designed as spike-tooth, rasp-bar, or hammer mill—which rotates at high speeds against the concave. The combined actions of beating, rubbing, and squeezing detach grains from ear heads or pods.

Perforations in the concave permit loose grains, husk fragments, and straw particles to fall downward, where they undergo further cleaning through sieves or oscillating screens. An aspirator or blower fan then separates lightweight impurities such as husks and dust, while cleaned grains are collected at the grain outlet and heavier residues are expelled through the straw outlet. Modern threshers often include multiple blowers and adjustable sieves to enhance cleaning efficiency. Power requirements vary depending on size and design, with energy supplied through diesel engines, electric motors, or tractor power take-off (PTO) systems.

Operational Efficiency Factors

The performance of a thresher depends on several critical variables:

- **Cylinder speed**: Excessively high speeds increase grain breakage, while slower speeds result in incomplete threshing.
- **Clearance between cylinder and concave**: Determines separation efficiency and grain damage levels.
- **Moisture content of the crop**: Wet or overly dry material affects detachment and cleaning quality.
- **Cleaning mechanism design**: Efficient blower and sieve systems are essential for minimizing impurities.

With proper adjustments, modern threshers consistently achieve more than 95% threshing efficiency with minimal grain loss. Multi-crop designs, capable of handling paddy, wheat, maize, pulses, and millets, incorporate durable materials and safety features such as dust covers, making them indispensable in mechanized farming systems.

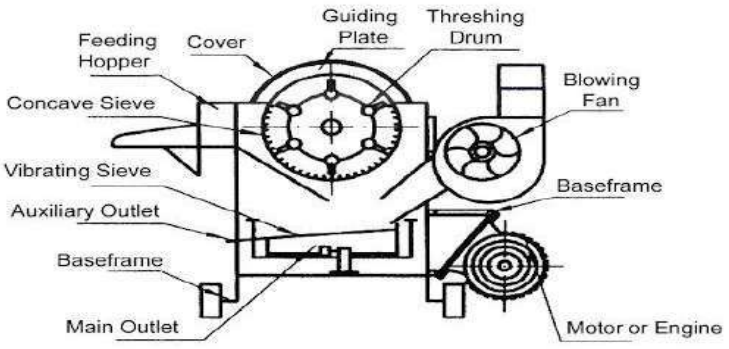


Fig 1: Components of a thersher

TYPES OF MODERN THRESHER

The types of thresher used in the modern era are, Spike-tooth thresher, Rasp-bar thresher, Hammer mill thresher, Axial-flow thresher, Multi-crop thresher, High-capacity paddy thresher, Maize thresher, Groundnut thresher, Sunflower thresher, Soybean thresher, Cotton thresher, Combine harvester thresher unit.

To separate the grains, the spike-tooth thresher uses a rotating drum with spikes that beat and rub the crop against a concave. It is widely used for wheat and paddy, offering a threshing efficiency of 95–98%, cleaning efficiency of 70–80%, and grain damage of about 2–3%.

When compared to spike-tooth models, the rasp-bar thresher uses rasp bars on its cylinder to gently rub and shear the grain from the crop. It is highly suitable for paddy and provides 96–98% threshing efficiency, 80–90% cleaning efficiency, and less than 2% grain damage.

The hammer mill thresher works on the principle of impact, where high-speed hammer-type beaters strike the crop to detach the grains. This design is effective for coarse grains but may cause slightly higher breakage, achieving 90–95% threshing efficiency, 65–75% cleaning efficiency, and about 3–4% grain damage.

System Type	Threshing Efficiency	Cleaning Efficiency	Grain Damage	Capacity (kg/hr)
Manual/Animal	50–60%	20–30%	5–10%	40–150
Pedal/Bullock	70–80%	40–50%	3–5%	150–300
Power Threshers	90–95%	60–70%	2–3%	500–2000
Modern Multi-crop	98–99%	85–95%	<1%	2000–5000

The axial-flow thresher is a modern design in which the crop moves axially along the rotating drum, ensuring uniform threshing with less loss. It achieves very high performance, with 98–99% threshing efficiency, 85–95% cleaning efficiency, and less than 1% grain damage.

The multi-crop thresher is built to handle different crops such as paddy, wheat, pulses, maize, and millets. These adaptable machines thresh grain at a rate of 95%–99%, clean grain at 80%–90%, and damage to grain is only 1%–2%. For threshing, the drummy type thresher makes use of a cylindrical drum that has spikes or teeth on it. Though more traditional in design, it is still used

in small-scale farming and provides 90–95% threshing efficiency, 60–70% cleaning efficiency, and grain damage of 2–3%.

To quickly process the crop, the rotary thresher uses a rotating mechanism with blades or spikes. It delivers 92–95% threshing efficiency, 70–80% cleaning efficiency, and about 2–3% grain damage. The paddy thresher is specifically designed for rice crops, ensuring gentle threshing that prevents cracking of delicate paddy grains. It is very efficient, threshing between 97 and 99 percent, cleaning between 85 and 90 percent, and causing less than 1 percent grain damage. The maize thresher has a wider concave and cylinder to handle corn cobs effectively. It achieves 95–98% threshing efficiency, 80–85% cleaning efficiency, and grain damage of about 1–2%.

The sunflower and groundnut thresher is made for handling large-seeded crops with care to prevent breakage of the seeds. Its threshing efficiency is 95–97%, cleaning efficiency 75–85%, and grain damage is only 1–2%. The soybean thresher operates with low cylinder speed to protect the fragile soybean seeds from cracking. It offers 95–97% threshing efficiency, 80–85% cleaning efficiency, and less than 1.5% grain damage.

The cotton thresher is specialized to separate cotton seeds from bolls while preserving fiber quality. It achieves 90–95% threshing efficiency, 70–80% cleaning efficiency, with fiber damage of about 2–3%. The tractor-operated (PTO) thresher uses the power take-off shaft of a tractor to drive the threshing mechanism, making it highly suitable for large farms. Its performance is excellent, with 95–99% threshing efficiency, 80–90% cleaning efficiency, and grain damage of about 1–2%.

Finally, the combine harvester threshing unit is an advanced machine that integrates harvesting, threshing, and cleaning in one operation. With 98–99 percent threshing efficiency, 90–95 percent cleaning efficiency, and grain damage of less than one percent, it provides the highest level of performance.

Evolution of Thresher Efficiency: From Traditional Practices to Modern Mechanization

The efficiency of threshing technologies has undergone a remarkable transformation, progressing from rudimentary manual methods to highly advanced mechanized systems. In traditional farming, threshing was performed manually using sticks, wooden flails, or animal trampling. Although inexpensive and accessible, these methods were extremely labor-intensive and time-consuming. Their performance was limited, with threshing efficiency typically ranging

between 50–60%, cleaning efficiency only 20–30%, and grain damage often as high as 5–10%. Processing capacity was particularly constrained, averaging just 40–150 kilograms per hour, which made them unsustainable for larger harvests.

A transitional phase emerged with the introduction of pedal- and bullock-driven threshers, which offered moderate improvements. These machines enhanced threshing efficiency to 70–80%, raised cleaning efficiency to 40–50%, and reduced grain damage to 3–5%. Their throughput capacity also improved, handling 150–300 kilograms per hour, but they remained limited to small-scale operations.

Period / Type	Threshing Efficiency	Cleaning Efficiency	Grain Damage	Capacity (kg/hr)
Manual/Animal (Olden Days)	50–60%	20–30%	5–10%	40–150
Pedal/Bullock Operated	70–80%	40–50%	3–5%	150–300
Power Threshers (Conventional)	90–95%	60–70%	2–3%	500–2000
Modern Multi-Crop Threshers	98–99%	85–95%	<1%	2000–5000

The mid-20th century marked a decisive shift with the widespread adoption of power-operated threshers, particularly spike-tooth and hammer mill designs. Powered by diesel engines or electric motors, these machines significantly increased efficiency, delivering 90–95% threshing efficiency, 60–70% cleaning efficiency, and grain damage levels reduced to 2–3%. Their capacity ranged from 500 kilograms to over 2 tons per hour, making them suitable for medium and large farms.

Contemporary innovations have advanced threshing performance to unprecedented levels. Modern high-capacity multi-crop threshers, including axial-flow and rasp-bar models, consistently achieve 98–99% threshing efficiency, 85–95% cleaning efficiency, and grain damage rates below 1%. Their processing capacity is equally impressive, ranging from 2 to 5 tons per hour depending on crop type and machine design.

Overall, the progression from manual to modern mechanized threshing reflects a near doubling of efficiency rates—from approximately 50% to nearly 99%. This evolution has not only minimized grain losses and breakage but has also reduced labor requirements and increased output capacity severalfold. By bridging efficiency, productivity, and sustainability, modern threshers stand as a cornerstone of agricultural mechanization and food security in the 21st century.

Conclusion

Threshing has remained a critical post-harvest operation throughout agricultural history, and its transformation from manual and animal-powered techniques to advanced mechanized systems represents one of the most significant milestones in farm productivity. Traditional methods, though accessible, were inefficient, labor-intensive, and resulted in considerable grain loss and damage. The gradual adoption of pedal-driven and power-operated threshers marked a turning point, introducing greater efficiency and scalability.

Modern threshing technologies particularly multi-crop, axial-flow, and combine harvester units now achieve efficiencies approaching 99%, with minimal grain damage and capacities ranging from 2 to 5 tons per hour. These advancements not only improve the quality and market value of agricultural produce but also reduce post-harvest losses, enhance labor productivity, and support food security.

The evolution of threshing machinery underscores the broader trajectory of agricultural mechanization, where innovations are increasingly driven by sustainability, energy efficiency, and adaptability to diverse cropping systems. Looking ahead, the integration of digital technologies, renewable energy sources, and smallholder-oriented innovations will be central to shaping the next generation of threshing systems. Collectively, these developments reaffirm the indispensable role of mechanized threshing in building resilient, efficient, and sustainable agricultural systems.

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VEGETABLE GRAFTING - A TOOL TO MITIGATE PESTS AND DISEASES IN SOLANACEOUS CROPS

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Introduction

Vegetable grafting is a promising, eco-friendly technology that combines the desirable traits of two plant genotypes - a 'rootstock' (providing tolerance or resistance to soil-borne stresses) and a 'scion' (providing superior yield and fruit quality). It has become an important component of integrated pest and disease management (IPDM) in solanaceous crops such as Tomato (*Solanum lycopersicum*), Brinjal (*Solanum melongena*), and Chilli/pepper (*Capsicum spp.*). The technology was first widely adopted in East Asian countries like Japan and Korea for watermelon and tomato production, and it is now gaining significant attention in India and other tropical regions due to the increasing prevalence of soil-borne pathogens and nematodes aggravated by intensive monocropping.

Principle and Technique of Grafting:

Grafting involves joining two plant parts, so that they grow as a single plant. The rootstock provides a strong root system and disease resistance, while the scion provides desired fruit characteristics.

Common methods used in solanaceous crops:

1. Tube (Top) Grafting – Most widely used in tomato and brinjal.
2. Cleft Grafting – Used when stem diameters differ slightly.
3. Approach (Inarching) – Used for brinjal and chilli where survival is critical.
4. Splice Grafting – For seedlings of equal stem thickness.

Procedure of grafting:

- Select disease-free seedlings (15–25 days old).

- Cut rootstock and scion at 45° angle (for tube/splice method).
- Join and secure using a silicon clip or tube.
- Maintain high humidity (90–95%) and moderate temperature (25–28°C) in a healing chamber for 5–7 days.
- Gradual acclimatization before transplanting in the field.



Importance of Grafting in Solanaceous Vegetables:

Solanaceous crops are highly susceptible to soil-borne pathogens, root-knot nematodes (*Meloidogyne spp*.), and bacterial and fungal wilts. Chemical control options are becoming less effective due to pathogen resistance and environmental concerns. Hence, grafting offers a sustainable and non-chemical alternative to maintain productivity.

Advantages include:

- Resistance to *Ralstonia solanacearum* (bacterial wilt)
- Resistance to *Fusarium oxysporum*, *Verticillium dahliae* (wilt and vascular diseases)
- Tolerance to root-knot nematodes (*Meloidogyne incognita*)
- Improved water and nutrient uptake
- Enhanced abiotic stress tolerance (salinity, drought, temperature)
- Extended crop life span and higher yields

Common Pests and Diseases Managed by Grafting

1. **Bacterial Wilt (*Ralstonia solanacearum*):**

- A major soil-borne disease of tomato, brinjal, and chilli in tropical regions.
- Causes rapid wilting, stunted growth, and yield loss up to 100%.
- Resistant rootstocks:

i. *Solanum torvum* (for brinjal and chilli)

ii. *Solanum sisymbriifolium, Solanum habrochaites, S. melongena* wild accessions (for tomato)

- Example:

Tomato cv. 'Pusa Ruby' grafted onto *S. torvum* rootstock showed up to 90% reduction in wilt incidence (Kumar et al., 2017).

2. **Fusarium and Verticillium Wilt**
   - Caused by *Fusarium oxysporum f.sp. lycopersici* and *Verticillium dahliae*.
   - Results in yellowing, vascular browning, and plant death.
   - Rootstocks: 'Hawaii 7996', 'Beaufort', and 'Maxifort' provide resistance.
   - Grafted tomatoes on resistant rootstocks yield 30–40% higher than non-grafted plants in infested soils.
3. **Root-Knot Nematodes (*Meloidogyne spp*.)**
   - Cause galls, stunted growth, and secondary infections.
   - Rootstocks: *S. torvum, S. sisymbriifolium, S. peruvianum*.
   - Example:
   - Tomato grafted on *S. torvum* reduced nematode gall index from 5.0 to 1.2 (Singh et al., 2020).
4. **Phytophthora Blight and Collar Rot**
   - Particularly in chilli and brinjal under humid conditions.
   - Grafting onto Capsicum chinense and *S. torvum* can improve tolerance

Examples of Successful Grafting in Solanaceous Crops:

Crop	Common Scion	Rootstock used	Target Disease/pest	Outcome
Tomato	Arka Rakshak, Pusa Ruby	S. torvum, Maxifort	Bacterial wilt Fusarium wilt	Reduced wilt by 80-90%
Brinjal	Arka Nidhi, Pusa Purple	S. torvum	Bacterial wilt Nematodes	Enhanced resistance, improved fruit yield

Chilli	Arka Harita, Byadagi	S. torvum, C. chinense	Bacterial wilt Root rot	Improved survival rate, reduced wilt

Challenges and Limitations

Despite its advantages, grafting faces practical and economic challenges:

- High seedling cost due to labor-intensive nursery practices.
- Limited availability of compatible rootstocks for local cultivars.
- Need for controlled healing chambers to ensure survival.
- Possible incompatibility between scion and rootstock leading to reduced vigor or abnormal growth.
- Knowledge gap among smallholder farmers and nursery operators.

Conclusion

Vegetable grafting serves as a biological and sustainable alternative to chemical pesticides in managing soil-borne pests and diseases in solanaceous crops. It ensures higher productivity, improved resource use efficiency, and resilience under biotic and abiotic stresses. Adopting this technology, especially in disease-prone regions of South and Central India, can contribute significantly to sustainable vegetable production and climate-resilient agriculture.

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USE OF ARTIFICIAL INTELLIGENCE IN HORTICULTURE

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Introduction

Artificial Intelligence (AI) is defined as the simulation of human intelligence processes by machines, particularly computer systems. These processes encompass learning, which involves acquiring information and the rules for using it, reasoning, which applies these rules to reach approximate or definite conclusions, and self-correction, which adjusts actions based on feedback. AI systems are designed to replicate cognitive functions like problem-solving, decision-making, and pattern recognition, which are typically associated with the human mind. This simulation enables machines to perform tasks that require a level of intelligence similar to human capabilities.

The development and application of artificial intelligence (AI) is profoundly influenced by its multidisciplinary nature, incorporating insights and techniques from several fields, including computer science, mathematics, psychology, neuroscience, and linguistics. Computer science provides the essential algorithms and data structures, while mathematics underpins the modelling and optimization processes crucial for AI systems. Contributions from psychology and neuroscience offer valuable understanding of human cognition, which is vital for designing AI that can mimic human thought. Additionally, linguistics is fundamental to natural language processing, enabling AI to comprehend and generate human language. The synergy between these diverse disciplines has significantly advanced AI, enhancing its capability and application across numerous domains (Jones 2022).

Why Artificial Intelligence (AI) in Horticulture?

- Artificial Intelligence (AI) is revolutionizing horticulture by offering innovative solutions to long-standing industry challenges.
- One of the key advantages of AI in this field is its capacity to improve crop monitoring.
- Through AI-driven technologies, farmers can conduct real-time surveillance of their fields, enabling early detection of diseases, pests, and nutrient deficiencies, which helps prevent significant crop losses and maintain yield quality.
- Additionally, AI enhances precision resource management by optimizing the use of water, fertilizers, and pesticides, ensuring that crops receive the exact inputs needed, thus reducing waste and costs while maximizing productivity.
- Furthermore, AI-driven automation significantly improves labor efficiency, allowing for tasks such as planting, watering, and harvesting to be performed with minimal human intervention, which lowers labor costs and increases operational efficiency. Beyond these benefits, AI contributes to the sustainability of horticulture by promoting resource conservation and reducing environmental impact, exemplified by smart irrigation systems and AI-guided pest management.
- Overall, AI's integration in horticulture not only boosts productivity and efficiency but also fosters a more sustainable and resilient agricultural sector, positioning it as a vital tool for meeting global food demand and addressing environmental concerns

Importance:

Artificial Intelligence (AI) is revolutionizing horticulture by integrating advanced technologies into various aspects of crop production and management, significantly enhancing efficiency, precision, and sustainability. AI-powered robots, such as the Greenbot, are transforming traditional farming practices by autonomously performing tasks like fertilizing, ploughing, and seeding, thereby optimizing resource use and reducing the labor-intensive nature of land preparation. In the sowing and planting phases, AI-driven robots equipped with advanced sensors and algorithms ensure precision in seeding, spraying, and weeding, adapting their operations to different crop types and leading to better yields and efficient use of inputs.

Moreover, AI significantly impacts weather forecasting, allowing farmers to make informed decisions that minimize crop losses by optimizing planting, irrigation, and harvest timings. Smart irrigation systems, combining AI with the Internet of Things (IoT), automate the

irrigation process by monitoring real-time data on soil moisture, weather, and crop needs, thereby reducing water waste and enhancing crop yield, especially in water-scarce regions. AI also advances fertilizer application by enabling precise, data-driven application based on realtime soil and crop conditions, minimizing waste, lowering costs, and improving crop health. Furthermore, AI-equipped drones and robots are transforming critical horticultural practices such as harvesting, weed and pest control, and disease detection by enabling early intervention and precise management, ultimately ensuring healthier crops, higher yields, and more sustainable farming practices

However, digital technologies, encompassing Information and Communication Technologies (ICT), present transformative solutions to these challenges. Innovations such as Artificial Intelligence (AI), Machine Learning (ML), Deep Learning (DL), Internet of Things (IoT), Virtual Reality (VR), Extended Reality (ER), Mixed Reality (MR), multispectral and hyperspectral imaging, drones, robotics, and blockchain technology offer promising applications in agriculture. The integration of sensors in crop fields and the use of cloud-based AI algorithms and Big Data Analytics facilitate the growth of Smart Farming. These technologies enable better decision-making, optimize resource use, and improve crop productivity and quality, ultimately reducing costs and enhancing farmers' income. This article explores key applications of AI-based techniques in the agricultural sector (Rathore 2021).

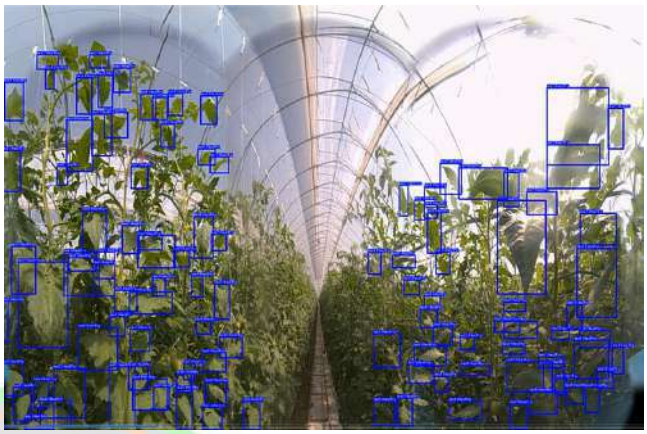
Current Approaches and Achievements

Blue River Technology leads the way in precision weed management with its "See & Spray" technology, which leverages AI to identify and target weeds selectively. This approach reduces herbicide usage and lessens environmental impact, promoting resource conservation and enhancing crop health, ultimately saving farmers significant costs. Similarly, Harvest CROO Robotics is revolutionizing strawberry harvesting with AI-driven robots that replicate the careful handling of human pickers, addressing labor shortages and boosting efficiency and productivity.

Driverless tractors mark a major advancement in agricultural automation by performing tasks like plowing and seeding with precision, reducing manual labor dependency and enhancing farm productivity. AI tools such as PEAT and B.Trace Genomics are advancing crop and soil health monitoring, using machine learning to detect issues early and optimize yields. Additionally, Sky Squirrel Technologies' AI-powered drones are transforming vineyard management by providing detailed assessments of grapevine health and maturity, improving

irrigation, fertilization, and harvesting decisions. These innovations collectively highlight AI's transformative impact on horticulture, driving sustainability, efficiency, and productivity while setting new industry standards (Zhang et al., 2023).





Ecoation-Disease-Detection-Software computer imaging

A robotic system autonomously detects and treats pests in greenhouse crops







Drones used for spraying against pest and diseases

Limitations:

The adoption of AI technologies in horticulture faces several significant challenges that hinder widespread implementation. One of the primary obstacles is the lack of familiarity among farmers with AI technologies, which creates a knowledge gap and limits the ability to integrate AI solutions effectively. This unfamiliarity often results in resistance to change and skepticism towards the benefits of AI. Additionally, the high costs associated with acquiring, maintaining and updating AI systems pose a substantial barrier, particularly for small and medium-sized farms that may not have the financial resources to invest in such advanced technologies. Moreover, the successful deployment of AI models requires large, high-quality datasets for training, which can be difficult to obtain in the horticulture sector due to the variability in crop types, growing conditions and regional practices. The collection, processing and labeling of these datasets demand considerable time, effort and expertise, further complicating the adoption process. Consequently, these limitations collectively slow down the integration of AI in horticulture, despite its potential to revolutionize the industry.

Conclusion

The integration of Artificial Intelligence (AI) in horticulture has brought about significant advancements, optimizing various aspects of the industry from precision farming to supply chain management. Recent developments have enabled AI to enhance crop yield predictions, automate labor-intensive tasks, and monitor plant health with unprecedented accuracy. Innovations like machine learning algorithms, robotics, and smart sensors are transforming traditional horticultural practices, making them more efficient and sustainable. As AI continues to evolve, its applications in horticulture are expected to expand, further improving productivity and environmental sustainability in the sector.

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ALTERNATIVE PROTEINS AND PRECISION FERMENTATION: ADDRESSING GLOBAL PROTEIN DEMAND WITH SUSTAINABLE INNOVATION

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Abstract

Proteins, act as an essential source for health from conventional sources. Rapid population growth is propelling global protein demand toward healthier more sustainable alternatives and cutting edge precision fermentation technologies. Innovations demand for extraction of protein from various sources such as plant-based proteins, insects derived meals, mycoprotein (fungal biomass), algae, cultured meat and ingredients produced via precision fermentation to offer promising solutions. This trend is strongly supported by rising market investments, with projections indicating a compound annual growth rate (CAGR) of 19 % and an estimated market turnover of USD 80 billion by 2035. Quorn, agro-industrial waste and mycoprotein places a major role in fungal based protein contained with 45-60 % protein. While the microalgal protein and insect meal source provide a protein content of 40-70 % and 40–80 % protein content. Food biotechnology sector plays a major role in this type of protein production, accounting the genetic modification in precision fermentation. Ultimately the alternative proteins and microbial fermentation will require coordination across disciplines viz., food science, systems biology, engineering, nutrition, behavioral sciences and policy. The outcome is not only a healthier planet but the democratization of nutrition and opportunity for billions.

Keywords: Protein, Cultured meat, Mycoprotein, Insect meal, Consumer acceptance.

Introduction

Proteins are the macromolecular substance that forms basic structural and functional unit

which regulate bodily functions. Though there are various types of protein available in nature, their bioavailability depends on source or origin. Conventional protein such as meat, egg, whey, soy, pea and gluten proteins offers good nutritional profiles and functional properties. These proteins are highly reliable both in human diet and industrial purpose. In addition, they also have strong market acceptance and regulatory clarity. Despite their advantages, they pose limitations such as sustainability, environmental impact including greenhouse emission. By 2050, a growing global population and heavy reliance on animal protein-using one-third of habitable land are placing immense strain on resources and driving environmental damage. It emphasis the urgent need for sustainable, resilient solutions to meet future nutritional demands [1,2].

Some of the conventional plant-based protein offer sustainability but the restriction of essential amino acid profile, anti-nutritional substance be detrimental. Considering these constraints the need for alternative protein arises. Alternate proteins such as plant based, microbial, insect and cultured meat require less land water when compared to conventional protein. Most of alternative protein are lower in saturated fat and cholesterol thus provides healthier diet option. Recently the demand for protein rises globally. The increase in demand for protein globally, along with the awareness about sustainability, ethical concern laid a road for innovation and development of alternative protein foods. This demand positions alternate protein as vital components of future-ready nutrition.

Fungal and Mycoprotein Based Proteins

Fungi, specifically filamentous fungi such as *Fusarium venenatum,* provide mycoprotein through a process known as biomass fermentation. The most recognized commercial product is Quorn now joined by a rising group of mycoprotein innovators and startups. Mycoproteins are produced under submerged airlift bioreactors, in tightly controlled, large scale fermentation vessels under either continuous or batch operation. Most agro-industrial waste streams (e.g. residues from seaweed/fruits, spent grains) act as carbohydrate sources, which are very much lower in land and water use than livestock or even plant crops. *F. venenatum* is valued for meat like texture, high essential amino acids, fiber, low fat and cholesterol free content [3]. On dry weight basis, mycoprotein contains 40-60 % protein (PDCAAS close to 1.0), 6-12 % fiber, low saturated fat and is generally rich in vitamin (including B12 analogs) and minerals (zinc, iron, phosphorus) [4]. Its amino acid bioavailability, high in leucine, makes it a strong for muscle protein synthesis. Recent clinical trials highlight benefits in safety, insulin response, and

cholesterol reduction. Consuming mycoprotein correlates with reduced glycemia, increased amino acid availability, and even a 10 per cent lower energy intake compared to comparable chicken meals. Mycoprotein's carbon footprint (5.5-6.2 kg CO_2-eq/kg) is 4-10 times lower than beef and significantly lower than chicken and pork. The water usage and land requirement is also less, when compared to beef, and even traditional plant crops [5].

Algae and Seaweed Protein

Algae, especially microalgae like *Chlorella vulgaris*, *Scenedesmus dimorphus,* and *Nannochoroposis spp.* offer highly sustainable and nutrients-dense alternatives to land-based protein. Spirulina can yield 40-70 per cent protein dry weight, require no arable land, can be farmed in seawater or non-potable water [6]. Extraction of proteins from algae uses mechanical, chemical, and enzymatic treatments in varying combinations, with novel developments considering mild extraction conditions to protect bioactivity. For example, acetone defatting with alkaline extraction from Nanochloropsis oceanica produces a protein concentrate of 86 % purity [7]. A very important finding is that essential amino acids constitute 40-45 % of algal protein, hence satisfying the FAO standards in quantity if not in quality. With the improved digestibility and sensory profile, efforts to remove any fishy or marine notes were supported using precision fermentation, flavour masking, and ingredient blending [8].

Insect Meal as Alternative Protein

Insect-derived proteins, chiefly from Black Soldier Fly (BSF), (*Hermetia illucens*), mealworm (*Tenebrio molitor*) and house cricket, stands out for converting organic waste into high –protein biomass. Insect meal contains 40-75 g/kg protein (dry basis) boasts a complete amino acid profile and is rich in micronutrients like iron, calcium and zinc [9]. Safety concerns such as accumulation of heavy metals or pathogenic microbes are being addressed through tight substrate control and proper processing. The powders of black soldier fly, cricket and yellow mealworms are approved for direct human consumption in several countries and their inclusion improves protein quality and digestibility [10]. Moreover, insect meal may have prebiotic or immunomodulatory effects, with ongoing research validating functional food claims [7].

Culture Meat Technologies and Bioreactors

Cultured meat also termed cell based or cultivated meat- represent a leap in protein production by growing animal cells in vitro, bypassing the need for raising whole animals [11]. Industrial scale cultured meat production depends on complex bio-reactors; stirred- tank, airlift

and perfusion system that maintain optimal cell growth parameters (oxygen, pH, nutrients, shear environment). To produce just 1 kg of meat, ten to hundreds of litre of bioreactor capacity are needed, depending on cell density and bioprocess design [12,13]. Cutting-edge facilities now employ continuous and perfusion systems with genetically stabilized cell lines and food-grade media- a transition away from pharmaceutical grade inputs in early proof-of-concept phases. Life cycle assessment studies showed that cultured meat can offer radical reduction in land, water and GHG emissions compared to beef 78-96 % less GHG emissions and land use (Table 1), and up to 99 % less water, depending on energy source [14].

Table 1. Cultured Meat vs. Conventional Meat (per 1kg product)

Sl. No.	Meat Type	GHG Emissions (kg CO_2-eq)	Land Use (m^2)	Water (L)
1.	Cultured Meat	10-30	10	500-2,000
2.	Beef	60-100	250	15,400
3.	Chicken	6-8	45	4,300

Precision Fermentation

Precision fermentation (PF) uses genetically engineered microorganisms (bacteria, yeast, fungi, microalgae) in controlled bioreactors to produce specific, high value proteins. Genes encoding the target compound (e.g., casein whey and ovalbumin) are inserted into the microbe, which-when provided a suitable substrate produces the ingredients during fermentation, purification and downstream processing yield a food-grade, animal free product. Recombinant casein, whey and ovalbumin replicate the texture and function of milk and egg proteins. PF is used to synthesize myoglobin (umami/meaty flavour), heme proteins (Impossible^{TM} Burger), and flavour active lipids [15, 16]. A global review by FAO (2025) concluded that PF involves no fundamentally novel safety risks compared to traditional fermentation or safety risk compared to traditional fermentation or enzyme production [17]. Existing framework (HACCP, GMP, Codex) are generally modified organisms and novel proteins is advised.

Market Trends, Investments and Regional Analysis

The alternative protein sector is growing at an unprecedented pace, forecast to expand from USD 21.5 million in 2025 to over 80 billion by 2035, with plant-based and fermentation-derived proteins leading the market. Asia-pacific is expected to from above 19 % CAGR, with the USA and EU also seeing significant investment and governmental support.

Table 2. Market Trends of Various Alternate Proteins Globally

S.I No.	Market segment	2025 value USD	2035 value USD	CAGR (%)
1.	Plant based (global)	~21.5	~80.4	14.4
2.	Insect based	2.7	~8.1	11-15
3.	Cultured meat	1.8	~5.9	>15
4.	Dairy/egg analogs (PF)	2.4	~12+	~20

Data synthesized from vantage, FMI, FBI [18,19]

Consumer Acceptance and Sensory Evaluation

Despite technical progress, consumer acceptance remains a linchpin for global adoption. Most of the people show readiness to try insects-based food and cultured meat, when they are incorporated into foods. Sensory challenge and texture mismatches, ranks as top concern which is followed by food safety and quality perceptions. Recent research and commercial sensory panels (e.g., Nectar sensory reach, 2025) demonstrated significant improvements following fermentation, hydrocolloid structuring, and precision flavor engineering [2,20,21].

Table 3. Sensory and Market Acceptance of Alternate Proteins

Product Type	Key sensory challenges	Solution strategies	Acceptance trends
Plant-based meats	Beany/earthy flavors, dryness, rubberiness.	Enzymatic hydrolysis, fermentation, hybridization	Increasing (with improvements)
Algae/seaweed proteins	Pigment/fishy odor, bitterness	Extraction refinements, blending, flavor masking	Increasing niche, expanding
Mycoprotein	Texture (rubbery/chewy), mild taste	Fiber alignment, blending, fermentation	High in EU/UK
Insect meal	Visual, psychological “ick” factor	Powdered forms, inclusion in blended foods	Moderate, rising
Dairy/egg alternatives	Off-flavors, watery mouthfeel	Precision fermentation, hydrocolloid structuring	Rapidly rising

Based on systematic reviews, NECTAR sensory data, and expert panel findings [20,21].

Conclusion

The alternative protein and precision fermentation revolution is creating a more resilient and environmentally friendly food system while expanding culinary potential and advancing

nutrition. Together, plant-based mycoprotein, insect, algae, and precision-fermentation-derived proteins offer a set of solutions that minimize resource strain on the traditional animal agriculture system, add dietary diversity, and allow for the development of set of food products with novel functionality and nutraceutical properties. Development in innovation and investment need now require hybrid formulations of protein but their consumer acceptance is limited. Improving the sensory engineering and nutritional fortification are key for mainstreaming and acceptance of these new proteins. Collaborations of various discipline such as food science, food technology, biology, engineering, and nutrition is needed to completely utilize the potential of alternate proteins. The result is not just a healthier planet, but the democratization of nutrition and opportunity for billions.

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BALANCING GROWTH AND SUSTAINABILITY: THE ROLE OF NOVEL FERTILIZERS IN CLIMATE-SMART AGRICULTURE

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Introduction

Agriculture has always been the backbone of human civilization, feeding billions and sustaining economies. But as the global population continues to grow—expected to cross 9.7 billion by 2050—farmers face the dual challenge of producing more food while protecting the environment. Traditional farming practices, especially the excessive use of chemical fertilizers, have indeed boosted yields in the past, but they also left behind footprints of soil degradation, water pollution, and greenhouse gas emissions.

This is where novel fertilizers step in—as a bridge between productivity and sustainability. By improving nutrient use efficiency, reducing losses to the environment, and ensuring crops get exactly what they need, these advanced fertilizers are now recognized as key players in climate-smart agriculture.

The Fertilizer Conundrum: Why Change is Needed

Conventional fertilizers, like urea and diammonium phosphate, have been the lifeline of the Green Revolution. Yet, their efficiency remains alarmingly low. For instance, crops often use **less than 40% of applied nitrogen**, with the rest lost through leaching, volatilization, or denitrification. These losses not only waste resources but also:

- **Pollute water bodies**, causing eutrophication and fish kills.
- **Release nitrous oxide**, a greenhouse gas nearly 300 times more potent than carbon dioxide.
- **Degrade soil health**, reducing fertility over time.

Enhanced Efficiency Fertilizers

The need for enhanced efficiency fertilizer (EEF) products was realized in the 1960s in light of the impacts of soil properties and crop growth on variable nutrient demand at different crop phenologic stages and the existence of many loss pathways The International Fertilizer Association (IFA) defines slow release fertilizers as products that release nutrients at a slower rate than their reference via biological, chemical, or biochemical mechanisms, which are not necessarily well-controlled. Examples include products such as sulfur-coated urea, neem-coated urea, urea supergranules, and partially acidulated phosphate rock. Controlled release fertilizers (CRF), are products that release nutrients at a controlled rate relative to their reference through physical mechanisms such as coatings, encapsulation, or occlusions. Examples include products such as polymer-coated fertilizers (Urea, NPKS, other straight fertilizers) or polymer-sulfur-coated urea. A third category is stabilized nitrogen fertilizers in which a more controlled-release or conversion is achieved through enzyme inhibitors (e.g., urease and nitrification inhibitors) designed to temporarily slow the biogeochemical transformation of urea or ammoniacal fertilizers.

Novel Fertilizers

Novel fertilizers are a new generation of plant nutrition products designed with efficiency, sustainability, and precision in mind. They differ from traditional fertilizers in how they deliver nutrients, minimize losses, and even enhance soil health. Some of the most promising categories include:

1. **Nano-Fertilizers** – Engineered at the nanoscale, these fertilizers release nutrients slowly and in controlled amounts. Because of their high surface area and reactivity, crops absorb them more efficiently.
2. **Novel enhanced-efficiency fertilizers:** Controlled-Release Fertilizers (CRFs) – Encapsulated with polymer, resin, or sulfur coatings, these fertilizers match nutrient release with the crop's growth stages, ensuring "right nutrient at the right time."
3. **Bio-Fertilizers** – Living microbes like Rhizobium, Azotobacter, or mycorrhizal fungi that fix atmospheric nitrogen, solubilize phosphorus, and enhance nutrient uptake naturally.
4. **Liquid and Foliar Fertilizers** – Applied directly to leaves or through fertigation, they provide quick nutrition and reduce wastage.

5. **Carbon-Based and Organic-Coated Fertilizers** – These improve soil carbon content, foster microbial activity, and act as climate-smart alternatives to purely chemical fertilizers.

Nanofertilizers

Nanoscale particles generally range from 1 to 100 nm in size and may be made from a wide range of raw materials. At present, however, nanofertilizers are poorly regulated, and marketed fertilizer products may exceed this size range despite their use of the term "nanoscale." Nanomaterials can be produced at low cost and at scale through top-down approaches, which utilize physical or chemical processes to grind, etch, or mill bulk materials to nanoscale particles or emulsions. Mechanochemistry methods can also yield nanoscale products. This contrasts with bottom-up approaches that involve smaller building blocks at the atomic or molecular scale to create nanoscale materials through self-assembly. Alternatively, nanofertilizers can be produced through biological or "green" synthesis methods.

The primary argument for nanofertilizers as EEFs is that the high surface area and small size of the fertilizer particles may enhance the uptake of nutrients by plants through nanoscale pores in plant tissues, complexation with transporters or root exudates, and exploitation of ion channels. This is of particular interest for foliar applications of fertilizer nutrients that tend to be less available to plants following soil application, such as phosphorus, manganese, iron, or zinc. Alternatively, nanostructures that encapsulate soluble fertilizers may control the release of nutrients of more mobile nutrients. As outlined by Mastronardi et al., there are three main types of nanofertilizers: (i) nanoscale bulk fertilizer inputs (e.g., emulsified urea and ammonium salts sheared to nanoscale), (ii) nanoscale additives (e.g.,NPK fertilizer containing nanocarbons), and (iii) nanoscale coatings or hosts (e.g., zeolite added to a composite fertilizer). Others conceptualize nanofertilizers by their composition (i.e., metallic nanomaterials, ceramic nanomaterials, and polymeric nanomaterials) or properties (i.e., nutrient based, action-based, and consistency-based). The exploration of novel raw materials to manufacture nanofertilizers is an area of active research and development.

Biofertilizers

Biofertilizers are defined here as formulations that contain one or more strains of microorganisms that colonize the rhizosphere, rhizoplane, or root interior of a plant and enhance its nutrition by mobilizing or increasing nutrient availability in the soil62. These bioformulations

are biological products that contain microbial inocula, solid or liquid carriers, additives, and/or treatments.

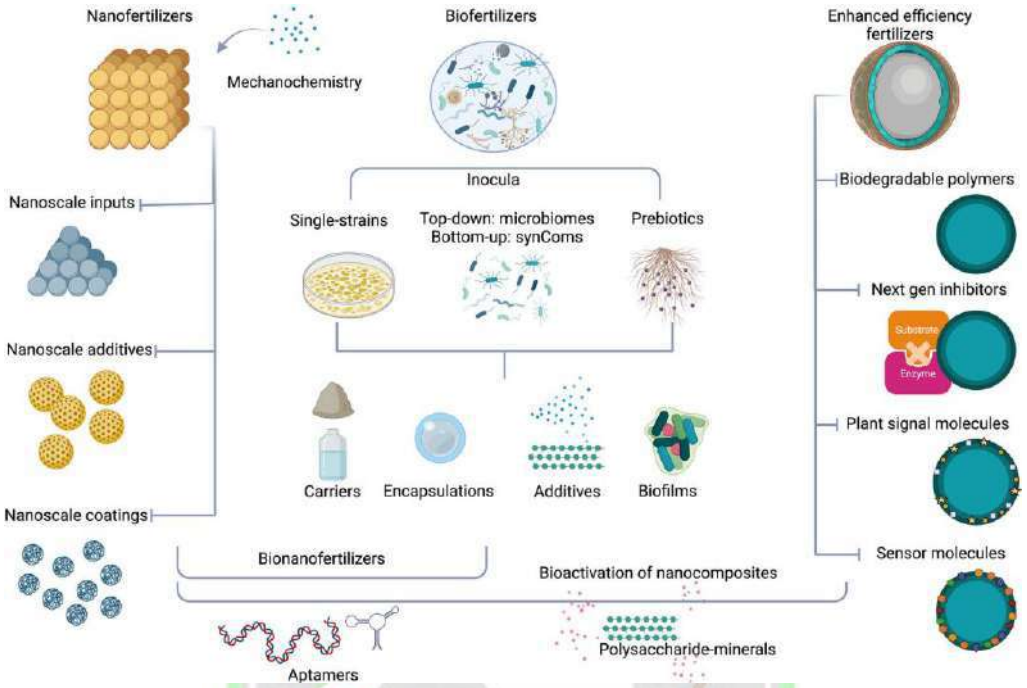


Fig. 1. Overview of novel fertilizers. Three categories of novel fertilizer products include nanofertilizers (left), biofertilizers (center), and enhanced efficiency fertilizers (right) (Source: Mazz et al., 2025)

The primary function of biofertilizers is to increase the availability of essential plant nutrients. General types of microorganisms include symbiotic and free-living nitrogen-fixing bacteria, phosphorus-solubilizing and mineralizing bacteria or fungi, potassium-solubilizing bacteria or fungi, bacteria that oxidize sulfur, microorganisms that exude chelating agents or solubilize micronutrients, and mycorrhizal fungi.

The bioformulation product development has largely moved away from single strain inoculation in favor of microbial consortia to improve survival and function of the microorganisms and/or to provide synergism, such as between arbuscular mycorrhizae and nitrogen-fixing bacteria. However, these microbial consortia may experience the same limitations that single-strain inocula face, including antagonistic interactions with resident

microorganisms, failure to establish under a range of environmental and soil conditions, and lack of persistence with time.

Novel enhanced-efficiency fertilizers

Enhanced efficiency fertilizers include formulations that provide physical or biochemical mechanisms to control the release of nutrients. Controlled release materials fall under this umbrella, which can be defined as nutrients mixed or coated with one or more materials or additives that exploit synergy and affect nutrient release. However, there is a great deal of overlap between controlled release fertilizers and nanofertilizers or biofertilizers. Traditional Controlled Release Fertilizer fall within this category, in which coating or matrices physically control the release of nutrients via organic or inorganic materials, hydrogels, hydrophobic matrices, or low solubility minerals. Likewise, stabilized forms of fertilizers, such as those treated with enzymatic inhibitors, too may be placed under the broader category of enhanced-efficiency fertilizers, in addition to other novel means to biochemically control the release of nutrients, such as via biosensors or plant signals.

Hydrogel materials, are a type of innovative technology with super absorbent properties that can either be coated onto fertilizers or prepared as a matrix. Hydrogels can be derived from naturally occurring sources or synthetic ones, and the most common polysaccharide materials include alginate, starch, cellulose, cyclodextrin, dextran, guar gum, pectin, chitosan, while acrylic acid or acrylamide are examples of synthetic sources. Nanoparticles, can coat fertilizers to modify their solubility and nutrient release. Ultimately, formulations would respond to stimuli and release nutrients as a function of environmental changes (e.g., pH, temperature, salinity, humidity, light), most reportedly governed by a diffusion mechanism.

Another novel mechanism for controlled nutrient release is to embed biosensor or receptor molecules into the fertilizer coat to respond to plant signaling molecules and then release nutrients. Aptamers, for example, are single-stranded synthetic oligonucleotides made using sequencing libraries that fold in unique shapes and bind to targets with high specificity, such as root exudates. These molecules interact with their targets through non-covalent interactions and shape complementarity, and they behave like biosensors to target root exudates or biomarkers, which allow the fertilizer to “sense” plant signals to release. In addition to aptamers, antibodies and molecular imprinted polymers are also affinity ligands that fall within this category.

Limitations and uncertainties

The commercialization of new compound products may be challenged by the risk for accumulation and toxicity, poor or weak formulations, chemical instability, and unpredictable field performance. The future efforts should identify if enhanced efficiency products provide a means to reduce agronomically or economically optimal fertilizer rates , which could increase its profitability, reduce pollution abatement costs, and achieve other long-termgoals such as producing more nutritious food and improving soil health.

Need for standard evaluations of novel fertilizers

Identifying new technologies with real potential to increase fertilizer use efficiency and meet multiple goals across diverse farming environments is contingent upon the adoption of a framework, or standard, for rigorous evaluation of product efficacy.

A rigorous evaluation framework of fertilizer products and nutrient management tools would achieve two goals: (1) accelerate the innovation process by obtaining reliable, cost-efficient information on the field performance of candidate innovations (e.g., products, practices, integrated solutions), and (2) robustly evaluate innovations across key regions for purposes of registration, market development, crop advisory for farmers, and environmental certification, etc.

Challenges in Adoption

Despite the promise, challenges remain in scaling up novel fertilizers:

- **Higher upfront costs:** Many of these fertilizers are more expensive than conventional ones, making small farmers hesitant.
- **Awareness and training:** Farmers need guidance on how to use them effectively.
- **Policy and subsidy structures:** Current policies in many countries favor bulk fertilizers over advanced ones.
- **Research gaps:** More long-term studies are needed to understand impacts on different crops and soils under varied climates.

If embraced widely, these fertilizers can help us grow more food with fewer resources, reduce the carbon footprint of agriculture, and restore balance to our ecosystems. In short, they can transform the age-old saying **“fertilizers feed the world”** into a more modern and hopeful vision: **“novel fertilizers sustain the world.”**

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COMPONENTS AND INDICATORS OF SUSTAINABILITY IN FISHERIES

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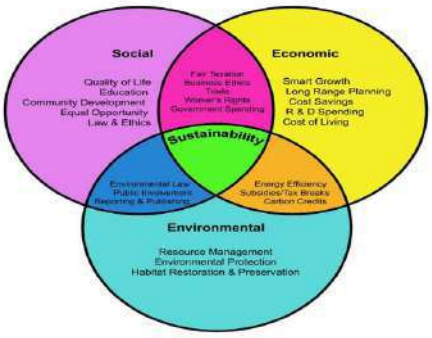
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Introduction

Sustainability or Sustainable development means that "The management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such sustainable development (in the agriculture, forestry, and fisheries sectors) conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technologically appropriate, economically viable and socially acceptable"(FAO).Sustainability has three pillars social, environmental and economic factors.



Sustainable fishing refers to the practice of harvesting fish in a way that ensures fish populations remain healthy and productive over the long term, while minimizing the impact on marine ecosystems. This involves managing fish stocks effectively, using selective fishing gear, and implementing measures to protect habitats and reduce by catch(MSC).Sustainable fishing can reverse the decline and ensure that there are enough fish left in the sea so that fishing can take

place indefinitely into the future. 16 million more tonnes of seafood could be produced every year if fisheries are managed sustainably, providing enough protein to meet the needs of 72 million people worldwide (MSC).

COMPONENTS OF SUSTAINABILITY

Ecological sustainability : At environment level, sustainability prevents nature from being used as an inexhaustible source of resources and ensures its protection and rational use. Environment conservation,investment in renewable energies ,saving water,Protection of bio-diversity .

Economic sustainability: Sustainability focuses on an efficient, responsible and just economic growth, without harming the environment. The idea is to promote the use of scarce resources in a way that is both efficient and responsible, and likely to provide long term benefits. Focuses on the macro level, i.e. on maintaining or enhancing overall long term economic welfare.

Social sustainability : At social level, sustainability can foster the development of people, communities and culture to help achieve reasonable and fairly-distributed quality of life, healthcare and education across the globe.The social welfare is based on focusing essentially on the generation of sustainable net benefits.Emphasis the 'micro' level, i.e. Focusing on the desirability of sustaining communities as valuable human systems in their own rights and more than simple collections of individuals.Enforcing social justice,
Community wellness,Conservation of culture, culture diversity, homelessness prevention.

Institutional sustainability:The sets of management rules by which fishery is governed, and the organizations that governs those rules, the bodies and the agencies that manage the fishery, whether at governmental, fisher or community level and whether formally or informally.The Global institutions influencing sustainable development governance are ECOSOC ,CSD,UNEP,WB,EMG,WTO and CEB. Some were formed under UN Charter assembly and some work as an individual organization.

INDICATORS

The basic function of indicators are – Simplification, Quantification and communication. Indicators generally simplify in order to make complex phenomena quantifiable so that information can be communicated. Each sustainability criterion is quantified appropriately whether through an objective variable, which is observable or measurable

Used to enhance

- Communication

- Transparency
- Effectiveness
- Accountability of management

PRINCIPLES OF SUSTAINABLE DEVELOPMENT INDICATORS:

Principles

- ✓ It should be universal in character, covering challenges to all countries rather than just developing nations
- ✓ It should express a broadly agreed global strategy for SD
- ✓ It should incorporate a range of key areas that were not fully covered in the MDGs, such as food security, water, energy, green jobs, decent work and social inclusion, SCP, sustainable cities, climate change, biodiversity and oceans, as well as disaster risk reduction and resilience.
- ✓ It should be comprehensive, reflecting equally the economic, social and environmental dimensions of SD and the interconnections between them.
- ✓ It should incorporate near-term benchmarks while being long-term in scope, looking ahead to a deadline of perhaps 2030
- ✓ It should engage all stakeholders in the implementation and mobilization of resources, including local communities, civil society and the private sector, along with Governments.
- ✓ It should include progress metrics alongside absolute targets, in order to focus policy attention as a means of driving development outcomes and to reflect various development priorities and conditions across countries and regions
- ✓ It should provide scope for the review of these goals in view of evolving scientific evidence.

PSR INDICATORS FOR MARINE CAPTURE FISHERIES

The Pressure, State and Response framework often used for marine capture fisheries, helps assess the ecological, economic and social dimensions of fisheries by examining the pressures they face, the resulting state of the resources and environment, and the responses to those pressures. The environmental degradation indicators the oil spills, marine diseases and typhoons as well as changes in coastal tidal flats can indicate the impact of human activities on the marine environment. The pressure indicators include the resource status, Ecosystem

health and biodiversity. The response indicators includes the management measures, economic ,social impact and community engagement.

PSR INDICATORS FOR MARINE CAPTURE FISHERIES

Dimensions	Pressure	State	Response
Ecosystem (resource and environment)	Total catch Total area fished Catch/ sustainable yield *% resources > target* Total effluent discharge	B/Target B F/ Target F E/Target E *% TR > target* *% NTR > target* Biodiversity index Community structure Trophic structure Area of critical habitat	TAC/sustainable yield % depleted stocks rebuilding Reduction of land-based pollution User rights established User fees established
Social	Fishing effort Number of vessels Growth rate of number of fishers Unemployment rate Immigration rate Social unrest	Number of fishers Demography Number of associations % below poverty line Income and asset distribution	Unemployment assistance Support to associations Resources allocation decision
Economic	Sector unemployment Subsidies Excess fishing capacity Resource rent potential	Profitability Wages and salaries Sector employment	Economic incentives & disincentives (e.g. subsidies, taxes, buy-back) Command & control measures
Institutions/ governance	Employment policies Absence of use of property rights	% resources assessed % with management plans % managt. cost recovery Rate of compliance % resources co-managed	% resources assessed Job conversion programmes Retraining programmes Number of compliance operations

Notes: B = Biomass, F = Fishing mortality, E = Exploitation rate, TR = Target resources, NTR = Non-target resources.

Integrated indicators are shown in italics

Table 1. Examples of PSR indicators

Activate Windows
Go to Settings to activate Windows

ECOLOGICAL SUSTAINABILITY INDICATORS

Sustainability criteria	Indicator	Range	Indicator at minimum if
Catch level	MSY	-∞ to 1	Catch exceeds maximum sustainable yield
Biomass	Biomass(relative to historical average)	0 to ∞	Total biomass or spawning stock biomass below a critical low level
Biomass trend	Multi year avg. Annual rate of change	-1 to 1	Biomass declining rapidly due to lack of recruitment
Fish size	Avg. Fish size(relative to historical avg.)	0 to ∞	Avg. Size at capture very low relative to optimal capture size
Environmental quality	Quality (relative to historical avg.)+ (% rate of change)	0 to ∞	Environmental quality low and declining
Diversity(harvested species)	(no. Of species)/(hist. Avg) + (diversity)/ (hist. Avg)	0 to ∞	No. Of species in each catch and diversity index both low relative to historical levels
Diversity (ecosystem)	(no. Of species)/(hist. Avg) + (diversity)/ (hist. Avg)	0 to ∞	No. Of species and diversity index both low and declining
Rehabilitated areas	Area rehabilitated as % of total area	0 to 1	Increasing area closed due to contamination
Protected areas	Area protected as % of total area	0 to 1	Decrease in areas protected from exploitation

SOCIAL AND ECONOMIC SUSTAINABILITY INDICATORS

Sustainability criteria	Indicator	Range	Indicator at minimum if
1. Community resiliency	Index of diversity in employment	0 to 1	Lack of livelihood alternative(low diversity in employment)
2. Community independence	% of economic activity based locally	0 to 1	High dependence on external economic forces
3. Human carrying capacity(livelihood)	Current sustainable employment	0 to 1	Sustainable economic or employment base is substantially below current
4.Human carrying capacity(environment)	Natural absorption capacity/ human waste production	0 to ∞	Generation of human wastes far exceeds the absorptive capacity of the environment
5. Sustainable fleet capacity	Ratio of capacity for harvesting at MSY to current capacity	O to ∞	Current capacity exceeds that required to harvest at MSY
6.Food supply	Food supply per capita	0 to ∞	Food availability per person is below minimum nutritional requirement
7. Long term food security	Probability of sufficient food being available over next 10 years.	O to 1	Stability of food supply is low , or food supply is declining rapidly

Institutional sustainability indicators

Sustainability criteria	indicator	range	Indicators at minimum if
1. Management effectiveness	Level of success to stand management and regulatory policies	0 to 1	Existing management structures are insufficient to control exploitation level and regulate resource users
2.Use of traditional methods	Extent of utilisation	0 to 1	Traditional resource and environment management methods not utilised
4. Capacity building	Extent of capacity building effort	0 to 1	Lack of capacity building within relevant organisations
5. Institutional viability	Level of financial and organisational viability	0 to 1	Management organisations lacks long term financial viability or there is a lack of political will to support such structures

Conclusion

The components and indicators of sustainability in fisheries is a holistic approach combining ecological health, economic stability, and community participation is essential for true fisheries sustainability now and for the future.

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WHY SOLAR ENERGY IS BLOOMING AS FASTEST SOURCE IN TAMIL NADU?

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Abstract

Tamil Nadu is rapidly becoming a leader in solar energy adoption due to its abundant sunlight, supportive government policies, and increasing public awareness. Initiatives like the PM-KUSUM scheme and the Chief Minister's Solar Pump Scheme have helped farmers secure irrigation while cutting fuel costs. Additionally, rooftop solar installations are rising among urban households and industries. Large-scale projects such as the Kamuthi Solar Plant demonstrate the state's prominent position globally. Besides economic benefits, solar energy reduces reliance on coal, lowers emissions, and contributes to India's net-zero goals. Expanding solar energy adoption is essential for Tamil Nadu's sustainable development and a cleaner energy future.

Keywords: Solar Power, Irrigation, Agriculture, Net-Zero, Rooftop

Introduction

Tamil Nadu has quickly established itself as a leader in solar energy, driven by its abundant sunshine and proactive policies. With an estimated 1,29,000 MW (1.29 lakh MW) of solar potential, the state is one of India's most resource-rich areas for solar power, according to the Central Electricity Authority (CEA) (Times of India, 2024). As of early 2025, Tamil Nadu has installed more than 9,400 MW of solar power, making it one of the leading states in India's renewable energy sector in terms of actual deployment (New Indian Express, 2025).

In terms of solar absorption, the state has also achieved noteworthy achievements. The highest-ever single-day solar energy absorption and peak generation in Tamil Nadu occurred on

April 23, 2024, with 40.50 million units (MU) and 5,398 MW, respectively (The Hindu, 2024). Through its state transmission utility, Tamil Nadu captured 11,033 MU of solar power for the fiscal year 2023–2024 (The Hindu Business Line, 2024). These accomplishments demonstrate the effectiveness of programs like the Tamil Nadu Solar Energy Policy (2019) and central government programs like PM-KUSUM, which support rooftop installations and solar pumps for agriculture.

Solar power is emerging as Tamil Nadu's fastest-growing energy source, with the state government declaring plans to install 10,000 MW of additional solar capacity in the next five years (Times of India, 2024) and the demand for clean energy continuously increasing.

State blessed with Solar Energy

Tamil Nadu is unique among Indian states in that it has a high solar insolation and long stretches of sunny, clear weather, which makes it an ideal place to generate solar electricity. The state receives between 5.6 and 6.0 kWh of solar radiation per square meter per day, particularly in flat, non-shaded, and coastal areas, according to government sources. It also has more than 300 sunny days annually, which gives solar installations a wide window of strong sunlight to function effectively (environment.tn.gov.in). Southern and coastal areas, such as Thoothukudi, have the greatest levels of Global Horizontal Irradiation (GHI), which varies from 5.13 to 5.66 kWh/m²/day in numerous sections of the state (OUP Academic).

The enormous solar potential is further supported by studies like Distributed Solar Mapping by Auroville Consulting, which projects a distributed energy resources (DER) solar potential of about 129,166 MW, of which about 60,479 MW comes from rooftop solar alone. Compared to cloudier places, Tamil Nadu's ample and consistent sunlight guarantees that solar panels receive more hours of efficient production, even though only a small portion of this potential has been realized to date. According to Auriolville Consulting, solar energy is a sustainable and economical source of electricity for the state because sunlight is "free," meaning it doesn't require fuel and has low operating expenses once installed.

Government Push and Policies

Tamil Nadu's solar energy boom is not coincidental. In 2012, the state government unveiled the Tamil Nadu Solar Energy Policy, which was revised in 2019 and included aggressive goals to increase the use of solar energy. The drive has been tremendous, ranging from residential panel subsidies to massive solar projects (TIDCO, 2019).

By offering solar pumps at discounted prices, the PM-KUSUM program helps farmers lessen their reliance on unstable electrical supplies. Net metering also helps households by enabling them to sell excess solar energy back to the grid. This can result in reduced electricity costs and even a little source of cash for many families.

Transforming Agriculture

Tamil Nadu is pioneering the integration of solar energy into agriculture with the dual objectives of enhancing sustainability and minimizing farmers' dependence on conventional energy sources. The Chief Minister's Solar Powered Pump Scheme extends substantial support, granting an 80% subsidy to small and marginal farmers from Adi Dravidar and tribal communities, while other farmers are eligible for a 70% subsidy (AED, 2022). Similarly, under the PM-KUSUM Scheme, both the central and state governments collectively contribute 60% of the subsidy, leaving 40% to be borne by the farmers (The Hindu, 2024; IndiaSpend, 2025). These programs are designed to promote the adoption of solar-powered pumps, reduce electricity costs, and foster environmentally responsible irrigation practices, thereby driving a transformative shift in the state's agricultural landscape.

For many years, farmers in Tamil Nadu have faced difficulties due to unreliable electricity and increasing diesel expenses. For instance, a farmer who previously spent about ₹2,000 each month on diesel for his motor can reduce this cost to almost nothing by switching to solar power. The savings can then be directed toward essential needs such as seeds, fertilizers, or even children's education. Through the PM-KUSUM scheme (The Hindu, 2024; IndiaSpend, 2025), farmers receive subsidies that cover up to 60% of the installation cost, providing reliable irrigation without depending on inconsistent electricity supply. This transition not only eases farming operations but also promotes sustainability and improves farmers' income and productivity.

Powering Homes and Industries

Rooftop solar panels are becoming increasingly popular in cities such as Chennai, Coimbatore, and Madurai, with both households and businesses adopting the technology. The **Green Energy Open Access Regulations, 2025**, issued by the Tamil Nadu Electricity Regulatory Commission, allow industries with a minimum connected load of 50 kW to buy renewable energy from third-party providers, encouraging a broader transition toward clean energy (Times of India, 2024; ET EnergyWorld, 2025)

Tamil Nadu is home to some of India's largest solar parks, including the Kamuthi Solar Power Project in Ramanathapuram (New Indian Express, 2016), which was among the world's largest at the time of its commissioning. These large-scale projects not only supply clean and reliable energy but also position Tamil Nadu as a significant player on the global renewable energy map.

A Cleaner, Greener Future

The move toward solar energy is driven not only by economic benefits but also by environmental responsibility. Tamil Nadu, like the rest of India, is grappling with increasing energy demand and the urgent need to address climate change. By generating electricity from the sun, carbon emissions are reduced, dependence on coal diminishes, and the state contributes to India's broader target of achieving **net-zero emissions by 2070 (**The Hindu, 2024).

With growing awareness, solar power is increasingly viewed as essential rather than optional. The younger generation, in particular, sees the adoption of renewable energy as both a source of pride and a duty toward building a sustainable future.

Conclusion

Tamil Nadu's plentiful sunshine and government-led initiatives have positioned it as a frontrunner in solar energy usage. Government schemes like PM-KUSUM and the Chief Minister's Solar Powered Pump Scheme have enabled farmers to move away from diesel, providing affordable and reliable irrigation. Rooftop solar installations are becoming more common among urban households and businesses, and large-scale projects such as the Kamuthi Solar Power Project showcase the state's leadership in renewable energy. Even with these achievements, further advancements are needed in developing affordable solar technologies, assessing region-specific solar capacity, and linking solar solutions with smart farming practices. It is also vital to examine how farmers adopt solar technologies, identify financial and technical obstacles, and assess the long-term environmental and economic benefits. Expanding the use of solar energy in agriculture remains crucial for sustainable farming and is a key component in reaching India's net-zero emissions objectives, making this field important for future research and development.

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BUNCH NUTRITION AND SPRAYS FOR SUPERIOR BANANAS

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Abstract

Banana (*Musa paradisiaca* L.) is one of the most important fruit crops grown under tropical conditions and requires effective bunch management practices to enhance quality and yield parameters. Post-shooting treatments such as chemical sprays, foliar nutrition, biostimulants, and bunch feeding, trimming, and covering methods have been explored in recent studies for their impact on fruit maturity, quality, and marketability. The literature reviewed highlights that foliar sprays of sulphate of potash (SOP) and brassinosteroids significantly improved bunch characteristics, while biostimulant applications enhanced fruit size and yield. Bunch feeding with integrated nutrient sources increased pulp-to-peel ratio, sugars, and total soluble solids (TSS), whereas non-woven and leno bag coverings improved fruit quality, reduced pest incidence, and extended shelf life. Hand retention practices also showed potential to balance fruit size and overall yield. This review consolidates research findings from 2017 to 2025, emphasizing that integrated post-shooting bunch management offers promising avenues for enhancing yield, fruit quality, and profitability in banana cultivation.

Introduction

Banana (*Musa paradisiaca* L.) is a staple fruit crop in India, with cv. Grand Naine being commercially dominant due to its high yield potential and acceptability in export markets. Despite its productivity, the fruit is vulnerable to environmental stresses, physiological disorders, and biotic stresses during bunch development. Effective post-shooting bunch management is essential to optimize maturity, improve quality parameters, reduce post-harvest losses, and enhance market value.

In recent years, significant research has focused on post-shooting interventions such as chemical sprays, fertilizer foliar applications, biostimulants, bunch feeding, trimming, and protective coverings. These efforts are aimed at improving physico-chemical attributes, maximizing yield, and ensuring higher profits for farmers under diverse agro-climatic conditions. This review presents compiled findings from various research studies conducted between 2017 and 2025 across India, highlighting the advancements and effectiveness of different bunch management practices.

Literature Review

1. Post-Shooting Chemical Sprays

Rajan *et al*. (2017) evaluated the effect of growth regulators and chemicals on banana cv. Grand Naine. Spraying with ethephon (2 ml L^{-1}) reduced maturity duration, while brassinosteroid (2 mg L^{-1}) enhanced TSS, pulp-to-peel ratio, and fruit yield. Similarly, Paradava *et al*. (2022) reported that CPPU at 4 mg L^{-1} improved pulp-to-peel ratio, whereas SOP (2%) significantly increased TSS and sugar content, especially in combination with non-woven bag covering.

2. Foliar Fertilizer Applications

Patil *et al*. (2018) demonstrated that SOP at 1.5% proved most effective in reducing maturity duration and enhancing bunch weight and yield. Covering bunches with 18 µ blue polythene increased gross income and benefit-cost ratio. Devang et al. (2021) highlighted that cow dung slurry with SOP (10 g) and ammonium sulphate (20 g) improved sugar content, TSS, and ascorbic acid levels compared to SOP and KNO_3 sprays alone.

3. Biostimulant Applications

Recent investigations have emphasized the importance of biostimulants in banana yield enhancement. Wankhade *et al*. (2023) revealed that combined application of Aminogrow Active and SiLife significantly improved bunch weight (25.75 kg), fruit size, and yield (114.41 t ha^{-1}), outperforming several chemical treatments and showing effectiveness in enhancing physiological growth.

4. Bunch Feeding Practices

Bunch feeding has also emerged as a key practice. Maksudan (2023) and Maksudan *et al*. (2024) reported that feeding a combination of urea (9 g), SOP (9 g), cow dung (500 g), and banana special (0.2%) significantly improved bunch weight, pulp-to-peel ratio, TSS, sugars, and

yield (82.20 t ha^{-1}). Such integrated practices proved superior to control in improving both yield and quality attributes.

5. Bunch Covering Methods

Bunch coverings play a vital role in modifying the microclimate around fruits. Murali *et al*. (2025) found that red and green leno bags not only improved bunch weight but also reduced pest incidence and chilling injury scores, thereby improving quality and income. Similarly, Yugandhar *et al*. (2021) demonstrated that spraying SOP (5 g L^{-1}) combined with non-woven bag covering reduced beetle infestation to 1.52% compared to 44.32% in uncovered bunches and enhanced fruit cleanliness and marketability.

6. Bunch Trimming and Hand Retention

Bunch trimming is another important management strategy. Wankhade *et al*. (2023, 2024) demonstrated that retention of fewer hands (6 per bunch) improved individual fruit size and weight, whereas retaining 9–10 hands optimized total yield (105–107 t ha^{-1}) and profitability with superior benefit-cost ratios. Such hand retention practices enable growers to strike a balance between quality and quantity depending on market demands.

Conclusion

The reviewed literature emphasizes that integrated bunch management practices are crucial in enhancing banana yield and fruit quality. Key strategies include foliar sprays of SOP and brassinosteroids, biostimulant application, nutrient-rich bunch feeding, protective bagging, and hand retention practices. Among these, SOP at 1.5–2%, biostimulants like Aminogrow Active with SiLife, and red/green leno bag coverings showed consistent results across multiple studies. Bunch feeding with cow dung, SOP, and banana special enhanced both yield and quality, while trimming practices optimized fruit size and proportionate yield.

Integrating these techniques offers a sustainable and profitable approach to banana production, especially for cv. Grand Naine, under tropical to sub-tropical conditions. Further research on combining chemical, organic, and protective measures could pave the way for precision bunch management technologies in banana.

The future prospects of bunch management in banana

The future prospects of bunch management in banana are highly promising, with research and technological innovations pointing towards increased productivity, quality enhancement, and sustainability in banana cultivation.

Precision Farming & Smart Technologies

Recent advances, such as IoT-enabled precision farming, allow growers to optimize water, nutrient, and fertilizer use, tailor interventions to crop needs, and improve both yield and resource-use efficiency. Automated systems, data-driven decision-making, and precision dosing of nutrients (especially potassium and biostimulants) are expected to become standard practices in progressive banana production.

Integrated Nutrient and Bunch Management

Continuous research supports the effectiveness of post-shooting nutrient sprays, integrating potassium sources (e.g., SOP, potassium dihydrogen phosphate), urea, and growth regulators for maximized yield, quality, and sugar accumulation. Combinations of nutrients and regulated bunch feeding are likely to be honed for tailored regional solutions, improving specific physico-chemical traits favorable for both domestic and export markets.

Sustainable and Organic Approaches

Growing concern for sustainability drives interest in organic amendments, biostimulants, and biological pest control options. Practices such as drone-assisted distribution of biocontrol agents (predatory mites) and organic manure use are proving viable for large-scale operations. Shifting from chemical inputs toward timed organic inputs feeds soil microbes, improves plant health, and helps maintain high yields with reduced ecological impact.

Improved Covering, Post-Harvest, and Value Addition

Innovations in bunch covering materials (non-woven bags, leno bags, biosourced plastics) will further protect fruits from pests, scarring, and environmental stresses while extending shelf life and minimizing post-harvest losses. Advanced sorting, cleaning, and packing, along with post-harvest maturity management, can greatly increase market and export potential. Value addition through banana-based processed products also presents new economic opportunities.

Adaptive Research and Farmer Adoption

Stakeholder-driven research, on-farm trials, and co-design of solutions are helping bridge gaps between laboratory findings, field environments, and market needs, ensuring that best practices are practical and easily adopted by farmers at scale. The focus is shifting toward transition pathways that couple technological progress with resilience, profitability, and environmental stewardship in banana systems.

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EMERGING BIOTECHNOLOGICAL APPLICATIONS OF BIOACTIVE COMPOUNDS FROM MICROALGAE AND SEAWEEDS

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Abstract

Microalgae and seaweeds have gained increasing attention as renewable bioresources for producing high-value compounds with nutritional, pharmaceutical, and industrial importance. Both groups synthesize a wide range of primary and secondary metabolites, including polysaccharides, pigments, polyphenols, vitamins, polyunsaturated fatty acids, and peptides, which display antioxidant, antimicrobial, anticancer, and anti-inflammatory properties. Recent developments in cultivation, extraction, and biorefinery technologies have enhanced the sustainable recovery of these bioactives for applications in food, cosmetics, pharmaceuticals, and agriculture. Additionally, algae-derived biomolecules play an emerging role in bioplastics, biofertilizers, and nanoparticle synthesis, highlighting their contribution to circular bioeconomy models and environmental sustainability. This communication briefly presents recent advances in the valorization of algal compounds and their potential to substitute synthetic alternatives in multiple industries.

Keywords

Microalgae; Seaweeds; Bioactive compounds; Polysaccharides; Pigments; Bioplastics; Nanoparticles; Biofertilizers

Introduction

Algae represent a vast and diverse group of photosynthetic organisms encompassing both macroscopic seaweeds and microscopic microalgae. They have emerged as sustainable feedstocks for bioactive metabolites owing to their rapid growth, ability to utilize saline or

wastewater resources, and minimal land requirements. Compared with terrestrial crops, algae possess higher biomass productivity and biochemical diversity, making them promising candidates for biofuel generation, nutraceuticals, and high-value product development.

Edible species such as *Spirulina*, *Nostoc*, *Aphanizomenon flos-aquae*, and *Pyropia* have long been consumed for their nutritional benefits, being rich in proteins, vitamins, minerals, and essential fatty acids. In recent decades, research has expanded to harness their biochemical potential for industrial and pharmaceutical purposes. Algae-derived compounds—such as polysaccharides (agar, alginate, carrageenan, fucoidan, laminarin, ulvan), pigments (carotenoids, chlorophylls, phycobiliproteins), and phenolic metabolites—exhibit potent bioactivities including antioxidative, antiviral, and anticancer effects.

Technological advancements in algal cultivation and extraction, such as mixotrophic growth optimization, enzyme-assisted and supercritical fluid extraction, and biorefinery integration, have substantially improved the yield and purity of these compounds. Consequently, algae are increasingly viewed as key contributors to the bio-based economy, offering sustainable alternatives to synthetic chemicals in multiple sectors.

Methods

1. **Cultivation and Biomass Production:**
   Strains such as *Spirulina platensis*, *Nannochloropsis salina*, *Porphyra umbilicalis*, and *Dunaliella salina* were highlighted for their high production of phycobiliproteins, fatty acids, and carotenoids under controlled light, nutrient, and salinity regimes. Mixotrophic culture conditions, nutrient limitation, and stress induction (e.g., high light or nitrogen starvation) were shown to enhance metabolite accumulation.
2. **Extraction and Purification Techniques:**
   Recent trends favor eco-friendly extraction using ultrasonication, enzyme-assisted digestion, microwave-assisted and supercritical CO_2 extraction. These methods improve recovery of thermolabile compounds like carotenoids, vitamins, and polysaccharides while minimizing solvent use.
3. **Analytical and Application Assessment:**
   Studies employed chromatographic and spectroscopic analyses (LC-QTOF-MS, FTIR, GC–MS) to identify compound profiles. Functional properties were tested in food,

pharmaceutical, and environmental models—such as antioxidant assays, cytotoxicity screening, and polymer formulation trials for bioplastics and nanoparticle stabilization.

Conclusion

Microalgae and seaweeds constitute a promising platform for sustainable production of bioactive compounds with wide-ranging applications. Their metabolites—particularly polysaccharides, pigments, fatty acids, peptides, and polyphenols—demonstrate significant biotechnological potential as natural antioxidants, antimicrobials, nutraceuticals, and biomaterials. Emerging uses in bioplastics, biofertilizers, and nanotechnology further expand their industrial value while supporting environmental remediation and circular economy principles.

Future efforts should focus on integrating advanced cultivation systems with scalable biorefinery processes, genetic engineering for yield enhancement, and green extraction technologies. These strategies will accelerate the commercialization of algal bioactives and establish algae as a cornerstone of sustainable biotechnology.

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SMART AGRICULTURE: LEVERAGING SENSORS FOR EFFICIENT WEED MANAGEMENT

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Abstract

Weeding plays a vital role in ensuring crop quality and yield, yet it remains one of the most time-consuming and cost incurring farm operation. Manual weeding typically consumes 40–50 hours of labour and costs farmers nearly ₹6,000–₹8,000 per hectare. Sensor-based and mechanized weeders have significantly reduced costs to between ₹2,000 and ₹3,000 per hectare and decreased operation time by up to 70%. With up to 95% accuracy, these advanced systems use AI cameras, infrared detectors and GPS navigation to identify weeds, ensuring precise control and minimizing herbicide use thus protecting the soil and crop diversity. As a result, they improve crop productivity, reduces labour dependency, lowers the chemical usage thus supporting sustainable, eco-friendly farming practices. By combining automation, precision and intelligence, smart weeding technologies are paving the way for a future in which every hectare works smarter rather than harder.

Introduction

Weeds are the biggest silent enemies of crops which cause a reduction of 30–40% of yield potential every season. They deplete essential nutrients, water and sunlight required by the crop. Among farmers, weed infestation comes on top among other issues including labour shortages, unpredictable rainfall, rising fuel prices and the growing demand for eco-friendly farming. Effective weed management practice is required to maintain optimum plant population and yield. Traditionally, hand weeding has been one of the most time-consuming and labour-intensive farm operations. A farmer spends nearly ₹6,000–₹8,000 per hectare and 40–50 man-hours on manual

weeding, often achieving inconsistent results. The overuse of herbicides further deteriorates soil health and pollutes the environment. Today, however, agriculture is entering a smart era. With the introduction of mechanized, power and sensor-based weeders, farmers can now remove weeds 3 to 4 times faster, cut costs by up to 60%, and protect both crops and soil. With AI cameras, infrared sensors and precision blades, these modern machines not only accurately detect weeds but also reduce herbicide use and energy consumption. In the face of global climate stress and labor scarcity, weeding mechanization and sensor innovation stand out as game-changers. They represent the perfect balance of technology, sustainability and practicality, ensuring that farming remains profitable, productive and eco-friendly for the future generations.

Smart Sensor based Weeder

The smart sensor-based weeder uses infrared, ultrasonic and proximity sensors to differentiate weeds from crops. Each sensor scans the soil, identifying differences in leaf color, height and spacing. When it spots an unwanted plant, a tiny blade or robotic arm swings into action thus trimming the weed without disturbing the healthy crop beside it. Some advanced models even include AI-powered cameras that "see" weeds better than the human eye, working perfectly under any light or soil condition. These smart weeders can move on their own or be attached to tractors. Farmers track their progress through IoT dashboards, which show weed maps and performance data in real time.



Fig.1.Smart sensor based weeder Source: Gaines, (2018)

PRINCIPLE AND MECHANISM OF OPERATION

The sensors detect the presence of weeds based on color, texture and position differences from the crop. The onboard microcontroller processes this data and activates a cutting tool or robotic arm to remove the weed selectively. The mechanism protects crop roots and minimizes soil disturbance while ensuring that only unwanted plants are removed.

DRONE-ASSISTED WEEDING SYSTEM

The adoption of drones has significantly advanced and revolutionized weeding operations. The drones use RGB and multispectral cameras to spot harmful plants from above. They analyze crop color, leaf texture and chlorophyll content to create detailed weed distribution maps. Drones either spray environmentally friendly bio herbicides on specific locations after identifying weeds or send coordinates to ground robots that mechanically remove them. Drones of today come equipped with variable-rate sprayers and GPS autopilots that automatically adjust spray volume and altitude. Smart, secure and long-lasting, this is precision farming at its finest.



Fig.2.Drone assisted weeding system

WORKING PRINCIPLE AND MECHANISM

Field images are taken by aerial cameras with high resolution. The onboard software analyzes these images to distinguish weeds from crops based on color and canopy variation. The drone's GPS system marks the infested spots, after which either a targeted sprayer or a robotic ground unit performs localized weeding or spraying.

SOLAR POWERED WEEDER

The Solar-Powered Weeder is a clean, green hero of sustainable farming. Solar panels capture sunlight and store it in batteries that power rotary blades or tines to remove weeds efficiently between rows. This innovation is perfect for farmers in off-grid or rural areas, cutting fuel costs while protecting the planet. Many models are self-propelled or tractor-mounted, featuring automatic depth control and solar-tracking panels to capture maximum energy. Eco-friendly, cost-effective, and low maintenance. This weeder proves that renewable energy can make even the toughest farm work effortless.



Fig.3.Solar power weeder

WORKING PRINCIPLE AND MECHANISM

Solar energy is converted into electrical energy by photovoltaic panels, which then charge onboard batteries. Brushless DC motors attached to rotary blades or tines are driven by the stored power. As the machine moves through the field, it uproots or cuts weeds while maintaining a constant working depth for uniform results.

WEEDER WITH AI AND VISION – THE GENIUS ON WHEELS

The AI and Vision-Guided Robotic Weeder uses deep-learning algorithms and high-resolution cameras to distinguish between crops and weeds based on their shape, color and texture. Once identified, its robotic arms or cutters remove weeds selectively, leaving crops untouched. These robots work day or night with LED-assisted vision and move independently with GPS navigation. Farmers can even monitor the patterns of weed growth and devise more effective planting strategies by using real-time mapping and data collection.



Fig.4.Weeder with AI and vision

PRINCIPLE AND MECHANISM OF OPERATION

The onboard vision system captures real-time field images. The AI algorithm processes each frame to classify plants as weeds or crops. The precise cutting or uprooting of the weed is then guided by a robotic actuator or microblade.

The robot uses GPS and sensor-based navigation to move precisely between crop rows without human intervention.

ELECTRIC / LASER WEEDER – POWER AND PRECISION WITHOUT CHEMICALS

Although using electricity or lasers to weed sounds futuristic, it actually takes place. Electric weeders destroy the weed stem and root with a high-voltage current without disturbing the soil. Laser weeders, on the other hand, instantly burn weeds with focused light beams guided by AI-based cameras. These high-speed machines can eliminate over 100,000 weeds per hour, making them ideal for large commercial farms. Both methods support organic farming, leave no chemical traces, and safeguard soil biodiversity.



Fig.5.Electric power weeder

PRINCIPLE AND MECHANISM OF OPERATION

Metal probes in electric weeders send controlled high-voltage electricity to the stem of the weed, killing plant cells and roots. In laser weeders, AI-guided cameras identify weed locations, and a focused laser beam is fired to burn the stem base. The precise, chemical-free removal of weeds is ensured by both mechanisms.

MULTI – FUNCTION MECHANICAL WEEDER

The Multi-Functional Mechanical Weeder is the master of multitasking in the industry. This smart design doesn't just pull weeds; it also aerates soil, mulches crop residue, and enhances soil fertility in one go. Rotary blades handle the weeds, while tines loosen the topsoil to improve airflow and root respiration. In the meantime, the mulching unit spreads organic residue that keeps moisture in the soil and keeps weeds from coming back. Some modern versions even run on solar or electric power, bringing together sustainability and strength. Farmers love it for its ability to save time, labor, and energy all while improving soil health.



Fig.6.Multi function mechanical weeder

PRINCIPLE AND MECHANISM OF OPERATION

The weeder is a unit that combines multiple tools. Rotary cutters remove weeds, aeration tines loosen soil, and the rear mulching plate spreads residues evenly. A power source (engine, solar, or electric) drives the rotating shafts, while adjustable depth controls maintain efficient weeding across different terrains.

Conclusion

From traditional hand tools to intelligent robots, farming has entered an age where machines don't just work, they think. The rise of smart weeders marks a new chapter where technology, nature and human creativity grow together. These next-generation weeders are guardians of green growth as well as mechanical helpers. They scan the soil, sense the difference between weed and crop, and act with precision that even nature admires. Whether powered by sunlight, guided by sensors, or driven by AI, they all share one mission to protect what feeds us. Each new development brings us one step closer to the day when data will take the place of guesswork, nature will provide the energy, and every field will become a living, learning ecosystem. Farmers are now more than just cultivators; they are smart innovators who combine science and soil to create a world that is more sustainable. The farms of tomorrow won't use any chemicals, will use cleaner air, and will learn from every harvest. Because the farming of the future is not just automated; rather, it is alive, intelligent, and growing indefinitely.

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FROM FARM WASTE TO SUPERFOOD: HOW INDIA'S NEW "MUSHROOM REVOLUTION" IS TAKING ROOT

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Abstract

Mushroom cultivation in India has transformed from a small-scale enterprise into a sustainable agribusiness. Traditionally limited to button and oyster mushrooms, production is now expanding towards medicinal and fortified varieties. New technologies from IoT-based smart chambers to solar-powered climate control are helping overcome environmental and disease-related challenges. This article reviews recent innovations in mushroom farming suited to Indian conditions, highlighting the role of plant pathology in ensuring healthy and sustainable production. India generates over 500 million tonnes of agricultural waste annually (Sharma et al., 2022), much of which is either burned or left to decompose inefficiently, contributing to environmental pollution and resource wastage. At the same time, malnutrition and unemployment in rural areas pose significant socio-economic challenges (Singh & Upadhyay, 2021). Mushroom cultivation has emerged as a sustainable and innovative solution (Ahlawat & Tewari, 2020) that repurposes farm residues such as rice straw, wheat husks, and sugarcane bagasse into a nutrient-dense superfood. This article explores how mushroom farming is transforming rural livelihoods, contributing to nutrition security, and promoting environmental conservation. It presents case studies from Odisha, Bihar, Jharkhand, and Arunachal Pradesh, showcasing how farmers, start-ups, and government initiatives are creating new opportunities. Despite challenges such as awareness gaps, infrastructure limitations, and market access, the

mushroom revolution holds promise for empowering farmers and advancing climate-smart agriculture across India.

Keywords: Mushroom cultivation, Farm waste, Sustainability, Nutrition security, Rural livelihoods, Circular economy.

Introduction

India has diverse climatic conditions, abundant agro-waste, and a growing demand for healthy foods, making it suitable for mushroom farming. However, climate control, pest and pathogen management, and market access remain major constraints. Recent innovations, aligned with local resources and farmer needs, offer practical solutions. Look at the fields across India—whether it's the lush rice paddies of Odisha, the wheat belts of Punjab, or the sugarcane farms of Uttar Pradesh—and you will find an unseen crisis brewing beneath the surface. Millions of tonnes of agricultural waste pile up after harvest, often burned or discarded, leading to air pollution, nutrient loss, and degraded soil health (ICAR-DMR, 2023). At the same time, rural communities struggle with unemployment, low incomes, and malnutrition. Amidst these challenges, a quiet revolution is unfolding in India's agricultural landscape—one that repurposes farm waste into food. Mushroom cultivation, once a niche practice, is now emerging as a cost-effective, environment-friendly solution that enriches livelihoods and boosts nutritional intake. From small backyard setups to large-scale farms, mushroom cultivation is enabling farmers to turn waste into wealth.

The Problem: Agricultural Waste and Its Consequences

Agriculture is the lifeblood of rural India, yet it comes with a significant environmental burden. After every harvest season, millions of tonnes of crop residues are left unused or burned, creating a crisis that affects not just farmers, but communities and ecosystems at large.

The Scale of the Problem

India generates 500–600 million tonnes of agricultural waste annually (ICAR-DMR, 2023), including residues such as rice straw, wheat husks, maize stalks, and sugarcane bagasse. Nearly 92 million tonnes are burned each year (Gupta et al., 2019), especially in northern states like Punjab, Haryana, and Uttar Pradesh, contributing to one of the highest levels of air pollution in the world. Crop residue burning releases large amounts of carbon dioxide, carbon monoxide, and particulate matter (PM2.5) into the atmosphere (Bhat et al., 2020), worsening respiratory diseases and smog-related health issues. An estimated 5–15% post-harvest loss further

compounds economic and food security concerns.

Environmental Consequences

- **Air Pollution:** Burning agricultural waste releases harmful gases that exacerbate smog, especially during winter months. This contributes to health problems such as asthma, bronchitis, and other respiratory disorders in nearby populations (Bhat et al., 2020).
- **Soil Degradation:** Unutilized crop residues deprive soils of essential organic matter that could enhance fertility. Without proper composting or recycling, nutrient cycles are disrupted, leading to greater reliance on chemical fertilizers.
- **Greenhouse Gas Emissions:** Crop burning accounts for a substantial portion of India's agricultural carbon footprint, undermining national and global climate targets. Methane and nitrous oxide emissions from unmanaged organic waste further intensify global warming.
- **Water Resource Stress:** Chemical fertilizers, often used as substitutes for organic matter, increase nutrient runoff into rivers and groundwater, contributing to water pollution and eutrophication.

Economic Impact

Farmers lose potential income by disposing of or burning waste instead of using it to create value-added products. Post-harvest wastage and soil degradation lower yields, increasing input costs and reducing profitability. Healthcare costs rise in affected regions due to pollution-related diseases.

Social and Health Implications

Rural communities face higher rates of respiratory illness, impacting labor productivity and increasing medical expenses. Nutritional deficits arise when organic waste that could enrich soil and support crop diversity is wasted. Migration patterns shift as younger populations seek urban employment due to shrinking agricultural incomes.

Why This Problem Demands Immediate Action

India's food security, environmental sustainability, and rural livelihoods are intricately linked to how agricultural waste is managed. The continued reliance on residue burning not only contributes to pollution but also wastes a valuable resource that could be repurposed for improving soil health, generating income, and addressing malnutrition. Mushroom cultivation presents a viable and scalable solution to this challenge (Singh & Upadhyay, 2021).

Mushrooms: A Sustainable Solution

Mushrooms thrive on organic waste materials and transform them into a nutrient-rich food source (Wasser, 2017). They are high in proteins (20–35% on a dry weight basis) (Chang & Miles, 2017), essential amino acids, fiber, vitamins (especially B-complex and D), minerals like iron, potassium, selenium, and antioxidant compounds. Low fat and cholesterol-free, making them ideal for diabetic and cardiac patients. Medicinal mushrooms like reishi (*Ganoderma lucidum*) and turkey tail (*Trametes versicolor*) are studied for immunomodulatory and anti-cancer properties (Patel et al., 2021).

Low resource demand: 1 kg of mushrooms requires ~20 L water vs. 2,000 L for soybeans (Royse et al., 2017).

Waste recycling: Converts crop residues into food and compost.

Myco-remediation: Certain mushrooms absorb heavy metals and degrade pollutants, improving soil health (Singh et al., 2019).

Production Systems of Mushrooms

Mushroom cultivation has evolved into several production styles depending on species, climate, and available resources:

1. **Seasonal/Outdoor Cultivation**
    - Common in small-scale farms.
    - Oyster mushrooms (Pleurotus spp.) and milky mushrooms (Calocybe indica) are often grown in open sheds using pasteurized straw beds.
    - Low-cost method but prone to contamination, insect pests, and environmental fluctuations.
2. **Indoor Controlled Cultivation**
    - Most widely adopted for button mushrooms (Agaricus bisporus).
    - Requires pasteurized compost, humidity (80–90%), and temperature control (16–20°C).
    - Helps maintain hygiene, reduces competition from molds, and ensures higher yields.
3. **Polyhouse and Vertical Farming Systems**
    - Used for shiitake (Lentinula edodes), oyster, and reishi mushrooms.
    - Space-efficient and suitable for peri-urban areas.

- Can integrate with hydroponic/organic farming units.

4. **Log Cultivation**
    - Shiitake, reishi, and wood ear mushrooms (Auricularia spp.) are grown on hardwood logs (teak, oak, rubber).
    - Traditional in Japan and Northeast India.
    - Yields high-quality fruiting bodies but requires patience and fungal disease monitoring.
5. **Container and Bag Systems**
    - Polythene bags, bottles, or trays are used for substrate inoculation.
    - Easy to sterilize and manage contamination.
    - Popular for oyster, milky, and enoki mushrooms.
6. **High-Tech Climate-Controlled Units**
    - Involves growth chambers or even AI-monitored shipping containers.
    - Allows year-round production independent of external climate.
    - Though capital-intensive, it promises consistent quality and export potential.

New Innovations in Mushroom Production for Indian Conditions

1. Paddy Straw Recycling & Biogas Integration

- India produces ~350 million tonnes of paddy straw annually, much of which is burnt, causing pollution.
- Instead of burning, straw is now being dual-used: part for mushroom substrate and the rest for biogas production.
- After mushroom cropping, the spent substrate (SMS) goes directly into biogas plants or as vermicompost, making it a zero-waste cycle.
- This model is already being piloted in Punjab and Haryana, where stubble burning is severe.

2. Solar-Powered Climate Control for Mushroom Units

- One of the biggest challenges in India is temperature and humidity control.
- Solar-powered misting and cooling systems are being tested in Telangana and Maharashtra, reducing dependence on costly AC-based setups.
- Low-cost evaporative cooling chambers using jute mats, bamboo, and solar pumps are being promoted for small-scale growers.

3. Fortified & Medicinal Mushrooms

- Researchers in India are experimenting with bio-fortification of mushrooms:
  - Enriching with Vitamin D by UV exposure.
  - Supplementing with selenium, iron, and zinc through substrate enrichment.
- Medicinal mushrooms like *Ganoderma lucidum*, *Cordyceps militaris*, and *Hericium erinaceus* are gaining popularity for their anti-cancer, anti-inflammatory, and immune-boosting properties.
- Farmers are being trained to diversify beyond oyster and button mushrooms into these high-value nutraceutical mushrooms.

4. Pathogen-Safe Mushroom Production

- *Trichoderma, Pseudomonas, and Bacillus*-based biocontrol formulations are being used to suppress green mould and competitor fungi in mushroom beds.
- Some labs are developing biodegradable protective sprays made from neem oil and chitosan to reduce pathogen load.
- Rapid molecular detection kits (LAMP-PCR, qPCR) are now being tested in Indian mushroom research centres for early detection of pathogens like *Trichoderma harzianum*.

5. Smart Mushroom Farming (IoT-based)

- Low-cost IoT kits are being designed by agri-startups in Bengaluru and Hyderabad.
- Sensors measure temperature, CO_2, and humidity, sending alerts to farmers' mobiles via WhatsApp.
- This allows precise climate management without manual intervention.
- These kits are being sold as affordable "plug-and-play mushroom chambers" for small farmers.

6. Urban & Rooftop Mushroom Units

- Pilot projects in Delhi, Hyderabad, and Kolkata are encouraging rooftop mushroom production using small insulated polyhouses.
- Even old rice bags, cardboard, and sawdust are being used to grow oyster mushrooms.
- This is being promoted for women entrepreneurs and SHGs, linking production to direct marketing (farm-to-table).

7. Myco-remediation & Carbon Credits

- Some research in India is exploring mushrooms for biodegrading pesticide residues and industrial pollutants.
- Oyster mushrooms (*Pleurotus* spp.) are being tested to break down polythene and pesticide-contaminated soils.
- If scaled, mushroom farmers could eventually earn carbon credits for their eco-services.

Future Prospects

India produces just ~1% of the world's mushrooms despite favourable agro-climatic conditions and abundant crop residues. Strengthening spawn production, farmer training, cold storage, and value addition is vital to boost production. Mushroom farming can be integrated into government schemes like the National Horticulture Mission and climate action programs, offering financial and technical support. Training through KVKs, agricultural universities, and digital platforms can build farmer capacity, while research institutions can develop high-yield, pest-resistant varieties for diverse regions. Investments in cold storage, processing, and direct marketing will reduce losses and improve profitability. Women's self- help groups, youth entrepreneurs, and small farmers can benefit from mushroom enterprises, promoting inclusive growth. Reusing spent mushroom substrate as compost or biofertilizer supports the circular economy and soil health. With coordinated efforts from policymakers, researchers, and farmers, mushroom cultivation can emerge as a sustainable, scalable, and climate-resilient pillar of India's agri-business.

Conclusion

The problem of agricultural waste is not merely an issue of disposal; it is a pressing challenge that affects the environment, public health, and rural livelihoods. With millions of tonnes of crop residues burned or left unused each year, the consequences are far-reaching. Mushroom cultivation emerges as a sustainable solution that recycles farm waste, improves soil fertility, and provides nutrition and income. With supportive policies, innovation, and collaboration, India's mushroom revolution can grow into a global model for sustainable agriculture.

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GRAFTING A NOVEL TECHNIQUE FOR THE MANAGEMENT OF PEST AND DISEASES IN VEGETABLE CROPS

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Introduction

Grafting is a technique where the shoot system (scion) of one plant is joined with the root system (rootstock) of another. The result is a single plant that combines the best traits of both — like disease resistance from the rootstock and high yield or preferred fruit quality from the scion. In vegetables, grafting has been widely adopted in countries like Japan, Korea, Spain, and China. It's now being promoted in India and other tropical countries where soil-borne diseases are a major problem.

Vegetable grafting is implored to impart resistance to soil borne pathogens like nematodes, increases yields and tolerance to abiotic stress conditions. Tolerance to soil borne diseases is one of the main reasons why vegetable grafting is practiced. Rootstocks are selected based on their tolerance to common diseases caused by *Verticillium, Phytophthora, Fusarium* and some nematodes in vegetable production. Vegetable grafting has been shown to increase yields of vegetables such as tomato and eggplants and enhances nutrient uptake together with improved water use efficiency. An improved water use efficiency and nutrient uptake enables grafted plants to withstand short dry spells and also increase photosynthetic activity.

Root knot nematode, *Meloidogyne* spp. is the predominant root-knot nematode genera infecting almost all vegetable crops. It causes dramatic galling on the roots of host plants and even low nematode population levels can cause significant yield losses. It can also increase the severity of soil borne diseases such as Fusarium wilt in vegetable crops. Management of root-knot nematode is generally based inorganic nematicides, but with the withdrawal of many nematicides, growers are looking for non-chemical approaches to manage nematode problems. In addition, the markets for organically grown fruit are increasing, where the use of chemicals is not allowed. Thus, the use of root-knot nematode resistant varieties is one of the most economical, efficient and environmentally friendly control measures.

Steps in Grafting

Rootstock selection

Grafting a selected crop variety on to another is based on the genetic attributes of both crop varieties. Farmers should select rootstocks with desirable genetic properties, for example resistance to nematodes, flooding, salinity, extreme temperatures and increased yield production. Tomato and eggplants are the most grafted plants in the Solanaceous family, although crops of the cucurbitaceous family are utilized. The most common rootstocks used for commercial tomato grafting are hybrids (F1) or interspecific hybrids, which have been specifically bred for resistance against pathogens and other diseases such as nematodes, *Verticillium* wilt, and *Fusarium* wilt. Hybrids are produced by crossing selected tomato varieties with other wild Solanum species with the genetic ability to offer resistance to specific diseases and pathogen infection.

Grafting Techniques

A successful grafting technique is one that would unite the scion and rootstock and enable both sections to grow together as a composite plant. The scion could be a small piece of shoot with several buds or a single bud that has been removed from an existing plant. The rootstock on the other hand forms the lower portion of the graft that forms the plant's root system. Several grafting techniques are used by farmers for vegetable production.

In grafting of vegetables, methods such as splice, whip and tongue, hole insertion, pin and cleft grafting methods can be used. However, the splice/tube grafting and cleft/wedge grafting are most commonly used because of the relative ease and strong vascular connection

formed between scion and rootstock. It can also be used on seedlings with age ranging from 3 to 4 weeks.

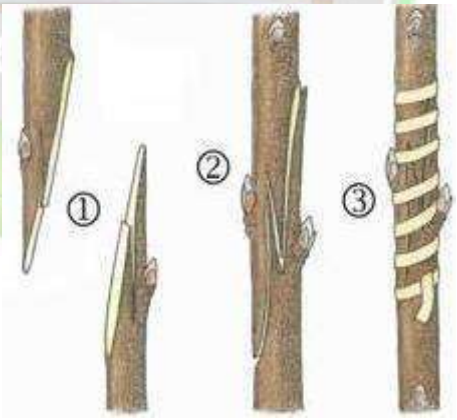
In splice grafting method, slanting cuts are made on both the scion and the rootstock at an angle of 45°, and the cut surfaces are then joined together to ensure the cambium layers of the scion and the rootstock, which are properly aligned. The joined surfaces are held firmly in place with the help of a grafting clip or tube.

The cleft graft method involves making a clean horizontal cut on the rootstock 5 mm below the cotyledon; a 4-mm vertical incision is then made in the middle of the root stock. The scion is then sharpened in the form of a wedge and gently inserted into the incision made in the rootstock. The selection of a particular grafting method or technique depends on the skill of the person carrying-out the grafting and the ease with which the technique can be carried out. Other factors such as type of vegetable crop and sowing period of the rootstock and scion are also considered.

For instance, some farmers prefer whip and tongue technique when grafting cucumbers because the seedlings of cucumber are large (hypocotyl length and diameter), making the grafting process easy. The tube grafting method also has a high per cent graft rate.



Splice Grafting



Whip and Tongue



Cleft Grafting

The grafting of two tomato cultivars (“PG3” and “Beaufort”) by tube and the cleft graft methods resulted in a high-percentage graft rate (79–100%), an indication of the suitability of both methods for tomato grafting.

Graft union formation

Graft union formation in compatible species involves a number of stages. In the first stage, parenchymatous cells are formed on the cut surfaces of the scion and rootstock followed

by the interlocking of the callus between scion and rootstock leading to the formation of a callus bridge. This is followed by the differentiation of cells and the formation of the vascular cambium across the callus bridge between the scion and the rootstock and the eventual connection between phloem and xylem of the scion and rootstock to form a composite plant. The vascular connection lays the foundation for the transport of nutrients and water. In tomato grafting, the formation of the xylem and phloem vessels occurs 8 days after grafting is performed. Temperature and relative humidity levels are crucial environmental factors for graft union formation and acclimatization of grafted plants.

Requirements for graft union formation

- The scion and rootstock should be compatible
- Proper cambial alignment between scion and rootstock
- Enough pressure to keep the cut surfaces firmly together
- Avoidance of desiccation by maintaining high humidity around the cut surface
- Both plants should be at proper physiological stage for grafting to occur

Rootstock Regrowth

Rootstock regrowth also referred as "suckering" or adventitious bud growth usually occurs about 14 days after grafting. The regrowth becomes vigorous and occurs beneath the graft union on the rootstock.

Post Graft Operation

The regulation of these post-grafting factors will influence the survival rates of the grafted plants, grafting success and yield. Higher relative humidity in the grafting chamber tends to favour grafted tomato plants, as grafted plants do not lose moisture at higher rates. High humidity within the grafting chamber can be achieved by misting the chamber regularly with water; the use of plastic polythene to cover the grafting chamber acts as an insulator which shields the plants from the adverse temperature and other weather conditions.

An ideal post-grafting operation includes the maintenance of an ideal air temperature and relative humidity of 25–28°C and 80–90% respectively, which will promote a higher survival rate and quality of grafted seedlings. In situations where temperature levels have exceeded 30–32°C, the leaf weights have been reduced significantly in watermelon.

Screening against Root knot nematodes

Field and pot screening have been used to identify plant cultivars that are resistant to

root-knot-nematodes as screening of rootstocks against root-knot nematodes is essential for every grafting program, because this informs the selection of the right rootstock for grafting. Tomato cultivars that are resistant to root-knot nematodes have a reproductive factor less than one, which implies that the plant is able to suppress the reproduction cycle of the organism once it gains entry into the roots.

The rootstocks, *S. sisymbrifolium*, *Physalis peruviana*, and *S. torvum* recorded the least nematode population of 39, 40 and 43 per 200cc of soil and a reproductive factor of 0.71, 0.74, and 0.84, respectively. *Solanum sisymbrifolium, P. peruviana, and S. torvum* were resistant to root-knot nematode (*Meloidogyne incognita*), and *S. incanum* and *S. aethiopicum* were found to be moderately resistant to *Meloidogyne incognita*.

How Does Grafting Help Fight Nematode Complexes?

The key lies in choosing the right nematode-resistant rootstock. When susceptible vegetable varieties are grafted onto resistant rootstocks, the root system becomes much less vulnerable to nematode attack. For example,

- Tomato scions grafted onto wild species or resistant lines like *Solanum torvum* or *Solanum sisymbriifolium* show significant resistance to root-knot nematodes and Fusarium wilt.
- In brinjal, grafting onto *Solanum torvum* can reduce nematode infestation and improve plant vigour.
- For cucurbits, grafting onto *Cucurbita moschata* or other resistant species offers protection against both nematodes and soil-borne fungi like *Fusarium* and *Pythium*.

Grafted plants not only resist nematode infection better but also exhibit:

Higher Yields

The rootstock can also greatly influence plant growth, yield and fruit quality. Grafting of watermelon onto Cucurbita enhanced the vegetative and root development of the plant, led to earlier and increased yield and improved the fruit quality.

Better tolerance to abiotic stresses

Agricultural production in arid and semi-arid regions relies mainly on irrigation. However, the water resources in these regions are scarce; therefore, the use of marginal water for irrigation is increasing. These marginal waters contain relatively high salt levels and, in some cases, high boron concentrations.

Moreover, fertigation can increase the salt concentration in soil. Grafted melons were more tolerant to salinity than non-grafted ones.

They suggested that grafted plants developed various mechanisms to avoid physiological damage caused by the excessive accumulation of Cl- and Na+ in the leaves, including exclusion of Cl- and/or decrease in Cl- absorption by the roots and the replacement or substitution of total K+ by total Na+ in the foliar parts. Grafted plants may also be more tolerant to low root temperatures.

Resistance to Biotic stress

Fusarium was controlled by grafting in: melon, cucumber, watermelon and tomato. Moreover, grafted plants may be more tolerant to other diseases, such as sudden wilt in melons, caused by *Monosporascus cannonballus*, bacterial wilt in tomato and eggplant and *verticillium* wilt in tomato.

Damage caused by soil nematodes (*Meloidogyne spp.)* can be controlled by grafting onto resistant rootstocks. For example, tomato grafted on a resistant roostock was more resistant to nematodes than non-grafted tomato. Grafting can transfer resistance against the carmine spider mite *(Tetranychus cinnabarinus)* from Lagenaria rootstocks to Cucurbita scions. Moreover, some rootstocks can render grafted plants resistant to some viruses.

Conclusion

In the battle against nematode disease complex, grafting offers a powerful, sustainable, and farmer-friendly solution. By adopting this technique, vegetable growers can not only protect their crops but also boost their income and contribute to safer, pesticide-free agriculture.

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IMPORT RISK ANALYSIS OF FISH AND FISHERIES PRODUCTS

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Abstract

Import Risk Analysis (IRA) is a scientific and policy-based process designed to evaluate the potential risks of introducing pathogens and other hazards through the movement of aquatic animals, their products, and related materials across international borders. The framework provides importing countries with a transparent and defensible approach to assessing disease risks while supporting safe trade. IRA involves four key components: hazard identification, risk assessment, risk management, and risk communication. Risk assessment is carried out through a structured sequence that includes entry, exposure, and consequence evaluations, ultimately integrating the findings into an overall risk estimate. Risk management applies these findings to develop appropriate sanitary measures that mitigate risks without imposing unnecessary barriers to trade, while risk communication ensures transparency and engagement of stakeholders. In India, IRA is governed primarily by the Department of Fisheries under the Ministry of Fisheries, Animal Husbandry and Dairying, supported by agencies such as the Coastal Aquaculture Authority and Animal Quarantine & Certification Services. By aligning with international standards set by the World Organisation for Animal Health (WOAH) and the WTO-SPS Agreement, India and other countries ensure that aquatic imports are regulated in a manner that safeguards animal health, public health, the environment, and the economy.

KEY WORDS

Import Risk Analysis (IRA); Aquatic animal health; Hazard identification; Risk assessment; Risk management; Risk communication; Aquaculture biosecurity; Quarantine; WOAH standards; India

Introduction

"**Import Risk Analysis** is a process used to determine the likelihood and consequences of a hazard being introduced into a country through trade in animals or animal products."(Murray, N. (2002). The **principal aim** of import risk analysis is to provide importing countries with an objective and defensible method of **assessing the disease risks associated with the importation** of aquatic animals, aquatic animal products, aquatic animal genetic material, feedstuffs, biological products and pathological material

The analysis should be **transparent** This is necessary so that the exporting country is provided with clear reasons for the imposition of import conditions or refusal to import.

This is usually undertaken by the **Competant authority** of the importing country, but risk analyses apply equally to the individual who wants to import live aquatic animals onto their farm or site

The components of risk analysis are **hazard identification, risk analysis, risk management and risk communication**

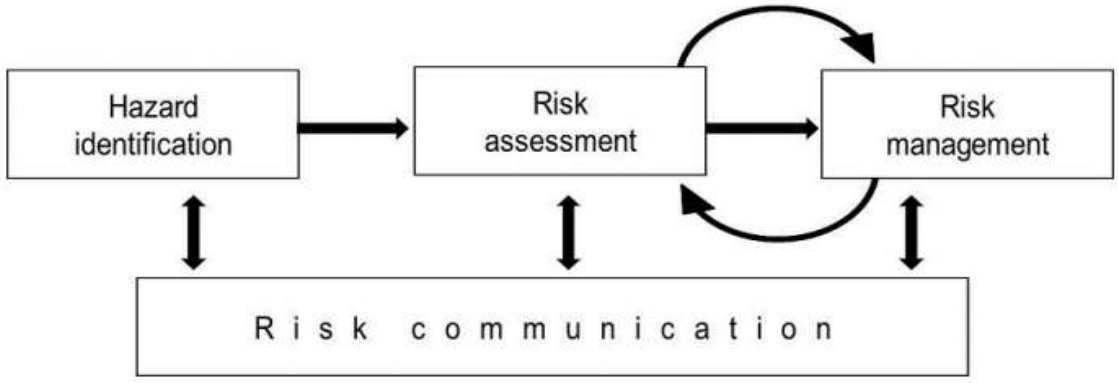


Fig 1: Components of Risk Analysis

HAZARD IDENTIFICATION

Hazard identification is the process of identifying the pathogenic agents which could potentially be introduced into a country through the importation of a commodity." (World Organisation for Animal Health (OIE), Terrestrial Animal Health Code, Chapter 2.1 – Import Risk Analysis, 2016.)

- **Hazard identification** is a categorization step, identifying biological agents dichotomously as **hazards** or not **hazards**. The risk assessment should be concluded if hazard identification fails to identify hazards associated with the importation.

- The evaluation of the Competent Authorities, surveillance and control programmes, zoning and regionalization systems are important inputs for assessing the likelihood of hazards being present in the aquatic animal population of the exporting country.
- An importing country may decide to permit the importation using the appropriate sanitary standards recommended in the Aquatic Code, thus eliminating the need for a risk assessment.

RISK ASSESSMENT

Risk assessment is the evaluation of the likelihood and the biological and economic consequences of entry, establishment, or spread of a hazard within the territory of an importing country**.** *(WOAH Terrestrial Animal Health Code, Chapter 2.1 – Import Risk Analysis (2023)*

- Risk assessment should be **flexible** in order to deal with the complexity of real-life situations. No single method is applicable in all cases.
- Both qualitative risk assessment and quantitativeassessment methods are valid
- **Consistency** in risk assessment methods should be encouraged and **transparency** is essential in order to ensure fairness and rationality, consistency in decision-making and ease of understanding by all the interested parties
- Risk assessments should document the uncertainties, the assumptions made, and the effect of these on the final risk estimate
- Risk increases with increasing volume of commodity imported.
- The risk assessment should be amenable to updating when additional information becomes available.

STEPS IN RISK ASSESSMENT

1.Entry assessment

Evaluates the **likelihood that a hazard will enter** the importing country via the specified pathway.

Considers: prevalence in the exporting country, volume of imports, survival during transport, inspection efficacy.

Biological factors

Species, strain or genotype, and age of aquatic animal

Strain of agent

Tissue sites of infection and or contamination

Vaccination, testing, treatment and quarantine.

Country factors

Incidence or prevalence

Evaluation of Aquatic Animal Health Services, surveillance and control programmes, and zoning and compartmentalization systems of the exporting country

Commodity factors

Quantity of commodity to be imported

Ease of contamination

- Whether the commodity is alive or dead
- Effect of the various processing methods on the pathogenic agent in the commodity
- Effect of storage and transport on the pathogenic agent in the commodity.

(If the entry assessment demonstrates no significant *risk*, the *risk assessment* does not need to continue.)

2.Exposure assessment

Exposure assessment consists of describing the biological pathways necessary for exposure of animals and humans in the importing countries to the *hazards*

Estimating the probability of these exposures occurring, either qualitatively (in words) or quantitatively (as a numerical estimate).

The probability of exposure to the identified *hazards* is estimated for specified exposure conditions with respect to amounts, timing, frequency, duration of exposure, routes of exposure, and the number, species and other characteristics of the animal and human populations exposed.

Biological factors

Genotype of host.

Properties of the agent (e.g. virulence, pathogenicity and survival parameters)

Country factors

Presence of potential vectors or intermediate hosts

Aquatic animal demographics (e.g. presence of known susceptible and carrier species, distribution)

Human and terrestrial animal demographics (e.g. possibility of scavengers, presence of piscivorous birds)

Customs and cultural practices

Geographical and environmental characteristics (e.g. hydrographic data, temperature ranges, water courses).

Commodity factors

Whether the commodity is alive or dead

Quantity of commodity to be imported

Intended use of the imported aquatic animals or products (e.g. domestic consumption, restocking, incorporation in or use as aquaculture feeder bait)

Waste disposal practices.

If the exposure assessment demonstrates no significant risk, the risk assessment may conclude at this step

3.Consequence assessment

The evaluation of the potential consequences of a hazard being introduced into a particular environment, including its impact on animal or plant health, human health, the economy, and the environment."

(WOAH Terrestrial Animal Health Code, Chapter 2.1)

The consequence assessment describes the potential consequences of a given exposure and estimates the probability of them occurring. This estimate may be either qualitative (in words) or quantitative (a numerical estimate).

Examples of consequences include:

Direct consequences

Aquatic animal infection, disease, production losses and facility closures

Public health consequences.

Indirect consequences

Surveillance and control costs

Compensation costs

Potential trade losses

Adverse, and possibly irreversible, consequences to the environment

4.Risk assessment

The integration of the results from the release assessment, exposure assessment, consequence assessment to produce overall measures of the likelihood and magnitude of the

adverse biological and economic consequences of a hazard." (WOAH Terrestrial Animal Health Code, Chapter 2.1)

RISK MANAGEMENT

Risk Management: Based on the risk assessment, appropriate measures are developed to mitigate identified risks. This may include quarantine measures, as seen in South Korea's response to DIV1, where specific species were designated for quarantine to manage the risk effectively (Kang et al., 2023).

Principles of risk management

- Risk management is the process of deciding upon and implementing measures to address the risks identified in the risk assessment, whilst at the same time ensuring that negative effects on trade are minimised.
- The international standards of the OIE are the preferred choice of sanitary measures for risk management.

Risk management components

- ***Risk* evaluation** - the process of comparing the *risk* estimated in the *risk assessment* with the reduction in *risk* expected from the proposed *risk management* measures.
- **Option evaluation** - Optional evaluation is like doing a double-check or review of the risk control measures you plan to use — before or after you actually use them. It's not required, but it's a smart and recommended step to make sure your decisions are: **Effective, Reasonable,Based on science,Fair for trade and people involved**
- **Implementation** - the process of following through with the risk management decision and ensuring that the risk management measures are in place.
- **Monitoring and review** - the ongoing process by which the risk management measures are continuously audited to ensure that they are achieving the results intended.

RISK COMMUNICATION

Risk Communication: This involves sharing the findings and management strategies with stakeholders to ensure transparency and facilitate informed decision-making. The WOAH emphasizes the importance of clear communication throughout the IRA process.

- The *communication of risk* should be an open, interactive, iterative and transparent exchange of information that may continue after the decision on importation.

- The assumptions and uncertainty in the model, model inputs and the risk estimates of the *risk assessment* should be communicated.
- Peer review of *risk analysis* is an essential component of *risk communication* for obtaining a scientific critique aimed at ensuring that the data, information, methods and assumptions are the best available.

IMPORT RISK ANALYSIS IN INDIA

In India, the Import Risk Analysis (IRA) of aquatic (fishery/aquaculture) products is primarily handled by the Department of Fisheries, under the Ministry of Fisheries, Animal Husbandry and Dairying. The Coastal Aquaculture Authority (CAA) and Animal Quarantine & Certification Services (AQCS) also play supporting roles depending on the product type (live, frozen, feed, etc.).

Aspect	**Details**
Primary Authority	Department of Fisheries
Governing Ministry	Ministry of Fisheries, Animal Husbandry and Dairying
Legal Framework	Coastal Aquaculture Authority Act, 2005 - Livestock Importation Act, 1898
Purpose of Risk Analysis	To assess risks of introducing exotic pathogens or diseases via import of aquatic organisms or products
Types of Products Covered	Live aquatic animals (broodstock, ornamental fish, seed) - Feed - Frozen/raw products
Type of Risk Assessed	Introduction of exotic diseases Ecological disruption Zoonotic risks

Procedure	Importers must submit an application and detailed risk assessment; reviewed by expert panels
Scientific Basis	Based on guidelines from OIE (World Organisation for Animal Health) and WTO-SPS Agreement
Quarantine Requirement	Mandatory for live aquatic animals before entry into India
Final Decision Authority	Department of Fisheries, in consultation with AQCS and expert committees

Table 1 : Overview of Import risk analysis of fish and fisheries products

CASE STUDIES AND APPLICATIONS

Australia – IRA on Penaeus spp. from Asia (DAFF, 2019)

- Identified WSSV and TSV as high-priority hazards
- Used scenario trees and expert elicitation for risk estimation
- Implemented enhanced border controls and testing

EU – IRA for live ornamental fish (EFSA, 2008)

- Evaluated risk of importing Koi herpesvirus (KHV) and spring viremia of carp virus (SVCV)
- Highlighted temperature-dependent virus survival and trade volume as key factors

Conclusion

Import Risk Analysis serves as a critical tool for balancing the dual goals of protecting aquatic animal health and facilitating international trade. By systematically identifying hazards, assessing their likelihood of entry and establishment, and evaluating their potential consequences, countries can make evidence-based decisions on import policies. The integration of risk management strategies—such as quarantine, surveillance, and sanitary standards—ensures that identified risks are effectively mitigated, while risk communication fosters transparency and trust among stakeholders. The Indian framework, guided by international standards and supported by national legislation, demonstrates how scientific principles can be

translated into regulatory measures that safeguard aquaculture sustainability. Ultimately, the value of IRA lies in its ability to provide a transparent, flexible, and defensible method for managing biosecurity risks in a globalized trade environment.

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NEURO-LINGUISTIC PROGRAMMING (NLP) FOR EFFECTIVE COMMUNICATION

Article ID: AG-V05-I10-58

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Introduction

The concepts within Neuro-Linguistic Programming (NLP), a psychological approach that explores the connection between neurological processes (thoughts), language, and behavioral patterns to improve communication and personal development. NLP can help individuals achieve personal goals that go beyond monetary and performance targets boost employee morale, loyalty, effort, and profitability. Neuro-Linguistic programming is linked to three fields: neurology, linguistics, and programming itself. NLP techniques enhance communication skills, enabling individuals to express themselves more effectively and understand others better. This leads to stronger relationships, increased influence, and better collaboration. NLP helps individuals identify and change limiting beliefs and behaviors that hold them back. By reframing negative experiences and adopting empowering beliefs, individuals can overcome obstacles and achieve their goals. It improves cognitive flexibility and creativity, enabling individuals to approach problems from different perspectives and find innovative solutions. It also provides strategies for effective decision-making, considering both logical and intuitive factors. NLP empowers individuals to develop a positive mindset, increase self-confidence, and enhance motivation. Through techniques such as anchoring and visualization, individuals can access resourceful states and boost their performance in various areas of life. Mastering effective communication is fundamental to success in various facets of life. NLP techniques offer a unique perspective on how language and behavior are interconnected, particularly when it comes to how to develop talking skills. By mastering NLP, individuals can

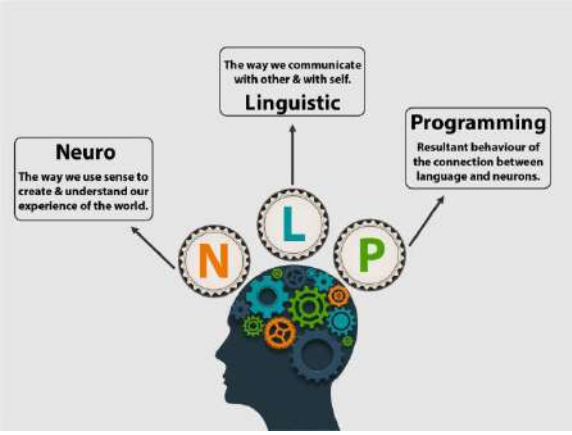
gain insights into the subconscious cues that influence communication and learn how to adapt their approach to better connect with others and enhance their talking skills. NLP techniques are applying in various scenarios that are professional presentations, negotiations, personal relationships, public speaking and conflict resolution.

Keywords: Neuro-Linguistic, Visualization, conflict resolution**,** cognitive flexibility and intuitive

Introduction

In a world where effective communication is the cornerstone of success, **Neuro-Linguistic Programming** (NLP) techniques for effective communication have emerged as a powerful toolkit for enhancing interpersonal communication skills. Whether you're engaging in personal conversations, presenting in front of a crowd, or negotiating in a professional setting, understanding and applying NLP principles can elevate your communication game to new heights. In this article, we'll delve into the key concepts of NLP and explore how these techniques can be harnessed to improve communication effectiveness across various scenarios.

What is NLP, and How Can It Be Used to Improve Communication Skills?



Neuro-linguistic programming, often referred to as NLP, is a psychological approach that was developed in the 1970s by

Mastering effective communication is fundamental to success in various facets of life. NLP techniques offer a unique perspective on how language and behavior are interconnected, particularly when it comes to how to develop talking skills. By mastering NLP, individuals can gain insights into the subconscious cues that influence communication and learn how to adapt their approach to better connect with others and enhance their talking skills. NLP also encompasses communication exercises aimed at further refining these skills for improved effectiveness.

Concept of NLP

- NLP is a positive attitude towards live, believing that you are perfect as you are.
- With NLP you have the possibility to choose your believes, your strategies and your attitude, that form your life and use your imagination to reach your purpose.
- Usually our thinking consists of images, sounds, feelings and to a lesser extent, tastes and smells. Change one of these and you may change the world you live in.
- As a result with NLP you have the ability to find other people's meaning in their communication, so you can be more capable in communicating with them. You can choose the filters through which you perceive the world.

Key NLP Techniques for Effective Communication

1. Rapport Building: Building rapport is the foundation of effective communication. NLP emphasizes mirroring and matching verbal and nonverbal cues, such as body language, tone of voice, and language patterns, to establish a connection and foster trust.

2. Sensory Acuity: Being attuned to subtle changes in another person's behavior, tone, and body language is a crucial aspect of NLP. This awareness allows you to adjust your communication style in real time to ensure better understanding and engagement.

3. Anchoring: Anchoring involves associating a specific emotional response with a particular stimulus, such as a gesture or a word. This technique can be used to evoke positive emotions and manage challenging situations effectively.

4. Meta-Model: The Meta-Model focuses on questioning and clarifying language to uncover deeper meanings and assumptions. By challenging vague or limiting statements, NLP practitioners can encourage clearer communication and uncover underlying thoughts.

5. Milton Model: On the flip side, the Milton Model involves using language patterns to induce a trance-like state of mind, making it useful in persuasive communication, storytelling, and building rapport.

Relevance of NLP in Enhancing Interpersonal Communication

NLP techniques hold immense relevance in today's communication landscape. In an era where misunderstandings and misinterpretations are common, NLP offers tools to bridge these gaps and foster meaningful connections. By honing your NLP skills, you can:

• **Improve Listening Skills:** NLP emphasizes active listening and sensory awareness, enabling you to grasp not only the words but also the underlying emotions and intentions of the speaker.

• **Enhance Persuasion and Influence:** With anchoring, language patterns, and rapport-building techniques, you can enhance your ability to persuade and influence others positively, whether you're pitching an idea or negotiating a deal.

• **Resolve Conflicts:** NLP techniques help de-escalate conflicts by understanding the perspectives of all parties involved. By using language to reframe situations, you can guide conversations towards resolution.

• **Boost Confidence:** Through the practice of modeling successful communicators, NLP can boost self-confidence and help you overcome communication apprehensions.

Applying NLP Techniques in Various Scenarios:

• **Professional Presentations:** Use anchoring to instill confidence before a presentation and employ storytelling (Milton Model) to captivate your audience and convey your message effectively.

• **Negotiations:** Build rapport through mirroring and utilizing the Meta-Model to clarify terms and avoid misunderstandings during negotiations.

• **Personal Relationships:** Enhance communication with loved ones by actively listening, mirroring emotions, and reframing negative language patterns.

• **Public Speaking:** Apply anchoring to control nervousness, and use pacing and leading techniques to guide your audience's emotions throughout your speech.

• **Conflict Resolution:** Utilize sensory acuity to pick up on nonverbal cues and use language patterns to guide conversations toward common ground.

Benefits of NLP Training

1. Enhancing Communication Skills

NLP is fundamentally about understanding the language of the mind. By learning NLP techniques, individuals can significantly enhance their communication skills. This involves not just verbal communication but also an acute understanding of body language and non-verbal cues. NLP teaches you to listen actively and empathetically, enabling you to connect better with people and convey your thoughts more effectively. This skill is invaluable in both personal and professional settings, where clear and effective communication is key to success.

2. Improving Decision-Making

NLP provides tools for clearer thinking and better decision-making. It helps in understanding the underlying patterns of our thoughts and behaviors, enabling us to make

decisions that are more aligned with our goals and values. Through techniques like reframing, NLP practitioners learn to view challenges from different perspectives, leading to more creative and effective solutions. This skill is especially beneficial in leadership roles, where decision-making is a daily responsibility.

3. Personal Growth and Career Opportunities

The self-awareness and self-improvement aspects of NLP are profound. It encourages continuous personal growth, helping individuals to identify and overcome limiting beliefs and behaviors. This ongoing process of self-improvement can open up new career opportunities, as employers value employees who are adaptable, resilient, and capable of self-directed growth. NLP's emphasis on goal setting and achievement also equips individuals with the tools they need to pursue and attain their career aspirations.

4. Helps to Overcome Fears and phobias

NLP is particularly effective in addressing fears and phobias. It does this by altering our mental associations and perceptions that fuel these fears. Techniques like the 'Swish Pattern' or 'Visual-Kinesthetic Dissociation' have been known to help individuals reframe and overcome deep-seated fears, sometimes in remarkably short periods. This aspect of NLP can be life-changing for those who have been hindered by phobias and irrational fears.

5. Increases Self-Confidence

By mastering NLP techniques, individuals often experience a significant boost in self-confidence. This is because NLP helps in understanding and leveraging one's internal dialogue, which plays a crucial role in self-esteem. Techniques like 'Anchoring' allow individuals to summon confidence in situations where they previously felt insecure or anxious, thereby fostering a more assertive and positive outlook on life.

6. Reduces Stress Levels

NLP offers numerous strategies for managing stress and anxiety. By teaching individuals how to change their thought patterns and manage their emotional states, NLP can lead to a more relaxed and positive mindset. Techniques such as mindfulness and dissociation help in achieving a calm state of mind, enabling individuals to handle stressful situations more effectively.

7. Improves Relationships With Other People

NLP's emphasis on empathy, active listening, and effective communication naturally leads to improved relationships. By understanding and respecting the viewpoints of others and

being able to communicate your own more effectively, relationships at home, work, and in social settings can be greatly enhanced. NLP also teaches conflict resolution techniques, which are invaluable in maintaining healthy and long-lasting relationships.

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ENHANCING THE LIVELIHOODS OF SMALL AND MARGINAL FARMERS THROUGH CUSTOM HIRING CENTERS

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Introduction

Agriculture continues to be the main source of livelihood for the majority of India's rural population. However, a large proportion of farmers, nearly 85 percent belong to the small and marginal category, possessing less than two hectares of land. These farmers often face challenges such as limited access to modern machinery, high input costs, and low productivity. To address these issues and make farming more profitable, **Custom Hiring Centers (CHCs)** have emerged as a transformative solution.

Concept and meaning of Custom Hiring Centers

These are facilities established at village or cluster levels where agricultural machinery and equipment are made available to farmers on a rental basis. Instead of investing large sums to purchase costly machines like tractors, power tillers, rotavators, transplanters, or harvesters, farmers can hire them as per need and convenience. This approach reduces their financial burden and encourages the use of modern technology in cultivation.

Benefits to Small and Marginal Farmers

1. **Cost Reduction:**

   Renting machinery through CHCs helps farmers save on capital investments, maintenance, and repair costs.

2. **Timely Operations:**

   Access to machinery during peak seasons enables timely sowing, harvesting, and other farm operations, key to achieving better yields.

3. **Increased Productivity:**
   The use of advanced tools enhances efficiency, reduces drudgery, and improves overall farm productivity.
4. **Employment Generation:**
   CHCs also create local employment opportunities by engaging rural youth in equipment maintenance, operations, and management.
5. **Encouraging Mechanization:**
   Through shared access to modern equipment, CHCs bridge the technology gap and promote mechanized farming even on small landholdings.

Way Forward

To further strengthen the impact of CHCs, there is a need to:

- Expand the network of centers across rural areas.
- Provide skill development and digital booking systems for ease of access.
- Encourage community ownership and FPO-led management for sustainability.

Challenges of Custom Hiring Centers

While Custom Hiring Centers (CHCs) have proven to be a boon for small and marginal farmers, their effective functioning faces several challenges that limit their long-term sustainability and impact.

1. Limited Awareness among Farmers

Many smallholders are still unaware of the services and benefits offered by CHCs. Due to lack of information, traditional practices continue, and the potential of mechanization remains underutilized.

2. Inadequate Infrastructure and Maintenance

Some CHCs struggle with insufficient infrastructure, such as lack of proper storage space, workshop facilities, or maintenance tools. Poor upkeep of machinery leads to frequent breakdowns and reduced efficiency.

3. Financial Constraints

Initial investment costs for establishing CHCs are high, and many centers depend on government subsidies. Without sustained financial planning or revenue generation models, centers often face operational difficulties once subsidies end.

4. Shortage of Skilled Manpower

Efficient operation of farm machinery requires trained operators and mechanics. In many rural areas, the shortage of skilled personnel affects the quality and timeliness of services.

5. Poor Utilization and Seasonal Demand

Agricultural machinery demand is seasonal. During off-seasons, machines remain idle, affecting profitability and return on investment. This also increases the risk of wear and tear due to improper storage.

6. Coordination and Management Issues

In cases where CHCs are managed by cooperatives, farmer groups, or panchayats, lack of clear roles, accountability, and management skills can lead to operational inefficiencies and disputes.

7. Limited Access to Spare Parts and Repairs

Availability of spare parts, especially in remote areas, remains a major bottleneck. Delays in repair and servicing during critical cropping periods lead to loss of valuable time.

8. Lack of Digital and Booking Systems

Most CHCs still function through manual systems for booking and record-keeping. The absence of digital platforms results in poor coordination, underutilization of equipment, and lack of transparency.

9. Transportation Challenges

Transporting heavy machinery from CHCs to farmers' fields can be logistically difficult and costly, particularly in villages with poor road connectivity.

10. Sustainability Concerns

Without proper business models, regular maintenance, and trained staff, many CHCs struggle to sustain operations beyond the initial phase of government or project support.

Conclusion

Custom Hiring Centers represent a practical and inclusive approach to modernizing Indian agriculture. By empowering small and marginal farmers with affordable access to machinery, CHCs contribute significantly to enhancing productivity, income, and overall livelihood security. As these centers continue to spread, they will play a vital role in realizing the vision of a more efficient and sustainable farming ecosystem.

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RECENT ADVANCES IN HEAVY METAL REMEDIATION

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Introduction

The contamination from heavy metals such as lead, cadmium, arsenic, mercury, and chromium poses significant risks to human health and the environment due to their toxicity, persistence, and bioaccumulation. Key sources of pollution include agricultural runoff, mining, industrial activities, and improper waste disposal. Traditional remediation methods face challenges such as high costs and limited effectiveness, leading to the development of newer, more sustainable technologies. Recent advancements in materials science and biotechnology have introduced methods like nanomaterials, biosorption, phytoremediation, and microbial remediation, which offer improved removal capabilities, selectivity, and reduced environmental impact.

Types of Heavy Metal Remediation Methods:

A variety of physical, chemical, and biological methods are used in heavy metal remediation to remove, stabilize, or detoxify hazardous metals from contaminated environments. These techniques fall into the following general categories:

1. Physical Remediation
2. Chemical Remediation
3. Biological Techniques (Bioremediation)
4. Techniques Based on Nanotechnology

Recent Advances in Heavy Metal Remediation are,

1.Nanotechnology:

Nanotechnology is revolutionizing environmental remediation by providing effective methods to remove heavy metals from contaminated water and soil. Nanomaterials, characterized by their high surface area, adaptable surface chemistry, and superior reactivity, enhance the capture, reduction, or immobilization of toxic metal ions. Recent innovations have boosted the efficiency, selectivity, and sustainability of these nanotechnology-driven solutions.

1.Nanoparticles of zero-valent iron (nZVI): Zero-valent iron nanoparticles are extensively studied for heavy metal remediation, effectively converting toxic metal ions such as Cr (VI), Pb (II), and As (V) into less harmful forms through reduction and adsorption. Recent advancements include surface modifications like carbon coatings or polymers, which enhance their transport and reactivity in soil and groundwater by preventing agglomeration and increasing stability.

2. Hybrid Materials and Nanocomposites: For the removal of metal ions, nanocomposites that blend various materials, such as metal oxides, carbon nanotubes (CNTs), and polymers, exhibit synergistic effects.

3. Nanoparticles of metal oxide: Heavy metal ions have been adsorbed and degraded using metal oxide nanoparticles, such as manganese oxide (MnO_2), zinc oxide (ZnO), and titanium dioxide (TiO_2). Developments: Selectivity and adsorption capacity are improved by functionalization with surface groups or doping with other metals.

4. Nanomaterials Based on Carbon: Because of their porous structure and functionalizable surfaces, materials such as graphene, carbon nanotubes (CNTs), and biochar-based nano sorbents are very effective at binding heavy metals.

Current Events:

For enhanced metal affinity, use doped carbon materials (such as N-doped graphene).

Nanoparticles of modified biochar for inexpensive, environmentally friendly remediation.

5. Adsorbents at the nanoscale Biopolymer-functionalized: High biosorption potential is demonstrated by nanoparticles coated or embedded with natural polymers such as cellulose, alginate, or chitosan. Benefits include the presence of active sites (such as $-NH_2$, -OH) for metal binding, biocompatibility, and biodegradability.

6. Membranes with nanostructure: Heavy metals can be selectively filtered out of aqueous streams using membrane technologies enhanced with nanomaterials (such as TiO_2 and CNTs).

Development of high-flux and anti-fouling membranes with high rejection rates for hazardous metals such as Pb^{2+}, Cd^{2+}, and Hg^{2+} is a trend.

2. Engineered Microbes and Plants:

The application of genetically modified organisms, including plants and microbes, has created exciting new avenues for heavy metal remediation. These organisms have the ability to effectively absorb, transform, or immobilize heavy metals from contaminated environments by introducing novel genes or improving natural detoxification pathways. Their remediation capabilities, specificity, and adaptability have been greatly enhanced by developments in metabolic engineering, synthetic biology, and genome editing (e.g., CRISPR/Cas9).

1. Microorganisms with engineering:

By means of biosorption, bioaccumulation, oxidation-reduction, and precipitation, microorganisms like bacteria and fungi naturally contribute to the cycling of metals. To improve performance, these mechanisms have been amplified through genetic engineering. Engineered bacteria enhance metal uptake through overexpression of high-affinity metal transporters targeting elements like cadmium and arsenic. Modifications to efflux systems enable regulation of intracellular metal levels. Additionally, incorporating genes for metallothioneins and phytochelatins enhances microbial bindings and storage of heavy metals. Furthermore, some engineered microbes can convert toxic metal ions, such as chromium, from Cr(VI) to the less toxic Cr(III) by boosting reductase activity.

3. Phytoremediation, or engineered plants

Genetically modified (GM) plants improve phytoremediation by overcoming issues such as slow growth and low biomass. Key advancements involve metal transporter proteins for better heavy metal uptake, enhanced tolerance through targeted genes, and optimized rhizosphere management through modified root exudates and symbiotic microorganisms. Successful transgenic lines include Arabidopsis thaliana for Hg^{2+} detoxification and Brassica juncea for enhanced Cd and Pb accumulation.

3.Biochar-based Remediation:

A carbon-rich substance produced from pyrolyzing organic biomass, biochar is effective and affordable for removing heavy metals through mechanisms like adsorption and ion exchange. Advances in biochar engineering include activated biochar with increased surface

area, functionalized biochar with enhanced metal affinity, and composite biochar that improves strength and reactivity for better remediation of contaminated environments.

Conclusion

The evolution of heavy metal remediation stresses the need for effective, sustainable, and cost-efficient methods. Current strategies leverage nanotechnology, engineered microbes, and plants, with biochar as a low-cost alternative for soil and water treatment. Challenges persist regarding long-term stability, environmental safety, and regulatory compliance. Future research should prioritize hybrid systems and extensive field testing to improve integrated strategies for managing heavy metal pollution.

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UREA: A POISONED CHALICE

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Abstract

India's urea addiction is both addictive and harmful; it has fueled the country's granaries while covertly contaminating its soils, rivers and even its citizens. With its enticing 46% nitrogen content and massively subsidized price tag, urea emerged as the go-to yield-boosting miracle powder. But like all excesses, this chemical fertilizer's abuse has turned into a nightmare of health issues, environmental risks and soil pollution. At the heart of this dilemma is Andhra Pradesh, which ranks fifth in the nation for excessive urea use. The state has made the audacious decision to reward farmers with ₹800 per bag for each reduction in urea usage, realizing that the situation is a ticking time bomb. This decision has more to do with survival, sustainability and sanity than it does with economics.

Key words: Urea, nitrogenous fertilizer, toxic, scheme, sustainability

Introduction

Andhra Pradesh is spearheading a daring detox initiative with financial incentives, natural farming and international lessons to save soils, farmers and the future of the country—from wonder fertilizer to toxic addiction. Andhra Pradesh's reliance on urea is especially severe in the rice and maize industries, where many farmers are unaware of the long-term consequences due to the drive for higher yields. This weakens crops, makes them more vulnerable to pests and

leaves soils depleted of vitality and balance. The government's Soil Health Card initiative, which has issued over 25 crore cards with nutrient profiles and recommendations, has worked to encourage farmers to utilize the cards sensibly throughout India. However, putting that understanding into practice is still extremely difficult, particularly given how inexpensive urea is. The harm caused by this addiction is severe. Overuse causes soils to become acidic, which gradually reduces their natural fertility and renders them unusable. The fragile microbial communities that give soil its life and respiration are destroyed and chemical dependence takes their place. Farmers are forced into a vicious cycle of chasing diminishing returns with ever-increasing inputs when nutrient imbalances lower the presence of essential elements like potassium and phosphorus. Because of their structural inability to retain water, soils collapse, transforming once-productive fields into desiccated wastelands. There are collateral wounds in the environment.

When nitrogen escapes the soil, it either flows off into rivers and lakes, causing eutrophication and dead zones, or it seeps into groundwater, poisoning drinking supplies. Because it contributes to emissions of nitrous oxide, which is 300 times more powerful than carbon dioxide, urea is a covert contributor to climate change. Both urban and rural populations' lungs suffer from particulate pollution, which is exacerbated by ammonia emissions into the atmosphere. Then there is the human cost: villagers in East Godavari district like Bhalabadrapuram are already speculating about an increase in cancer cases connected to improper fertilizer use. Even foreign markets are resisting: China rejected consignments of Andhra chillies tainted with fertilizer residues, a financial setback that highlights the crisis's global scope.

The "Cancer Train," a spooky phenomenon in the Malwa district of Punjab, has drawn national notice. This train travels to Bikaner, Rajasthan, from Bathinda. It transports hundreds of cancer patients in search of reasonably priced care. It is more than just a means of transportation for many. It is an agonizing, hopeless journey characterized by illness, debt, and despair. The Cancer Train represents more than just tragedy. It is indicative of a more serious public health emergency that has its roots in the state's agricultural revolution. Punjab, which was once a thriving region during the Green Revolution, is currently dealing with a startling increase in cancer occurrences. The Malwa region, where chemical dependence and intensive farming methods have become commonplace, is at the center of this dilemma. The overuse of

synthetic fertilizers, such as urea, has increased dramatically in recent decades. These substances were formerly thought to be instruments of advancement. They are now being connected to fatal outcomes. A poisonous living environment has been produced by contaminated water, damaged land, and polluted air. The health of nearby populations is suffering as a result. It looks at how chemical farming degrades the environment. It examines scientific research and health data. It also explores the socioeconomic challenges that families in impacted districts confront.

In India, the Green Revolution got its start in the 1960s. Its primary testing field was Punjab. Preventing famine and increasing food production were the objectives. Large-scale introductions of chemical fertilizers, insecticides and high-yield variety (HYV) seeds were made. Punjab was perfect for this change because of its rich soil and consistent irrigation. Farmers were urged to stop using conventional methods. They switched to farming that used a lot of chemicals instead. The government provided assistance in the form of electricity, irrigation and fertilizer subsidies. Credit was readily available. Crop yields increased dramatically in a matter of years. Production of rice and wheat surged. Punjab was praised as the breadbasket of the nation.

However, there was a price for this success. They strained the soil to its breaking point. The natural balance started to change as a result of the ongoing usage of pesticides and fertilizers. Pests became resistant over time. In order to counter this, farmers used more chemicals. A vicious spiral has started. In the past, Punjab's farms flourished due to their inherent fertility. Its nutrients have been depleted by years of intensive chemical application. Fertility has drastically decreased. To raise even the most basic crops, farmers today mostly rely on artificial inputs.The soil's organic matter has decreased. The beneficial microbes are no longer there. The soil's innate capacity for regeneration is nearly extinct. The issue has gotten worse due to monoculture farming. Certain nutrients are depleted when the same crops are planted repeatedly. In an attempt to make up for this, fertilizers are used excessively. The soil frequently has excess phosphate and nitrogen. However, the levels of micronutrients such as manganese, iron, and zinc are dangerously low. The equilibrium has been upset. High-input farming has made soil health a victim.

The story of water contamination is just as bleak. The primary source of drinking water in the Malwa region is groundwater. According to reports, the state is on the verge of health

risks like cancer and blue baby syndrome as a result of the careless usage of nitrogenous fertilizers in Punjabi villages. According to a study by Greenpeace Research Laboratories, there is 322 kg of nitrogen per hectare in 50 hamlets in the districts of Muktsar, Bathinda and Ludhiana, compared to the state average of 210 kg and the national average of 113 kg. The usage of synthetic nitrogen fertilizers, such as urea, is unquestionably associated with nitrate pollution. According to Dr. Reyes Tirado, a scientist from the University of Exeter in the United Kingdom, "the more application, the more contaminated the drinking water in wells adjacent to fields." Dr. Jai Rup Singh, the vice-chancellor of the Central University of Punjab, announced the Greenpeace report Thursday in Bathinda. According to a survey conducted in three regions, 20% of all wells studied had nitrate levels over the WHO safety threshold.

The home seat of Punjab Finance Minister Manpreet Badal, Doda (Gidderbaha), has the worst level of drinking water pollution. Gidderbaha is already notorious for having a high cancer case rate. Nitrate levels in two Doda water samples are 94.3 mg/l and 72.8 mg/l, respectively, far higher than the WHO safety standard of 50 mg/l. In 1983, the state consumed 126 kg of chemical fertilizer per hectare; by 2007, that amount had risen to 210 kg. Crops only require around 100 kg of nutrients, thus the easiest way to guarantee soil fertility is to provide nitrogen through organic fertilizers like pulse crops and manures, according to the paper.

The overuse of chemicals leads to widespread soil degradation and a decrease in output. "Blue baby syndrome," which is caused by high levels of nitrate poisoning in groundwater, reduces a newborn's hemoglobin's capacity to carry oxygen and finally leads to death.

PM-PRANAM scheme

The PM Programme for Restoration, Awareness Generation, Nourishment, and Amelioration of Mother Earth is known as PM-PRANAM. This is a special stage in maintaining the health of Mother Earth, just as we would our own mother. Mother Earth will guarantee a bountiful return in this manner. Only with our combined efforts, beginning at the village level, will it be feasible. The Government of India launched this innovative scheme to reward States that actively support the balanced use of chemical fertilizers. Farmers that reduce their production are rewarded with ₹800 per bag under the PM PRANAM plan, which directly links sustainable behavior to financial gain.

By encouraging biofertilizers, natural farming and organic manures, the state has also set a goal to cut the use of chemical fertilizers by 11%, or an astounding 4 lakh metric tonnes. The

plan calls for giving the corresponding State or Union Territory 50% of the saved fertilizer subsidy, which comes from using less chemical fertilizer than the preceding three-year average. This creative strategy seeks to motivate areas to take proactive measures for environmental preservation and sustainable agriculture. The excessive use of chemical pesticides and fertilizers in agriculture is a serious problem that the PM-PRANAM aims to solve. Excessive use of pesticides and fertilizers in the quest for increased output is sickening Mother Earth and lowering its capacity for production.

It is often known that using chemicals excessively can lead to major illnesses like cancer. For soil nutrition security, bio/organic fertilizers must be integrated into agriculture in order to implement soil test-based balanced fertilizer use. In addition, resource-saving technologies such as crop rotation, mulching, microirrigation, integrated farming systems, and no-tillage should be incorporated into farming practices, as should organic and natural farming methods. Long-term agricultural productivity will increase, soil fertility will be improved, and environmental pollution will be decreased as a result of this transition to sustainable farming methods. Farmers are being informed by campaigns about the risks associated with urea and the potential benefits of substitutes. Success, however, will hinge on regularity, openness and sincere interaction with farming communities, who require the information and self-assurance to break long-standing patterns.

Recommendations: Supporting Sustainable Agriculture

Andhra Pradesh's policy shift is both essential and innovative in light of these facts. Lessons can be learned from the global playbook. Coated urea, which releases nitrogen gradually and increases efficiency by up to 50%, is used in the United States and Japan. Through Integrated Nutrient Management, the European Union maintains fertility without relying too heavily on chemicals by combining organic and chemical inputs. Australia and Brazil rely on conservation agriculture, which includes crop diversity, cover crops, and no-till farming, to improve soil health while maintaining yields. These models demonstrate that sustainability and productivity do not have to conflict. India has motivational instances as well. Zero Budget Natural Farming, which uses local bioresources rather than chemicals, was invented in Andhra Pradesh. Financial incentives for going natural are provided by organic agricultural programs such as MOVCDNER (Mission Organic Value Chain Development for North Eastern Region) and Paramparagat Krishi Vikas Yojana. Already in use, urea coated with neem

minimizes nitrogen loss and acts as a pest deterrent. To slow its discharge, district officials are experimenting with useful changes like combining urea with neem cake. The foundation of individualized nutrient management may be the Soil Health Card program, provided it is properly digitalized and implemented. Expansion of soil testing, precision irrigation, and regional biofertilizer manufacturing should be the medium-term objectives. Diversified cropping patterns, legume integration, systematic policy coordination and significant investment in nanofertilizer and biostimulant research are all necessary for long-term transformation. Making the switch from urea to sustainable alternatives cannot be done quickly; it calls for support, creativity and incentive alignment in the fields of economics, the environment and health. Today, Andhra Pradesh has the chance to take the lead in India's agricultural reform.

Conclusion

If it can demonstrate that lowering urea not only protects soil and health but also boosts profitability and access to global markets, it will set an example for the rest of the nation. The challenge is not as big as the stakes. The promise of a future with fertile fields, clean rivers, clean air and safe food makes every rupee of subsidies and every ounce of labor worthwhile. Urea was the wonder of the past, but if left unchecked, it will be the bane of the future. Andhra Pradesh must ensure that, after lighting the first flame in this long-running dispute, the flame never dies out.

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BIO CONTROL METHODS FOR LEAF SPOT DISEASE OF MULBERRY

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Introduction

Mulberry trees are the backbone of sericulture, the age old art of silk production. But just like any crop, they face their share of enemies. One of the biggest threat is Leaf spot disease. These pesky brown or black spots might look harmless, but they can seriously damage mulberry leaves which silkworms depend on for food.

Leaf Spot Disease

Leaf spot in mulberry is caused by various fungi and bacteria, including *Cercospora*, *Phyllosticta*, and *Myrothecium*. These pathogens leave behind ugly spots on the leaves, reduce leaf quality, and eventually lead to lower silk yields.

Traditional control methods involve fungicides, but they come with a cost — to the environment, human health, and beneficial organisms. That's why bio-control is becoming the hero of the mulberry field.

What Are Bio Control Methods?

Bio control or biological control uses natural enemies or biological agents to suppress plant diseases. These agents can be:

- Beneficial microbes (like bacteria and fungi)
- Insects or predators (less common for leaf spots)
- Botanical extracts (plant based natural fungicides)

Bio Control Methods for Mulberry Leaf Spot

1. Trichoderma

Trichoderma harzianum and *T. viride* are beneficial fungi that colonize plant roots and

leaves. They do three amazing things:

- Compete with harmful fungi for space and nutrients
- Produce enzymes that kill pathogens
- Boost the plant's immune system

Spraying Trichoderma based solutions on mulberry leaves has shown significant reduction in leaf spot severity.

2. Pseudomonas fluorescens

This friendly bacterium lives in the soil and on plant surfaces. It works by

- Releasing antibiotics to suppress pathogens
- Triggering the plant's natural defenses
- Outcompeting harmful microbes

When applied as a foliar spray or soil treatment, *Pseudomonas* helps protect mulberry from both fungal and bacterial leaf spot pathogens.

3. Neem Extract

Neem (*Azadirachta indica*) is a powerful botanical with antifungal and antibacterial properties. Farmers use neem oil or neem leaf extract as a natural spray to reduce leaf spot incidence and It's safe for silkworms and beneficial insects.

4. Compost and Vermiwash

Organic compost and vermiwash (a liquid extract from earthworm composting) contain a cocktail of beneficial microbes and nutrients that strengthen mulberry plants. Regular application improves plant resistance and soil health reducing the chances of disease outbreaks.

Why Bio Control Matters?

- **Eco-Friendly**: No harmful chemicals in the soil or water.
- **Silkworm Safe**: Essential in sericulture where chemical residues can harm silkworms.
- **Cost-Effective**: Less reliance on expensive fungicides.
- **Sustainable**: Builds long-term plant and soil health.

As the world shifts toward sustainable agriculture, bio-control methods are becoming essential not just in big farms, but also in backyard mulberry gardens and sericulture units across rural India and beyond.

Silkworms are so sensitive that even a trace of pesticide can kill them. That's why bio-control isn't just a good idea it's a necessity in sericulture.

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SAFE ROUTE WITH A CHART PLOTTER IN NAVIGATION SYSTEM

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Abstract

A chart plotter acts as a digital guide for mariners, helping them navigate safely through the unpredictable sea conditions. Before selecting a suitable model for a vessel, it is essential to understand the various features and functions that different brands offer. The setup process involves learning to configure the boat icon, input navigational draft, and interpret the map display. It not only aids in positioning and route planning but also enhances voyage safety by providing critical information such as currents, tides, and nearby vessels. For smooth and effective functioning, operators must follow certain precautions and ensure that the equipment and charts are regularly updated. In essence, a chart plotter simplifies marine navigation and plays a vital role in ensuring the safety and efficiency of fishing and shipping operations. It integrates GPS, electronic charts, and advanced sensors to provide real-time positioning and route planning enhancing safety, efficiency, and confidence at sea.

Key Words: Chart Plotter, Navigation, Maritime Safety, Navigational Map

Introduction

A chart plotter is essentially a marine GPS unit combined with digital nautical charts. It displays a vessel's exact position on a map, allowing the skipper to track their route, avoid

hazards, and monitor changes in depth, weather, and traffic. Most modern plotters also interface seamlessly with other on board systems like radar, AIS (Automatic Identification System), sonar/fish finders, and autopilot, creating a centralized command hub for navigation. Recently, significant advancements have emerged in fishing technology, particularly in protecting fishermen during the fishing operations. For fishermen, knowing their exact location in the vast ocean is essential. Unlike land, the ocean lacks natural landmarks, making navigation challenging. Every spot in the open sea appears nearly identical, with water stretching in all directions. This global challenge has led to solutions such as GPS (Global Positioning System), RADAR (Radio Detection and Ranging), SONAR (Sound Navigation and Ranging), AIS (Automatic Identification System), chart plotters, and other technologies. Each technology has its own advantages and limitations. Among them, chart plotters are commonly used and suitable for both commercial and small fishing vessels.

Chart Plotter

1. Pre-Setup

A chart plotter is a navigational marvel that integrates GPS with an electronic navigational chart. Generally, it looks like a box that displays maps, routes, several markings, the current location by a cursor shaped like a boat, etc.

- The GPS is used for providing the position of the particular vessel, and the chart helps in visualizing the position in the world's electronic map.

Some advanced chart plotters also have a Radar and AIS system being installed.

- The radar provides information underwater like the availability of fish species, ocean depth, sea bed, etc., while the AIS system helps in other functions like real-time monitoring of the vessel, enhancing safe situational awareness.

In simple terms, a chart plotter enables ships to determine their exact location and position at sea.

These plotters are commercially available in the market and e-commerce platforms like amazon, IndiaMART, topRik, etc., representing several brands. A few are listed below:

1. Garmin chart plotter like echoMAP
2. Raymarine axion
3. Simrad NSS
4. Raymarine lighthouse
5. Humminbird apex

There are even various paid and unpaid chartplotter apps operable via iphones or android phones. These can be used as a substitute of a chartplotter device:

1. Navionics
2. iNavX
3. iSailor
4. openCPN (open source)

It is also worth noting that having a backup navigation method, like paper charts or a handheld GPS is an alternative for safety. These become useful during adverse conditions where none of the electronics works.

The qualities of a chart plotter that the owner should keep in mind while purchasing:

1. Map quality
2. Reliability
3. Durability
4. Good resolution
5. Auto-pilot support

2. Setup

Once a chart plotter is purchased and installed, the basic but important settings that are needed to be carried out:

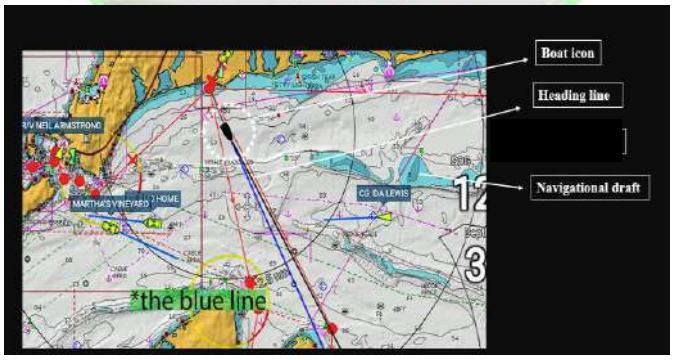


Fig: Important parts of a plotter's chart. (Source: Boat Training Online. URL: https://youtu.be/J6XlxtNxJgo?si=p_Sf_pu0F7V5VNwR)

1. **Boat icon and Fixed Position**:

When you switch on your plotter screen, a boat symbol will be present in the centre, presenting your location. Some manufacturers will let you choose this symbol according to your

convenience. Different ranges of sizes will be available. It is advisable to choose the smallest one such that it doesn't hinder the visibility of the chart.

2**. Heading line and relative heading line**:

On your plotter screen, there will be a black line from the boat cursor. This line shows where you are heading to. If the feature is not on, refer to the manufacturer's guidelines to turn it on.

Next to the chart is a relevant heading flash known as set and drift. It shows your actual movement in the ocean because of waves, wind, and the sea.

3. **Navigational draft**:

Draft refers to the depth from the water line on the ship to the keel. It presents the depth of the vessel under the water. On the other hand, a navigational draft is an extra depth added to the original draft. This is to have an extra safety measure and thus prevent grounding. It is required for the owner to enter his/her navigational draft manually on the plotter.

On the plotter screen, areas with varying depth are shown using light and dark blue colors. Light blue areas indicate shallower water where your vessel is at risk of touching the bottom—known as grounding risk—and should be avoided.

4. **North up and heads up**

A chart plotter can display information using either "North up" or "Heads up" orientation. In "North up" mode, north is always at the top of the screen, and the boat symbol moves according to your course. In "Heads up" mode, the boat symbol stays at the centre, pointing toward the top of the screen, and the chart itself rotates as your heading changes. "North up" orientation is generally easier for long-term navigation, but some users prefer "Heads up" for simplicity.

5. **Current and Tide Tables**

Normally on the right side of the chart, there is a white box with numbers displayed in the centre. These numbers represent the speed of the current.

The tide table are tide station usually must roll over the cursor and press on it. A pop-up window will appear providing information like the state of the tide.



Fig: current and tide tables (Source: Boat Training Online. URL: https://youtu.be/J6XlxtNxJgo?si=p_Sf_pu0F7V5VNwR)

3. Post setup

After all the basics has been installed, the chart plotter is ready to be use in voyages or during fishing. To be able to operate, the owner needs to know

- how to read the chart,
- then how to create a waypoint and
- finally, how to navigate through it.

At the minimum, we need to learn the following tasks to be able to use the plotter:

- create a waypoint
- create a course
- start and stop navigation
- move or change
- reverse a course
- delete waypoints and courses
- zoom chart in and out
- scroll around the chart

Different plotters have different ways to do the above-mentioned tasks.

The chart plotter should be installed in the most accessible position of the wheelhouse such that the navigator can keep a check on the plotter map during the entire voyage or operation. Various advanced plotters continuously assist by providing guidance on safe routes, alerting to upcoming obstacles, and suggesting necessary course changes. A few shows AIS data about

nearby vessels like its name, location, vessel type, dimensions, destination, etc. We can even shift the navigation to autopilot mode for automatic course steering.

As we will be dealing with electronic charts, there are a few precautions that need to be taken:

1. Never over-zoom the chart; it might create negative errors.
2. While choosing a course, review the entire course in zoom-in mode to prevent missing any overlooked details.
3. Before taking off for a trip, make sure that the navigational chart is up to date.
4. Always be cautious while travelling to less-travelled waters or unknown waters since these parts may not be re-surveyed in many years.
5. Always believe in your eyes prior to the charts if both of them are giving contradicting information.
6. Ensures all watch officers know waypoint entry, rerouting, and emergency procedures.

Uses of Chart plotter in Navigation system

1. Chart plotters have become an essential part of modern navigation systems, especially in the marine world. They combine GPS technology with digital charts to help boaters and mariners know exactly where they are and where they are going.
2. One of the main uses of a chart plotter is **real-time positioning**. It shows your boat's location on an electronic map, which makes it easier to track your route and avoid getting lost especially in unfamiliar waters.
3. Chart plotters are also used for **route planning and navigation**. You can set waypoints, create safe routes, and even calculate distances and estimated arrival times. This is extremely helpful for long journeys, where careful planning is key.
4. Another major benefit is **hazard detection**. Chart plotters can show shallow areas, underwater rocks, buoys, and other important markers. Many systems also connect with sonar, radar, and AIS (Automatic Identification System), providing alerts for nearby vessels or obstacles a big help in poor visibility.
5. Fishermen often use chart plotters to **mark fishing spots**, track fish movement using sonar overlays, and return to the same location with pinpoint accuracy.
6. The chart plotters improve **safety**, **accuracy**, and **efficiency** on the water. Whether you are cruising, fishing, or navigating commercially, a chart plotter helps you stay on course and make informed decisions at sea.

Conclusion

Chart Plotter has proved to be the backbone of marine navigation. It has become an indispensable tool in modern marine navigation, combining positioning, charting and automation into a single integrated system. By providing real-time information on location, routes, and potential hazards, it significantly enhances operational safety and efficiency. However, effective navigation depends not only on technology but also on the mariner's skill in correctly managing and interpreting the data. Operators must remain vigilant, conduct regular system checks, and maintain alternative navigation backups such as paper charts or handheld GPS units in case of equipment failure. In the long term, the use of chart plotters promotes safer voyages, better route planning and time-efficient fishing operations, true seamanship lies in balancing technology with human judgement – using the chart plotter as a reliable companion, but never as a substitute for a navigator's awareness and experience.

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NANO-SELENIUM: A TINY NUTRIENT WITH BIG POTENTIAL IN MITIGATING ABIOTIC STRESS

Article ID: AG-VO5-I10-64

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Introduction

Agriculture is the backbone of human survival, yet it is under continuous threat from abiotic stresses such as drought, salinity, extreme temperatures, and heavy metal toxicity. These stresses disturb plant metabolism, lower yields, and compromise food security. With the global population rising and climate change intensifying, there is an urgent need for innovative solutions to protect crops. One such emerging tool is nano-selenium (nano-Se)—a smart, eco-friendly form of selenium that is revolutionizing stress tolerance in plants.

Selenium: A Micronutrient with a Macro Role

Selenium (Se) is an essential trace element for humans and animals, but its role in plants has long been debated. In recent years, researchers have discovered that selenium, even at low doses, acts as a beneficial element that can:

- Improve antioxidant defense systems
- Enhance photosynthetic activity
- Regulate growth and metabolism
- Protect plants from oxidative stress caused by environmental challenges.

However, conventional selenium fertilizers (like selenate and selenite) have low bioavailability and may become toxic at higher doses. This is where nanotechnology steps in.

Why Nano? The Advantage of Nano-selenium

By reducing selenium to the nanoscale (1–100 nm), its surface area and reactivity increase significantly. Compared to bulk selenium forms, nano-selenium offers:

Higher uptake efficiency by plant roots and leaves

Controlled release that reduces the risk of toxicity

Improved mobility within plant tissues

Stronger antioxidant activity at lower concentrations.

Thus, nano-selenium acts as a precision nutrient, ensuring plants get exactly what they need under stress conditions.

How Nano-selenium Mitigates Abiotic Stress

1. Drought Stress

Water scarcity is the biggest limiting factor in agriculture. Nano-selenium helps plants adapt by:

- Enhancing root architecture, allowing deeper soil exploration for water
- Increasing osmolyte accumulation (like proline), which maintains cell turgor
- Boosting photosynthetic efficiency even under limited water
- Stimulating the antioxidant system to reduce oxidative damage caused by drought.

2. Salinity Stress

Saline soils affect millions of hectares of farmland worldwide. Nano-Se offers relief by:

- Maintaining ion balance (reducing harmful sodium and enhancing beneficial potassium uptake).
- Protecting chloroplasts and stabilizing chlorophyll for efficient photosynthesis.
- Improving water retention and reducing membrane leakage.

3. Heat Stress

Rising global temperatures are a major threat to crop production. Nano-Se mitigates heat effects by:

- Enhancing the synthesis of heat-shock proteins (HSPs) that protect enzymes
- Stabilizing cell membranes and photosystems under thermal stress
- Improving antioxidant enzyme activities (superoxide dismutase, catalase, peroxidase)

4. Heavy Metal and Oxidative Stress

Industrialization and modern farming have increased soil contamination with cadmium, arsenic, and lead. Nano-selenium can:

- Reduce heavy metal uptake by binding toxic ions
- Convert harmful reactive oxygen species (ROS) into harmless molecules
- Stimulate phyto-chelatin and glutathione pathways for detoxification

Research Insights

- Studies in wheat and maize show that nano-selenium enhances drought tolerance by improving biomass and chlorophyll stability.
- In rice, nano-Se application reduced salinity-induced oxidative stress, improving yield.
- Experiments with tomato and cucumber demonstrated better fruit quality and reduced cadmium accumulation when treated with nano-selenium.
- These findings suggest that nano-selenium has the potential to be integrated into future stress-management strategies for multiple crops.

Global Relevance

Climate change projections show that by 2050, drought and salinity could affect over 50% of arable land. At the same time, human selenium deficiency is widespread in many countries, including India and China. The dual role of nano-selenium—improving crop resilience and enhancing nutritional quality—makes it a game-changer for sustainable agriculture. International research communities, especially in China, the USA, and Europe, are actively exploring nano-Se for food fortification, environmental remediation, and crop productivity. In India, nano-selenium synthesized from green sources (like plant extracts or agricultural waste) is gaining momentum as a low-cost and eco-friendly innovation.

Future Outlook

While the promise of nano-selenium is exciting, a few challenges remain:

- Establishing safe dosage ranges to prevent over-application.
- Developing low-cost, eco-friendly synthesis methods (green nanotechnology).
- Understanding long-term effects on soil health, microbes, and food chains.
- Translating lab-scale findings into field-level applications for farmers.

If these challenges are addressed, nano-selenium could become a cornerstone of climate-smart agriculture, providing both stress tolerance and nutritional benefits.

Conclusion

Nano-selenium is more than just a micronutrient—it is a tiny shield with enormous potential. By helping plants combat drought, salinity, heat, and toxic metals, it paves the way for resilient agriculture. With climate change threatening food security, nano-selenium stands out as a smart, sustainable, and powerful ally for farmers worldwide. In the years to come, nano-selenium might just transform how we protect crops and feed the world—one nanoparticle at a time.

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MOLECULAR SHIELDS: HARNESSING BIOTECHNOLOGY FOR PEST RESILIENT FARMING

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Abstract

Biotechnology has transformed agricultural pest management by adding tools that are more species-specific, environmentally benign, and compatible with integrated pest management (IPM) frameworks. This chapter reviews the principal biotechnological approaches used in insect and other pest control — including transgenic crops and plant-incorporated protectants, microbial and natural-product biopesticides, RNA interference (RNAi) technologies, genetic control strategies (sterile insect technique, gene drives, sex-ratio distortion), symbiont-based control, and genome editing (CRISPR/Cas). Strengths, limitations, biosafety and regulatory concerns, socio-economic implications, and future directions are discussed, illustrated with case studies and practical recommendations for research-to-application pathways.

Introduction

Crop losses from pests (insects, nematodes, weeds, pathogens) remain a major constraint on global food security. Traditional chemical pesticides, while effective, cause non-target effects, resistance development, and environmental contamination. Biotechnology provides alternative and complementary strategies that can reduce reliance on broad-spectrum chemicals and improve long-term sustainability. These strategies operate at molecular, organismal and ecological levels — from engineering crops that express insecticidal proteins, to altering pest populations genetically, to using molecular tools to design species-specific biopesticides. A modern IPM program should consider biotechnological options as vital components, not as standalone silver bullets.

Conceptual framework

Integrated Pest Management (IPM) emphasizes multiple tactics cultural, biological, chemical, and genetic applied in an ecologically and economically informed way. Biotechnology augments IPM by:

- Providing targeted tools that minimize non-target risk.
- Allowing monitoring/diagnostics (molecular detection of pests and resistance).
- Offering durable control options when combined with resistance management strategies. Recent reviews emphasize biotechnology's role in sustainable IPM programs and the need to integrate socio-economic and regulatory considerations in deployment.

Transgenic crops and plant-incorporated protectants (PIPs)

Bt crops and other PIPs

Bacillus thuringiensis (Bt) genes encoding insecticidal proteins remain the most widely used transgenic approach. Crops expressing Bt toxins (cotton, maize, etc.) have reduced insecticide use and improved yields in many regions. PIPs also include lectins, protease inhibitors, and plant-expressed RNAi constructs. Advantages include targeted activity and compatibility with beneficial organisms when refuge and resistance management guidelines are followed.

Microbial biopesticides and natural products

Microbial control agents (*Bacillus thuringiensis* formulations, entomopathogenic fungi like Beauveria and Metarhizium, entomopathogenic nematodes, and viruses such as baculoviruses) are core biotechnological options for pest suppression. Natural-product derivatives (pyrethrum, spinosyns, botanical oils) and microbial secondary metabolites are also widely used.

Recent innovations include genetic improvement of microbial strains (for virulence or environmental tolerance) and formulation technologies (nanoencapsulation, UV protectants) to enhance field persistence.

RNA interference (RNAi) — gene silencing for pest control

RNAi uses double-stranded RNA (dsRNA) to specifically silence target genes in pests. Delivery modes include transgenic plants expressing dsRNA, topical sprays of formulated dsRNA, or microorganisms engineered to produce dsRNA.

Mechanism and target selection

dsRNA taken up by the insect triggers the RNAi pathway, degrading complementary mRNA. Effective targets are genes essential for development, digestion, reproduction, or detoxification. Species specificity is a major advantage: well-designed dsRNA minimizes off-target effects.

Challenges: delivery, stability and variability

Major hurdles include dsRNA stability in the environment, uptake efficiency (varies widely between insect orders), and dsRNase activity in gut fluids. Formulations (protective nanoparticles, carrier peptides), transgenic expression, or microbes as delivery vehicles are active research areas. Biosafety and non-target risk assessments focus on sequence homology and exposure pathways. Recent reviews highlight critical factors affecting RNAi effectiveness and underscore the need for robust delivery systems and resistance monitoring.

Genetic control strategies

Sterile Insect Technique (SIT)

SIT involves mass-rearing, sterilizing (irradiation or genetic sterilants) and releasing large numbers of sterile males that mate with wild females, reducing reproduction. SIT has been successful against several pests (e.g., screwworm, Mediterranean fruit fly). Modern improvements include genetic sexing strains and automation. SIT is species-specific and non-chemical, but requires area-wide implementation and high logistic investment. Recent literature reaffirms SIT's value and explores integration with newer genetic tools.

Genetic drive systems and CRISPR-based approaches

CRISPR/Cas systems allow precise genome editing and the development of gene drive constructs that bias inheritance to spread traits (e.g., female sterility or sex ratio distortion) through pest populations. While powerful, gene drives raise ecological and ethical concerns due to potential irreversible ecosystem impacts. Containment, stepwise testing, molecular safeguards (split drives, self-limiting constructs), and robust risk assessment frameworks are essential. Reviews summarize CRISPR progress and emphasize careful governance before field release.

Precision-guided SIT (pgSIT) and related innovations

Novel approaches such as pgSIT combine genome editing to create strains that produce only sterile males or conditional lethality, improving SIT efficiency while avoiding irradiation's fitness costs. Early field trials and contained experiments show promise.

Symbiont-based control and paratransgenesis

Many insects host symbiotic bacteria (e.g., Wolbachia) or fungi that affect host reproduction, vector competence, or fitness. Manipulating symbionts (release of Wolbachia-infected mosquitoes to reduce dengue transmission through cytoplasmic incompatibility or reduced vector competence) is a mature example with operational programs in several countries. Paratransgenesis engineering symbionts to express antipathogen effectors — offers routes to reduce vector competency but requires deep knowledge of symbiont ecology and horizontal transfer risks.

Diagnostics, genomic surveillance and precision pest management

Biotechnology also improves detection and monitoring: molecular diagnostics (qPCR, LAMP), environmental DNA (eDNA), remote sensing linked to molecular markers, and genomic surveillance (population genetics to track resistance alleles) enable targeted and timely interventions. Genomic resources facilitate identification of molecular targets (e.g., receptors, digestive enzymes) amenable to RNAi or gene editing.

Case studies

Bt cotton/maize : successes and lessons

Bt crops dramatically reduced insecticide use in many countries and improved farmer incomes. However, resistance evolution in pests (e.g., certain Lepidoptera) emphasizes the importance of integrated resistance management (IRM) — refuges, pyramided traits, and monitoring.

RNAi sprays : topical applications for coleopterans

Some coleopteran pests (e.g., western corn rootworm) show high sensitivity to orally delivered dsRNA, making sprayable dsRNA and root uptake strategies fruitful. Yet field efficacy depends on formulation and persistence.

Wolbachia releases for arbovirus control

Wolbachia-based programs in Aedes aegypti have shown reductions in dengue transmission in pilot deployments; community engagement and regulatory compliance were key to acceptance.

SIT and pgSIT trials

Area-wide SIT programs successfully eradicated or suppressed important pests when logistics and monitoring were well coordinated. Novel pgSIT approaches show potential to reduce costs and increase male competitiveness.

Environmental, regulatory and socio-economic considerations

- Deployment of biotechnology in pest management requires addressing:
- Biosafety: non-target effects, gene flow, persistence and ecosystem impacts.
- Regulatory frameworks: varying internationally; require case-by-case risk assessment.
- Public perception and socio-economic impacts: transparency, stakeholder engagement, benefit-sharing and consideration for smallholders.
- Intellectual property and access: technologies must be accessible to resource-poor farmers; public-private partnerships and open-source breeding platforms can help.
- Regulatory science must keep pace with rapid technological advances (e.g., gene editing), and decision-making should be evidence-based and participatory.

Risks, resistance and mitigation strategies

Biotechnologies are not immune to resistance. Resistance management should be proactive and multi-tiered:For PIPs: refuges, pyramiding, mosaic deployment.

For RNAi: rotating targets, multi-target dsRNA constructs, combining with other tactics.

For genetic control: modeling population genetics, containment trials, molecular reversal strategies. Continuous monitoring, stewardship programs, and adaptive management are essential.

Conclusion

Biotechnology offers transformative tools for pest management that can reduce environmental impacts and improve the sustainability of agricultural systems. However, no single technology is a panacea. Responsible deployment requires robust science, careful governance, socio-economic consideration, and integration into IPM frameworks. Continued research into delivery systems, ecological impacts, and governance models will shape how these tools contribute to future food security.

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POWER OPERATED SPRAYER

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Abstract

Spraying fertilizers, pesticides, and herbicides has a significant impact on crop protection and agricultural productivity. In terms of coverage, traditional hand and knapsack sprayers are more labor-intensive, time-consuming, and inefficient. The present study focuses on the design and evaluation of a power sprayer developed to overcome these limitations. A portable frame, a petrol engine with 1 horsepower, a diaphragm pump, a 16-liter tank, and two nozzles with hollow cones make up the sprayer. Evaluations of the coverage area, fuel consumption, discharge rate, and droplet size were carried out in both the laboratory and the field. Results indicated an average discharge of 1.2 L/min at 2.5 kg/cm² pressure with uniform droplet distribution. When compared to a manual knapsack sprayer, the coverage rate was 20% higher. A payback period of less than one cropping season and a 35% reduction in labor costs were found through economic analysis. As a result, the newly developed power sprayer is an effective, cost-effective, and farmer-friendly option for small to medium-sized agricultural farms.

Keywords: Power sprayer, pesticide application, mechanization, crop protection, agricultural engineering

Introduction

Sustainable crop production necessitates pest and disease control. Pesticides and herbicides are widely used by farmers to reduce yield losses. Even though they are commonly used, manual and knapsack sprayers often apply the product inconsistently and take a long time. Mechanization through power-operated sprayers improves pesticide coverage, reduces

labor, and increases efficiency. The goal of this study is to create and evaluate a portable power sprayer that overcomes the drawbacks of conventional spraying techniques.

Specific objectives include:

- To design and fabricate a cost-effective power sprayer.
- To evaluate its field performance under different operating pressures.
- To analyze its economic feasibility compared to conventional sprayers.

MATERIALS AND METHODS:

Design of Power Sprayer

Engine: 1 HP petrol engine (2-stroke).

Pump: Diaphragm type, pressure range 1–3 kg/cm².

Tank: 16 L capacity, HDPE material.

Nozzles: Two hollow-cone nozzles mounted on a boom.

Frame: Mild steel with wheels for portability.

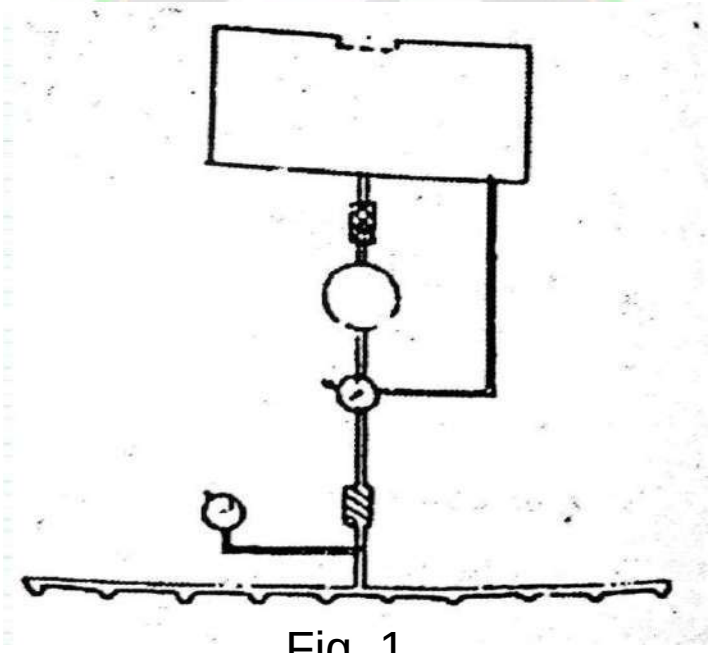


Fig. 1

Field layout

WORKING PRINCIPLE:

The power sprayer works on the principle of converting mechanical energy from an engine or motor into hydraulic energy, which is then used to pressurize and atomize the spraying liquid. A pump, typically of the piston, diaphragm, or plunger variety, is driven by the engine or

motor to draw the pesticide or fertilizer solution from the tank. The liquid is then pressurized and forced through a delivery hose to the spray nozzles. Atomization is the sudden release of pressure at the nozzle tip that breaks the liquid into fine droplets. These droplets are then directed onto the crop surface, ensuring uniform coverage and penetration into the crop canopy. Any excess liquid is recirculated back into the tank through a bypass line to maintain consistent pressure and prevent pump overload. The power sprayer is able to effectively control pests and diseases thanks to this continuous cycle, which also cuts down on time, effort, and labor costs.

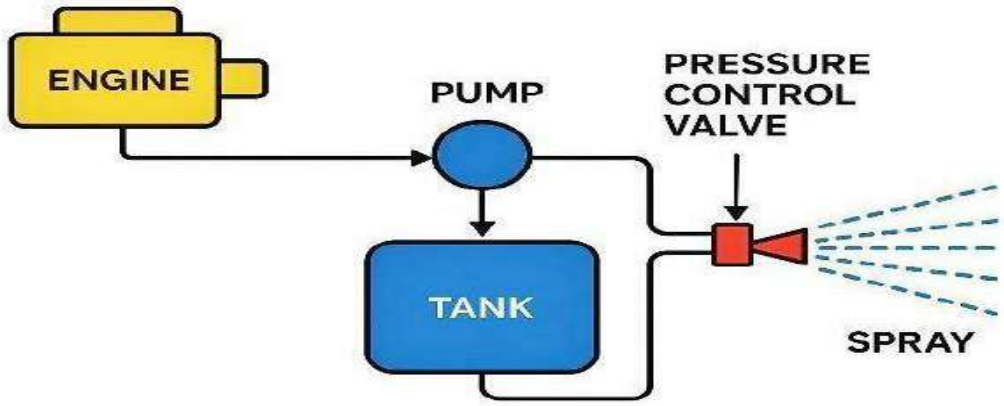


Fig. 2

Flow chart

Parameters	Description
Pump discharge	3-6 l/min
No of nozzles	1-4
Spray width	1.5 – 3.0
Field efficiency	70 – 80%

Methodology:

Laboratory calibration was carried out to measure discharge rate at different pressures. Field trials were conducted with three replications.Economic analysis was performed by comparing cost and labor requirements with manual knapsack sprayers



Fig. 3

SPECIFICATIONS

Performance Evaluation

- Average discharge rate: 1.2 L/min at 2.5 kg/cm².
- Droplet size: 220–260 µm, suitable for pesticide application.
- Coverage: 15–20% higher than manual knapsack sprayer.
- Fuel Consumption: Average fuel use: 350 ml/hour, covering nearly 1 hectares

Conclusion

The developed power sprayer successfully improved spraying efficiency, reduced labor requirements, and ensured uniform application of pesticides. It proved to be cost-effective and farmer-friendly. The system can be adapted for different crops with minor modifications in nozzle arrangements.

FUTURE SCOPE:

- Development of solar-battery hybrid models for sustainable energy use.
- Integration with IoT sensors for real-time monitoring of spray uniformity.
- Adaptation to drone-mounted sprayers for large-scale farms.

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FUNGICIDE RESISTANCE (MECHANISMS, MONITORING AND MANAGEMENT)

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Abstract

Fungicide resistance has emerged as one of the greatest challenges in sustainable crop protection worldwide. Intensive and repetitive use of fungicides has accelerated the evolution of resistant pathogen populations, threatening effective disease management. This article explores the fundamental mechanisms underlying fungicide resistance, current strategies for monitoring resistant strains, and integrated management approaches to mitigate resistance development. Understanding these aspects is crucial for ensuring the long-term efficacy of fungicides in modern agriculture.

Keywords: Fungicide resistance, Target site mutation, Efflux pump, Monitoring, FRAC, Integrated disease management

01. INTRODUCTION

Fungal pathogens cause devastating crop losses, and fungicides have been essential tools in disease management. However, continuous and improper use of fungicides has led to resistance development in several economically important fungi. Fungicide resistance is defined as "an acquired, heritable reduction in sensitivity of a fungus to a fungicide that results in failure of a product to control the disease when used according to the manufacturer's recommendations" *(Brent, 1995; Brent & Hollomon, 2007, FRAC).*

This definition emphasizes that resistance is not temporary but a genetic and stable change in pathogen populations. Resistant strains have been documented in pathogens such as ***Botrytis cinerea***, ***Zymoseptoria tritici,*** and ***Blumeria graminis***, highlighting the urgent need for effective monitoring and management.

02. Mechanisms of Fungicide Resistance

- Target Site Modification – Single-point mutations alter fungicide binding (e.g., G143A mutation in cytochrome b gene).
- Overexpression of Target Genes – Increased CYP51 expression conferring resistance to sterol demethylation inhibitors (DMIs).
- Efflux Pump Activation – ABC and MFS transporters expel fungicides (e.g., multidrug resistance in *Botrytis cinerea*).
- Metabolic Detoxification – Pathogens degrade fungicides into non-toxic forms (e.g., benzimidazole detoxification).
- Reduced Penetration or Altered Membrane Composition – Limits fungicide uptake.

03. Monitoring Fungicide Resistance

Accurate monitoring is critical for resistance management. Methods include in vitro bioassays, PCR-based detection of resistance mutations, next-generation sequencing (NGS), field surveys, and resistance risk assessment based on fungicide mode of action and usage patterns.

04. Management Strategies

- Rotation of fungicides with different modes of action (avoid repeated FRAC code use).
- Use of fungicide mixtures with distinct target sites.
- Optimized application practices – correct timing and dosage.
- Integration with non-chemical methods – resistant varieties, crop rotation, biocontrol, and sanitation.
- Adherence to Fungicide Resistance Action Committee (FRAC) guidelines.
- Regular monitoring of resistance development in fields.

05. Future Perspectives

Emerging tools such as RNAi-based fungicides, nanotechnology, genome editing (CRISPR/Cas), and advanced molecular diagnostics provide new opportunities for resistance management. Integrating host resistance, biocontrol agents, and precision agriculture with fungicide stewardship will be critical for sustainable crop protection.

TABLE 1. MECHANISMS OF FUNGICIDE RESISTANCE IN PLANT PATHOGENS

Mechanism	Description	Examples
Target Site Modification	Mutation in target site reduces fungicide binding	QoI resistance in Botrytis cinerea (G143A)
Overexpression of Target Genes	Increased expression reduces fungicide sensitivity	CYP51 overexpression in *Zymoseptoria tritici*
Efflux Pump Activation	Transporters pump fungicide out of cells	Multidrug resistance in *Botrytis cinerea*
Metabolic Detoxification	Pathogen degrades fungicide to non-toxic forms	Benzimidazole detoxification in fungi
Reduced Penetration	Changes in membranes or walls limit uptake	Observed in several resistant strains

TABLE 2. EXAMPLES OF FRAC FUNGICIDE CLASSIFICATION

FRAC Code	Mode of Action	Examples
1	Methyl benzimidazole carbamates (tubulin inhibitors)	Carbendazim, Thiophanate-methyl
3	Sterol demethylation inhibitors (DMIs)	Tebuconazole, Propiconazole
7	Succinate dehydrogenase inhibitors (SDHIs)	Boscalid, Fluopyram
11	Quinone outside inhibitors (QoIs)	Azoxystrobin, Pyraclostrobin
M	Multi-site inhibitors	Copper, Mancozeb, Chlorothalonil

Conclusion

Fungicide resistance poses a significant threat to agricultural productivity. A clear understanding of resistance mechanisms, combined with robust monitoring and integrated management practices, is essential. Collaboration among scientists, policymakers, and farmers will help sustain fungicide efficacy and global food security.

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ARTIFICIAL WETLANDS: NATURE-INSPIRED SOLUTIONS FOR WASTEWATER TREATMENT

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Abstract

Artificial wetlands (constructed wetlands) represent innovative, sustainable wastewater treatment approaches mimicking natural wetland purification processes. These engineered systems utilize synergistic interactions between plants, microorganisms, soil media, and physical-chemical processes to remove pollutants. This article explores fundamental principles, design configurations, treatment mechanisms, and practical applications addressing water quality challenges. With growing concerns about water scarcity and high conventional treatment costs, artificial wetlands offer cost-effective, energy-efficient alternatives. Discussion encompasses different wetland types—surface flow, subsurface flow, and hybrid systems—with their advantages, limitations, case studies, and future prospects for sustainable water management.

1. Introduction

Water pollution threatens ecosystems, human health, and global economic development (Vymazal, 2011). Growing populations and urbanization escalate wastewater volumes, placing enormous pressure on existing infrastructure. Conventional treatment plants require substantial capital investment, high energy consumption, and technical expertise, making them economically prohibitive for many communities, particularly in developing nations (Kadlec & Wallace, 2009).

Artificial wetlands have gained attention as viable alternatives, harnessing wetland ecosystems' inherent purification capabilities that have naturally filtered water for millions of years (Mitsch & Gosselink, 2015). By recreating these processes in controlled environments,

engineers have developed systems effectively removing pollutants while providing habitat creation, carbon sequestration, and aesthetic enhancement. Scientific understanding has evolved significantly since Dr. Käthe Seidel's pioneering 1950s work in Germany (Vymazal, 2005). Today, constructed wetlands are mature technology with thousands of successful installations across diverse climates, treating wastewater from domestic sewage to industrial effluents.

2. FUNDAMENTAL PRINCIPLES AND MECHANISMS

Treatment efficiency relies on complex interplay of physical, chemical, and biological processes (Vymazal, 2007). Physical mechanisms include sedimentation as wastewater velocity decreases, filtration through substrate media and plant roots, and adsorption onto surfaces. Chemical transformations involve precipitation reactions converting dissolved contaminants to solid forms, oxidation-reduction reactions facilitating nutrient and metal transformations, and substrate participation in processes like phosphorus binding (Vymazal, 2011). Biological activity represents the most efficient mechanism—microorganisms colonize surfaces forming biofilms that metabolize organic matter and nutrients. Aerobic bacteria decompose organic compounds while anaerobic bacteria facilitate denitrification. Plants contribute through nutrient uptake, oxygen transfer via aerenchyma tissues, and root exudates supporting microbial communities (Brix, 1997; Stottmeister et al., 2003).

3. TYPES OF ARTIFICIAL WETLANDS

Constructed wetlands are classified by hydrology, vegetation, and flow characteristics (Vymazal, 2013).

Surface Flow (SF) Wetlands most resemble natural wetlands with water flowing above substrate through emergent vegetation. They excel at treating high-volume, low-concentration wastewaters and provide wildlife habitat but require larger land areas (Kadlec & Wallace, 2009).

Subsurface Flow (SSF) Wetlands maintain water below substrate surface, including horizontal flow (HSSF) and vertical flow (VSSF) configurations. HSSF wetlands are widely used for domestic wastewater, offering odor control and cold climate operation advantages (Vymazal, 2005). VSSF wetlands provide superior oxygen transfer and nitrification capacity, particularly effective for ammonia removal (Cooper et al., 1996).

Hybrid Systems combine multiple stages with different configurations for comprehensive treatment. Common designs pair VSSF wetlands for nitrification with HSSF for denitrification,

demonstrating superior performance and meeting stringent discharge standards (Vymazal, 2013; Nivala et al., 2013).

4. DESIGN CONSIDERATIONS

Successful implementation requires careful parameter consideration (Kadlec & Wallace, 2009). Site characteristics—topography, soil permeability, groundwater levels, land area—fundamentally influence design options. Sizing calculations must account for influent characteristics, desired effluent quality, climate, and wetland type. Generally, subsurface systems require 2-8 m^2 per person equivalent while surface flow systems need 10-20 m^2 (Vymazal, 2011).

Substrate supports plant growth, provides microbial attachment surface, facilitates water flow, and participates in chemical reactions. Gravel, sand, and soil are common, with specific gradations selected for hydraulic conductivity and treatment objectives. For phosphorus removal, high sorption capacity materials like lightweight aggregates or blast furnace slag may be incorporated (Vohla et al., 2011).

Plant selection considers climate adaptability, pollutant tolerance, growth characteristics, and maintenance. Common species include cattails (*Typha* spp.), reeds (*Phragmites australis*), bulrushes (*Schoenoplectus* spp.), and sedges (*Carex* spp.). These possess aerenchymal tissues transporting oxygen to roots, creating oxidized rhizospheres supporting aerobic processes in anaerobic substrates (Brix, 1997).

Hydraulic design ensures adequate residence time and uniform flow distribution through appropriate length-to-width ratios, inlet/outlet configurations, and water depth profiles, with provisions for flow regulation and bypass capabilities (Kadlec & Wallace, 2009).

5. APPLICATIONS AND PERFORMANCE

Domestic Wastewater: The most common application treats sewage from homes, communities, and urban areas. Properly designed systems achieve 80-95% BOD and suspended solids removal, 40-60% nitrogen removal, and 30-50% phosphorus removal. In Europe, thousands serve rural communities at fractions of conventional plant costs (Vymazal, 2011).

Industrial and Agricultural Wastewater: Systems effectively treat food processing wastewater, dairy operations, winery waste, pulp and mill effluents, mine drainage, livestock operations, aquaculture discharge, and agricultural runoff. Wetland processes robustly

accommodate variable loading conditions typical of these sources (Kadlec & Wallace, 2009; Vymazal, 2014).

Stormwater Management: Wetlands designed for stormwater provide quality improvement and flow attenuation benefits, reducing peak discharge and protecting receiving waters. Many municipalities integrate wetlands into green infrastructure networks creating multifunctional landscapes (Carleton et al., 2001).

6. ADVANTAGES AND LIMITATIONS

Advantages include lower construction costs versus conventional plants, minimal energy requirements relying on natural processes, reduced operational complexity, wildlife habitat creation, biodiversity enhancement, carbon sequestration, aesthetic value, modular expansion flexibility, and resilience to variable loading conditions (Vymazal, 2011; Kadlec & Wallace, 2009).

Limitations include prohibitive land area requirements in urban settings, climate-affected performance with reduced cold temperature efficiency, challenging treatment of certain industrial contaminants requiring pre-treatment, difficult phosphorus removal often requiring supplementary processes, and initial 1-2 year establishment periods for vegetation and microbial maturation (Vymazal, 2011).

7. GLOBAL PERSPECTIVES

Europe leads implementation with Germany, UK, Czech Republic, and Austria having thousands of installations serving small communities where conventional treatment would be economically unfeasible. Long-term monitoring has provided valuable performance data (Vymazal, 2011). North America emphasizes larger-scale applications including municipal wastewater polishing, mine drainage treatment, and stormwater management. Notable examples include California's Arcata Marsh treating municipal wastewater while providing wildlife habitat, and Appalachian coal mine drainage systems remediating acidic waters (Kadlec & Wallace, 2009). In developing countries, constructed wetlands address sanitation needs where conventional infrastructure resources are limited. Projects in India, China, Brazil, and African nations demonstrate that locally appropriate designs using available materials provide effective low-cost treatment (Haberl et al., 2003).

8. FUTURE DIRECTIONS

Ongoing research expands capabilities (Vymazal, 2013). Enhanced Treatment Technologies

include bioaugmentation with specialized microbial consortia, integration of biochar or advanced media for improved sorption, and passive aeration systems. Intensified designs incorporating recirculation and staged treatment trains are being developed for space-constrained urban applications (Wu et al., 2015).

Climate Change Adaptation: Systems buffer against extreme weather by providing flood attenuation during storms and water storage during droughts. Research into plant selection and design for enhanced resilience under changing conditions is expanding (Masi et al., 2018).

Resource Recovery: Wetlands as resource recovery facilities rather than merely treatment systems is gaining traction. Opportunities include harvesting biomass for bioenergy, nutrient recovery for fertilizer, and integration with aquaculture or agriculture. This shift toward circular economy principles aligns with sustainability goals (Vymazal & Kröpfelová, 2015).

Smart Technologies: Modern wetlands increasingly incorporate sensor networks, real-time monitoring, and data analytics. Remote sensing using satellite or drone imagery assesses vegetation health. AI and machine learning predict performance and guide operations, bridging nature-based solutions with cutting-edge technology (Stefanakis, 2019).

Conclusion

Artificial wetlands represent a paradigm shift in wastewater treatment, moving from energy-intensive mechanical processes toward nature-inspired, sustainable solutions. Their ability to effectively treat diverse wastewater while providing ecological co-benefits positions them as essential components of integrated water resource management. Decades of research and thousands of worldwide installations demonstrate proven, economically viable, environmentally beneficial, and socially acceptable technology.

Continued evolution through innovative design, enhanced understanding of mechanisms, and integration with emerging technologies promises expanded applicability. In an era of increasing water stress and climate uncertainty, artificial wetlands exemplify how working with nature addresses critical environmental challenges. For communities, industries, and nations seeking cost-effective, resilient solutions, artificial wetlands deserve serious consideration. Success requires appropriate site-specific design, realistic performance expectations, and commitment to proper maintenance. With these elements, constructed wetlands provide reliable treatment for generations, demonstrating that the best solutions harness natural systems' timeless wisdom.

As we face imperatives of protecting water resources and adapting to environmental change, artificial wetlands testify to biomimicry and ecological engineering power.

They remind us that nature possesses remarkable purification capacities we can thoughtfully replicate for pressing environmental problems. Continued development represents not merely technical advancement but philosophical commitment to working harmoniously with natural processes for current and future generations' benefit.

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DISEASE MANAGEMENT OF PET BIRDS

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Introduction

Management of pet birds in the clinical setting can be challenging, because birds have the ability to mask or hide the clinical signs of illness until late in the disease process, they are often not presented until they are in advanced stages of illness, or until the owners realize something is wrong

1. **Bacterial Diseases**
2. **Viral Diseases**
3. **Fungal Diseases**

Bacterial Diseases of Pet Birds

- Bacterial diseases are common in pet birds and should be considered in the differential list of any sick bird.
- The most commonly reported pathogens are gram-negative bacteria (Klebsiella, Pseudomonas, Aeromonas, Enterobacter, Proteusand Citrobacter spp,Escherichia coli, and Serratia marcescens). Pasteurella spp have been reported as possible septicaemic agents in birds attacked by pet cats or rats. Mycobacterium and Chlamydia are common intracellular bacterial pathogens. Infections with Salmonella spp are occasionally seen.

1. Chlamydiosis – Parrot fever

Chlamydia psittaci is an obligate intracellular bacterium that can infect all companion birds but is especially common in cockatiels, budgerigars, and small parrots. The incubation period of C psittaci is from 3 days to several weeks. The organism is excreted in the faeces and in nasal and ocular discharge of infected birds. Although labile in the environment, the organism can remain infectious in organic debris for >1 month.

Clinical signs: Anorexia, dyspnoea or greenish diarrhoea.

Diagnosis

A PCR assay of a combined conjunctival, choanal, and cloacal swab along with serologic testing is recommended.

Treatment

Doxycycline is the treatment of choice and is given orally or by injection for 45 days. Psittacosis is a zoonotic and reportable disease.

2. Avian Mycobacteriosis

Avian mycobacteriosis is an important disease that affects companion, exotic, and domestic birds. This disease is most commonly caused by **Mycobacterium avium and M. genovense**.

Clinical Signs

Clinical Signsof disease are generally nonspecific depending on duration of infection and organ system affected. These organisms are slow-growing, and disease is typically chronic in nature, so it tends to be a disease of older birds.

Diagnosis

PCR assay, acid-fast staining, and in some cases biopsy, cytology, and/or histopathology.

Treatment

A combination antimicrobial therapy for 6–12 months or longer. Use of multiple antimicrobials (typically three) is recommended, because mycobacterial organisms are prone to developing antimicrobial resistance. Antimicrobials in differing combinations that have been used successfully are rifabutin (45 mg/kg), clarithromycin (60–85 mg/kg), ethambutol (30 mg/kg), and enrofloxacin (20–30 mg/kg).

Zoonotic aspects

Infections in humans have not been associated with exposure to birds, precautions should be

taken for zoonotic risk, especially in immunocompromised humans.

Viral Diseases

Poxvirus Infections

Poxviruses are large DNA viruses that induce intracytoplasmic, lipophilic inclusion bodies (Bollinger bodies) in the epithelial cells of the integument, respiratory tract, and oral cavity.

The three clinical forms of poxvirus infection are:

- Cutaneous form or "dry pox" –wart-like lesions typically on the face, beak, and legs (most common form)
- Diphtheritic form or "wet pox" –lesions on the mucosa of the oral cavity and respiratory tract
- Septicemic "generalized pox" –internal lesions affecting the respiratory and GI tracts, causing systemic disease

Transmission is primarily via insect vectors (mosquito bites).

Clinical signs

Clinical signs depend on the form of disease, location of the lesions (eye, oral, ear), and overall health of the bird and may include lethargy, respiratory distress, partial blindness, difficulty eating, weight loss, emaciation, and skin lesions

Diagnosis

Pox virus infection is typically confirmed through history, physical examination findings, and histologic findings of Bollinger bodies in affected tissues.

Treatment

supportive care, fluids, parenteral vitamin A, ophthalmic ointments for eye infections, assisted feedings, and antimicrobials to prevent or treat secondary infections. Lesions on the skin may need daily cleaning.

Transmission is via insect vectors (mosquito bites) or other entry through breaks in the skin. Therefore, mosquito control and indoor housing are vital to prevent outbreaks.

Vaccines for canarypox, fowlpox, and pigeonpox are available but are specific for their host species.

Pacheco's Disease

Psittacine herpesvirus is an alpha herpesvirus that is the causative agent of Pacheco's disease and internal papillomatosis in parrots. Pacheco's disease causes a viral hepatitis seen predominantly in New World species (Amazon parrots, macaws, and conures).

Clinical Findings of Pacheco's Disease of Pet Birds

Terminal signs of Pacheco's disease include acute death in well-fleshed birds and bright yellow urates with scant feces. Other clinical signs are diarrhea, green urates, lethargy, regurgitation, weakness, and depression.

Diagnosis of Pacheco's Disease of Pet Birds

Diagnosis of Pacheco's disease in a live bird can be done by DNA probes of combined oral and cloacal swabs and blood samples. Increases in plasma AST activity and marked leukopenia have been reported.

Because of the acute nature of the disease, histologic lesions may not be evident. However, most affected birds will have hepatomegaly, splenomegaly, and renomegaly. The liver may be mottled or grossly discolored. Ecchymotic and petechial hemorrhages may be present on the pericardium and within the mesenteric fat. Intranuclear inclusions are seen histologically in the liver, spleen, intestinal epithelium, and pancreas.

Treatment and Prevention of Pacheco's Disease of Pet Birds

In addition to supportive care, acyclovir (80 mg/kg, 3 times a day, or 400 mg/kg in feed) can be used during an outbreak; however, the risk of increased transmission because of handling is great.

Autogenous **vaccines** have been developed during outbreaks and have effectively decreased morbidity and mortality.

Proventricular Dilatation Disease (PDD)

Avian bornavirus (ABV) is a neurotropic virus that causes proventricular dilatation disease (PDD).Proventricular Dilatation Disease (PDD) is one of the most confounding avian disorders. The disease affects the nerves that supply the bird's gastrointestinal tract, though it can also affect nerves that supply other organs.

PDD is also known as **Macaw Wasting Syndrome** and **Parrot Wasting Syndrome** because it's most commonly diagnosed in Macaws, African grey parrots, Amazon parrots, cockatoos, and conures.

Symptoms

- Weight loss,
- Vomiting,
- Changes in the bird's droppings,
- Swollen crop

Treatment

- Nonsteroidal anti-inflammatory drugs (NSAIDs), and the bird may have to be put on a special diet.
- However, there's no cure for the disease, so these treatments are just to reduce pain for the rest of the birds' lives.

Fungal (Mycotic) Diseases of Pet Birds

Fungal diseases are common in companion birds. Often, they are a secondary infection in an already ill or immunocompromised bird. The most common fungal diseases are respiratory tract infections caused by Aspergillus spp and GI tract infections caused by Candida spp. Macrorhabdus is an unusual fungus that affects the GI tract and occurs most commonly in small pet birds (budgerigars, lovebirds, finches, parrotlets, and cockatiels).

Candidiasis

Candidiasis is a common fungal disease, seen mostly in young or immunocompromised birds. Birds on broad-spectrum antimicrobials are most at risk. Often, candidiasis is secondary to poor husbandry and an unclean environment

The etiologic agent is the opportunistic yeast Candida albicans, which commonly affects the GI tract. Although C albicans is the most common isolate, others including C tropicalis, C parapsilosis, C glabrata, and Hansenula spp may also be found and may be refractory to treatment.

Clinical Findings of Candidiasis in Pet Birds

- Mild weight loss,
- lethargy, and
- dull plumage.
- Young birds may have more severe disease, especially if they are immunocompromised.
- Anorexia,
- Crop stasis, white plaques in the oral cavity, regurgitation, and weight loss

- Thickening of the crop may develop ("Turkish-towel" appearance).

Diagnosis of Candidiasis in Pet Birds

Diagnosis of candidiasis is by identifying Candida spp on a Gram, Romanowsky-type, or new methylene blue stain of the faeces, crop contents, or regurgitated material. Scrapings or impression smears may also be performed to diagnose suspected yeast infections of the skin.

Treatment of Candidiasis in Pet Birds

Flock treatment has been accomplished with use of chlorhexidine at 10 mL/gal. of drinking water for 1–3 weeks.

Aspergillosis

Aspergillosis is an opportunistic infection that typically occurs in immunocompromised birds. **Clinical Signs** Depression, anorexia, voice change, increased respirations, and/or dyspnea. Diagnosis is based on species, clinical signs, blood tests, and diagnostic imaging.

Diagnosis of Aspergillosis in Pet Birds

- History, clinical presentation
- CBC, biochemistry profile, serology, PCR assay
- Imaging (radiographs, CT, endoscopy)
- Cytology, histopathology, culture

Treatment

- Antifungals (oral, intravenous, intranasal, nebulization)
- Supportive care (oxygen, nutrition, fluids), possible air sac tube placement
- Endoscopic examination and/or surgical debridement

Other Diseases

Heatstroke

The ultimate concern in the first aid of heatstroke is to get the bird's body temperature lowered immediately.

Management

- Spray the feathers with alcohol (keeping away from bird's face) or cold water. Alcohol will last longer on the feathers.
- Place the bird in an air-conditioned room or in front of a fan.
- Immerse the bird's feed in cold water or place cold water, a few drops at a time, in the bird's vent with a syringe or dropper to help lower internal temperature rapidly.

- If the bird is conscious, allow it to drink – or give it manually – a few drops of water at a time.
- There is always the danger of shock following heatstroke. Water the bird carefully – when its panting has lessened and it appears more alert and comfortable to prevent chills. Keep it quiet and get it to the vet immediately.

Some foods can be particularly unhealthy or even toxic to birds.

- Raw potato and starches
- Chocolate
- Onion and garlic
- Wild berries
- Dairy/eggs/meat

Zoonotic Diseases of Pet birds

The zoonotic diseases of pet birds are mainly divided into bacterial, viral, parasitic and fungal diseases as mentioned below

Bacterial Diseases:

- Chlamydophilosis
- Salmonellosis
- Tuberculosis

Viral Diseases

- Avian Influenza Virus
- New Castle Disease
- Parasitic Disease
- Cryptosporidium Infection

Fungal Disease

- Cryptococcus
- Aspergillus Infections

Guidelines for welfare of pet birds and for prevention of potential zoonotic diseases

- Free access to water and food for good health of pet birds
- Good housing facility which protects from harsh environment conditions
- Sufficient space to maintain the natural behaviour
- Careful handling

- Prevention and control of diseases of pet birds
- Cleanliness of clothing and shoes following contact with other birds
- Washing of hands before and after handling birds
- Regular cleanliness of cages, food and water
- Discard the remaining food (fruits and vegetables) regularly
- Regular washing and cleanliness of cages at least once a week
- Storage of food in clean and sealed containers
- Cleanliness and disinfection of cages before use
- Quarantine of the sick or newly introduced pet birds
- Restricted access to persons having their own pet birds
- Follow the rules for import or export of pet birds
- It is also recommended that breeders or pet shop owners should control the transmission and spread of zoonotic diseases

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AI-POWERED DRIP IRRIGATION IN PRECISION FARMING

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Introduction

Climate change, a lack of water, and a demand for more food production are all issues facing agriculture today. Water is frequently wasted during traditional irrigation, resulting in uneven crop growth. Modern technology is utilized in precision farming to address these issues. Although drip irrigation is effective because it delivers water directly to the roots, farmers still struggle to determine when and how much to irrigate. To schedule irrigation, artificial intelligence (AI) aids by analyzing data from crops, the weather, and soil. This guarantees the appropriate amount of water at the appropriate time, resulting in increased yields, decreased expenses, and sustainable farming.

PRECISION FARMING AND THE NEED FOR SMART IRRIGATION

Smart irrigation is required for precision farming. Technology is used in precision farming to better manage crops and provide each plant with the right amount of water and nutrients. An essential part of this procedure is irrigation. Traditional methods typically result in lower yields because they either waste water or fail to meet crop requirements. This problem is solved by smart irrigation, which decides how much water to give to a crop at the right time by analyzing data from weather models, soil sensors, and crop models. Farmers can support sustainable farming, save water, improve crop health, and monitor crops in real time with AI-powered drip irrigation.

DRIP IRRIGATION: CONCEPT

Drip irrigation is a practice that uses pipes and tiny outlets called emitters to get water directly to the roots of plants. It saves water by reducing waste from runoff and evaporation, unlike conventional methods like flooding.



Importance:

- Uses less water and saves more money than other methods.
- Reduces weed growth and maintains a balanced soil moisture level.
- Enhances plants' ability to absorb nutrients.
- Very useful in areas that lack water and are dry.
- Improves crop quality and yield. When used with smart systems like sensors or AI, it allows precise control of watering for sustainable farming.

AI POWERED IRRIGATION SCHEDULING

Although AI-powered drip irrigation has shown great promise for increasing crop productivity and water efficiency, its implementation still faces some obstacles. At the same time, significant advancement opportunities are provided by upcoming developments.

KEY BENEFITS

- **Efficient Water Use**

  Sensor used: Soil Moisture Sensor.

- **Better Crop Yield and Quality**

  Sensor used: Crop health sensors (like NDVI or temperature sensors).

- **Less labor and Cost**

  Sensor used**:** Flow meter and pressure sensor.

- **Climate Adaptability**

Sensor used: Weather sensor (rain, humidity, temperature).

- **Sustainable farming**

  Sensor used: Nutrient and pH sensors.

BENEFITS OF AI IN DRIP IRRIGATION

Drip irrigation made possible by AI has numerous benefits for farmers and the environment:

- Efficient Water Use: AI makes sure that only the amount of water needed is given to the plant, reducing waste from over-irrigation and evaporation.
- Better Crop Yield and Quality – Timely and accurate water supply prevents crop stress, leading to healthy growth, higher productivity, and good-quality produce.
- Lower Labor and Cost – Automation reduces the need for manual checking, saving energy, fertilizer, and operational expenses.
- Climate Smart: AI adjusts irrigation schedules based on weather data to help farmers deal with droughts and unpredictable rainfall.
- Sustainable farming: Effective irrigation safeguards the health of the soil, conserves natural resources, and promotes environmental sustainability over the long term.

CHALLENGES

- High Initial Investment: It costs a lot to put in drip systems, sensors, IoT devices, and AI platforms all at once. Without financial assistance, many marginal and small farmers cannot afford these technologies.
- Technical Knowledge Gap: AI and sensor-based systems require farmers to understand data, software, and system operation. Lack of training and awareness among rural farmers can limit adoption.
- Problems with Infrastructure and Connectivity Sensors need reliable internet, cloud platforms, and electricity for real-time data transfer. Poor connectivity hinders the performance of smart irrigation systems in remote areas.
- Maintenance of Devices: Calibration and upkeep on soil moisture sensors, flow meters, and weather stations are necessary on a regular basis. Damage due to dust, water, or climate conditions can increase costs for farmers.
- Data Accuracy and Reliability: The quality of the data gathered by sensors and weather

services is crucial to AI. Irrigation decisions can be made incorrectly due to inaccurate sensors or incomplete data.

FUTURE SCOPE

- Utilization of Modern Sensors Precision irrigation will become more affordable thanks to low-cost, wireless sensors for soil moisture and nutrients. Use of multispectral cameras, drones, and satellite imaging can improve crop water requirement predictions.
- Affordable AI Platforms: Farmers can receive AI irrigation advice directly from cloud-based mobile applications. Smallholders' subscription models can be designed at a low cost by governments and Agri tech startups.
- IoT and robotics Drip valves and pumps can be controlled automatically by connecting sensors to IoT devices. Crops can be irrigated by fully automated systems without human intervention.
- Agriculture that is climate-resistant AI models using real-time weather forecasts will help farmers manage irrigation during droughts, heatwaves, or floods. This guarantees adaptability to the effects of climate change.
- Conservation of Resources and Sustainability Irrigation powered by AI will be crucial in reducing water consumption, preserving soil health, and ensuring food security over the long term. The adoption of eco-friendly devices and biodegradable sensors will further advance sustainable farming.

Conclusion

Drip irrigation with AI is a significant advancement in modern farming. It helps farmers save money, increase crop yield, and make better use of water. Using actual data, AI systems supply the right amount of water at the right time. New technologies like the Internet of Things (IoT) and smart sensors are making AI irrigation easier for all farmers, despite issues like high costs and a lack of technical expertise. This method helps ensure future food security, conserves water, and supports sustainable farming.

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MECHANIZATION OF INTERCULTURAL OPERATION USING POWER WEEDER FOR ENHANCED CROP PRODUTIVITY

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Abstract

A power weeder is a machine used in farming to remove weeds easily and quickly. It works with the help of an engine that turns blades to cut and remove weeds from the soil. This machine is mainly used between crop rows like paddy, maize, sugarcane, and vegetables. It helps farmers save time and reduce hard manual work. The blades used in the weeder such as L-type, J-type, or C-type help to work better in different soils. A power weeder also improves soil air and keeps the field clean. It is a useful machine for modern and efficient farming, especially for small and medium farmers.

Keyword

Power Weeder, Mechanized Weeding, Intercultural Operation, Soil Aeration, Weed Control, Agricultural Machinery, Engine Operated Weeder, Crop Productivity, Labor Efficiency, Sustainable Farming.

Introduction

A power weeder is a mechanized intercultural implement designed for effective weed management and soil pulverization in agricultural fields. It operates through an internal combustion engine or electric motor, transmitting power via belt drive or gear mechanism to the rotary blades (tines) for cutting and mixing soil. The machine ensures uniform soil tilth, enhances aeration, and maintains optimum moisture content for crop growth. It is suitable for

row crops such as paddy, maize, sugarcane, cotton, and vegetables. The use of a power weeder reducing labour intensity and operational time.

TYPES OF POWER WEEDER

Power weeder divided into four types which is based on different power sources

1.Rotary weeder

2.Engine operated weeder

3.Battery operated weeder

4.Tractor operated weeder

ROTARY WEEDER



Fig 1. Rotary weeder

The rotary motion and soil-cutting action underpin the operation of the rotary weeder. To cut, uproot, and incorporate weeds into the soil, it makes use of rotating blades mounted on a horizontal shaft that spins at a high speed. The power required for this rotation is supplied either by a petrol/diesel engine, electric motor, or tractor PTO (Power Take-Off), depending on the type of weeder.

The rotary blades penetrate the surface of the soil as the machine advances and shear the weeds at their root zones, effectively eliminating them. Additionally, the rotation contributes to the pulverization of the upper soil layer, enhancing soil aeration, moisture retention, and root growth. The rotary weeder basically works by converting mechanical energy into a rotary cutting action. This ensures uniform weeding between crop rows, improves the texture of the soil, and helps better crop establishment and yield.

BATTERY OPERATOR

A battery-powered weeder is an innovative and eco-friendly agricultural machine designed to simplify and accelerate the process of weed removal in fields, gardens, and orchards. Unlike conventional engine-operated weeders that rely on petrol or diesel, battery-powered weeders use rechargeable batteries, making them quieter, emission-free, and environmentally sustainable. These machines are typically lightweight, compact, and easy to manual, which reduces operator fatigue and allows for precise operation even in narrow or densely planted areas. The working principle involves an electric motor that drives rotating blades, tines, or discs, which uproot or cut weeds efficiently while causing minimal disturbance to the soil structure. Advanced models may come with adjustable blade speed, depth control, and ergonomic handles to enhance performance and operator comfort. Battery power weeders are particularly suitable for small and medium-scale farming, organic fields, and areas where noise and air pollution need to be minimized. They offer advantages such as low maintenance, cost-effective operation, and longer service life of components due to the absence of combustion engines. With technological improvements, these machines are becoming more powerful, capable of covering larger areas on a single charge, and are emerging as a sustainable alternative to traditional mechanized weeders, contributing to both productivity and environmental protection.

ENGINE OPERATOR

An engine operated power weeder is a mechanized agricultural machine that uses an internal combustion engine (IC engine) as its main power source to remove weeds effectively from crop fields. Through combustion, the engine, which typically runs on gasoline or diesel, transforms chemical energy from the fuel into mechanical energy. After that, a gearbox and shaft carry this mechanical energy to rotate the blades which remove weeds from the soil and cut them up. Mechanical power transmission underpins the engine-powered weeder's operation. In order to improve aeration and conserve moisture, the rotating blades cut through the soil at the weeds' root zones and loosen the topsoil. The machine's handles or wheels control its forward movement, making it simple to navigate between crop rows. Engine-operated weeders are suitable for medium to large-scale farms and are highly efficient in paddy, maize, sugarcane, and vegetable cultivation. They are available in two-stroke and four-stroke engine models, typically ranging from 1.5 HP to 10 HP, depending on field size and crop type.

These machines are valued for their high working efficiency, durability, and ability to operate in tough soil conditions, making them one of the most widely used types of power weeders in modern agriculture.

TRACTOR OPERATOR

Power Weeder Operated by Tractor A high-capacity agricultural tool designed to get rid of weeds in large-scale farming operations is a tractor-operated power weeder. It is attached to a tractor through the Power Take-Off (PTO) shaft, which transmits power from the tractor's engine to the weeder. The rotary blades mounted on the weeder rotate at high speed, cutting, uprooting, and mixing weeds into the soil while also improving soil aeration and structure.

The working principle of the tractor operated power weeder is based on mechanical power transmission via the PTO system. The rotary shaft of the weeder is rotated by the tractor engine as it drives the PTO shaft. This rotational motion powers the blades to perform the weeding and soil pulverizing action. The crop spacing and the state of the field can be used to adjust the depth and width of the operation. Large farms, row crops, and commercial cultivation of paddy, sugarcane, cotton, maize, and pulses all benefit greatly from tractor-operated weeders. They are capable of covering a wide area in less time and are efficient even in heavy and clayey soils.

These machines offer a number of advantages, including lower labour costs, increased field capacity, uniform weeding, and increased crop yield. Hence, the tractor operated power weeder plays a vital role in modern mechanized agriculture by ensuring efficient, large-scale, and cost-effective weed management.

SPECIFICATION IN TYPES OF POWER WEEDER

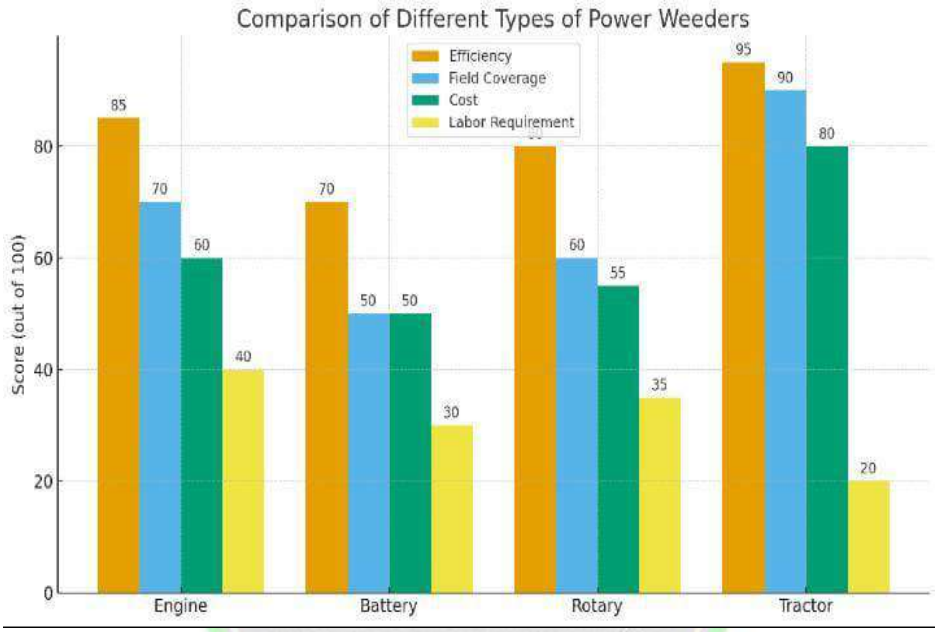
PARAMETERS	ROTARY OPERATOR	ENGINE OPERATOR	BATTERY OPERATOR	TRACTOR OPERATOR
Power source	Manual or Engine driven (rotary motion)	Petrol or diesel engine	Rechargeable Battery (12v-48v)	PTO power from tractor
Power rating	1-3 HP (manual) (or)3-7HP	3-7 HP	0.5-1.5 HP equivalent	20-45 HP (tractor dependent)

	(motorized)			
Type of drive	Rotary shaft	Engine shaft or Belt drive	Electric motor drive	PTO shaft drive
Tine/teeth type	L-type, S-type, (or)Straight rotary tines	L-type, S-type, Hardened steel blade	L-type, Star shaped blades	L-type, C-type, Zig-Zag blades
Working width	600-1200 mm	600-1000 mm	300-600 mm	1200-1800mm
Working depth	50-100mm (adjustable)	50-120 mm (adjustable)	30-60mm (light operation)	100-150mm
Rotation speed (rpm)	150-250 rpm	180-300rpm	100-180rpm	250-400rpm
Field capacity	0.05-0.12 ha/hr	0.08-0.15 ha/hr	0.03-0.07ha/hr	0.25-0.5 ha/hr
Fuel/Energy use	Manual or minimum fuel	0.5-1.0 L/hr	0.5-1kw/hr (battery power)	2-3 L/hr(diesel)
Efficiency	Weeding 75-90%	80-95%	70-85%	90-98%
Application	Vegetable, row crops	Intercultural operation in field crops	Gardens, Greenhouse crops	Large scale farming, Tillage
Advantage	Simple, low cost, easy maintenance	High efficiency,	Low noise, eco-friendly	Covers large area quickly, high durability
Limitation	Less power, manual control	Need fuel, emit exhaust	Limited battery backup, less torque	Requires tractor, high cost

Table 1(Comparison Between Different Types of Power Weeder)

- Notes on blade/Teeth types
  - L -type /T-type: Standard for loosening soil and uprooting weeds
  - S-type / Star blades: Rotational blades for better mixing and weed control.
  - Flat blades: Used in battery weeders for light soil and small weeds.
  - Disc blades: Used in tractor weeders for deeper tillage and large fields.

Comparison of different types of power weeder by using graph;



Graph 1(types of power weeders)

Conclusion

The power weeder is an efficient agricultural machine designed to reduce human effort and improve the productivity of weeding operations. It helps in removing weeds between crop rows, loosening the soil, and enhancing soil aeration for better crop growth. By using engine, battery, or tractor power, it saves time, labour, and fuel compared to manual weeding. Overall, the power weeder increases field efficiency, ensures uniform weeding, and supports sustainable and cost-effective farming practices.

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EXPLORING DIFFERENT TYPES OF HAND SPRAYER

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Abstract

A hand sprayer is an easy-to-use and effective agricultural tool for applying liquid fertilizers, pesticides, herbicides, and fungicides to crops. It operates manually by creating pressure through a hand pump mechanism, which atomizes the liquid into fine droplets for uniform coverage on plant surfaces. Due to their portability, low cost, and simplicity of operation, hand sprayers are frequently utilized in nurseries, gardens, and small-scale farming. They reduce chemical waste, encourage healthy crop growth, and aid in the control of pests and diseases. The tank, pump, nozzle, pressure chamber, and delivery pipe are the main parts of a hand sprayer. Depending on the purpose, various types, including knapsack, trigger, and compression sprayers, are utilized. Hand sprayers play a vital role in achieving effective chemical application, ensuring better crop yield and sustainable agricultural practices.

Keywords: Hand sprayer, Fertilizers/Pesticides, Manual operation, Uniform coverage, Crop yield

Introduction

In agriculture, a hand sprayer is a portable device used to manually apply liquids like pesticides, herbicides, fungicides, and fertilizers onto crops, weeds, and other plants. These sprayers are operated by hand, often in a knapsack or compression design, to provide controlled and uniform coverage, helping to protect plants from pests and diseases and improve crop health and yield in small to medium-sized fields and gardens. They are also used for general tasks like cleaning and applying uniform watering and applying growth regulators to plants. They are ideal

for home gardens, small-scale farming, and treating crops like cotton and rice in their early stages of growth due to their portability, ease of use, and low cost.

CLASSIFICATION AND USES OF HAND SPRAYER

The Hand sprayer classification based on:

1. Design and Function-Based Classification of Hand Sprayers.
2. Categories and Types of Hand Sprayers.
3. Agricultural Hand Sprayer Classification.
4. Different Classes of Hand Sprayers and Their Applications.
5. A Study on the Types and Classes of Hand Sprayers.
6. Categorizing Hand Sprayers: Functionality and Mechanism.

The following tasks are performed with the spraying equipment:

For the insecticides application to control insect pests on crops and in stores, houses, kitchen, poultry farms, barns, etc. for the application of insecticides to crops, stores, homes, kitchens, poultry farms, barns, and other locations to control pest insects.

a) For the acarices application to control phytophagous mites. For the application of fungicides and bactericides to combat plant diseases. For the application of herbicides to eradicate the weeds. For the application of harmonized sprays to either extend the fruit set or stop fruit from dropping too soon.

b) For foliar spray application of plant nutrients. For applying the powdery formulation of poisonous chemicals on the crops and for any other purposes.

FUNCTION AND MECHANISM OF HAND SPRAYER

A hand sprayer's function is to apply liquids like pesticides, fertilizers, or cleaning solutions to surfaces or plants in a controlled mist or jet. In a sealed tank, its mechanism relies on manual pumping to create pressure. The liquid is forced through a spray lance and nozzle by this compressed air, where it is atomized into fine droplets and released by pressing a flow control level.

FUNCTION OF SPRAYER

a) **Controlled Application:** Hand sprayers apply liquids with precision, preventing overuse and ensuring effective coverage for small-scale tasks.

b) **Portability:** Their lightweight and compact design makes them versatile for various environments, including gardens, orchards, and homes.

c) **Versatility:** They can be used for a variety of tasks, including watering plants and applying foliar fertilizers, controlling pests, and disinfecting surfaces.

d) **Cost-Effectiveness:** For small jobs, hand sprayers provide an affordable and efficient solution for applying chemicals and liquids.

MECHANISM OF A COMPRESSION SPRAYER

a) **Fill the Tank**: The liquid, such as water or pesticide, is poured into the tank, typically to a capacity of 75-80%.

b) **Build Pressure:** The sprayer's integrated vertical air pump is manually operated.

- The upward stroke of the pump draws air the cylinder.
- The downward stroke compresses this air and forces it into the main tank, creating internal pressure.

c) **Release Liquid:** When the operator presses a flow control lever, the compressed air in the tank pushes the liquid up the spray lance.

d) **Atomize the Liquid:** The liquid exits through the nozzle, which is designed to break the liquid stream into a fine mist or a more directed jet.

e) **Repeat:** The operator continues to pump and spray as needed, creating a continuous flow of pressurized liquid.

TYPES OF HAND SPRAYER

HAND HELD SPRAYER

The pressurized fluid is then let out through a nozzle, and sprayed into fine droplets. An air pump equipped with a cylinder, plunge, and plunger rod is required if the pressure inside the container is to be built. When the plunger is pulled up, the air is sucked into the cylinder and when pushed down the air bubble is releases into the container with 80% of its volume filled with the fluid. The fluid is pressed by the air as it reaches the space above the free fluid surface. Through a trigger cut in the valve, the pressurized fluid is drawn up to the nozzle, where it is atomized and sprayed. In another type, the air pump and the container are separate components that are connected so that the pressurized air is released through an orifice at the top of the container. The fluid is lifted through an office at the top of the container.



(Fig.1.Hand Held Sprayer)

Due to the high velocity air's surface tension at the outlet, the fluid is lifted through a capillary tube before being sheared off by the air and sprayed as droplets.

SPECIFICATION

- **Capacity:** The capacity of a tank can be as small as one liter for household use or as large as nine to twelve liters for agricultural purposes.
- **Tank Material:** Brass is a common material due to its durability and resistance to chemicals, though cold-rolled steel is also used for industrial quality tanks.
- **Material of the Pump**: For long-lasting performance, pumps typically use brass.
- **Working Pressure:** To ensure effective spraying, typically produces a working pressure of approximately 60 psi (4bar).
- **Spray Lance:** Includes a spray lance, often with a trigger cut-off, an extension rod, and a duro mist nozzle made of stainless steel for durability.
- **Delivery Hose:** The tank and the spray lance are connected by a delivery hose, which can be as long as 110 cm.
- **Accessories:** Accessories can include adjustable shoulder straps, a filling funnel, and a wrench.
- **Dimensions and Weight:** These vary widely based on the tank size, from approximately 2.5 kg for a 3.5-liter model to around 6.0 kg for a 9-liter sprayer.

KNAPSACK SPRAYER

The pressure chamber also includes an agitator for agitating the fluid to prevent the suspension of particles from settling. A delivery tube is attached on the other end of the pump which carries the pressurized fluid to the spray lance. The flow to the nozzle is controlled by a trigger cut-off valve. An air pump is used to create air pressure above the free surface of the spray fluid in the container in the case of a compression knapsack sprayer. Fig.2.Knapsack Sprayer

Typically, the unit is kept on the ground and then sprayed until the air pressure drops. The unit is again brought back to the ground for pumping air and then the spraying is contained as before.



(Fig.2.Knapsack Sprayer)

The spray fluid, which does not enquire any agitation, can be sprayed by using this type of sprayers.

SPECIFICATION

- **Tank capacity:** Typically 10–16 liters, designed for small-scale applications.
- **Pump:** Operated by a side lever, which the user pumps manually to build and maintain pressure. The pump is often made of brass or HDPE material.
- **Operating pressure:** Produces pressures that are adequate for small trees and field crops. A typical working pressure of 3 bar (3 kg/cm2) is stated by one model.
- **Frame and straps:** Includes a frame or back shield and adjustable, padded shoulder straps for comfortable carrying.
- **Weight:** Around 5 kg when empty, with a full weight not exceeding 25 kg for safety.
- **Nozzle:** Comes with a spray lance and an adjustable nozzle, often with different spray patterns.

BUCKET SPRAYER

The open container, typically a bucket, is where the spray fluid is pumped directly into the bucket sprayer. The hydraulic pump will be put inside the bucked and held properly with the help of foot rest. The fluid enters the pressure chamber through a ball valve assembly when the plunger is pressed down, and the suction valve closes as the fluid enters the pressure chamber when the plunger is pulled up.

Pressure builds up in both the pressure chamber and the delivery hose as the plunger is continuously operated. As soon as the required pressure is built up, the spraying will be done. The majority of models develop a pressure of 4 kg/cm2. (Fig.3.Bucket Sprayer)

SPECIFICATION



Fig.3.Bucket Sprayer

- **Pump mechanism**: A hand lever controls a hydraulic piston pump.
- **Pressure generation:** With each up-and-down stroke of the plunger, fluid is drawn from the bucket and forced into a pressure chamber.

- **Working pressure:** The spraying pressure is built and maintained by constant manual pumping. These models typically achieve pressures around 4 kg/cm2, or 60 psi.
- **Output:** As long as the pump handle is turned, this design produces a continuous spray.

FOOT SPRAYER

A foot sprayer is a manual, foot-operated agricultural pump that allows users to spray pesticides, fertilizers, herbicides, and other chemicals onto crops by pumping with their foot, freeing up their hands for better control and maneuverability.

These devices are ideal for applying chemicals with consistent pressure and are used by farmers and gardeners for field crops, orchards, and tall trees, offering a cost-effective and efficient method for pest and disease management.



Fig.4.Foot Sprayer

SPECIFICATION

- **Operating pressure:** Foot sprayers can develop a high average working pressure, with some models reaching 600kPa (6bar). Higher pressures are possible, such as 17–21 kg/cm² for some modified versions.

Discharge rate: A minimum discharge rate of 1,200 ml/min is common, ensuring efficient coverage.

Spray throw: The high-pressure capabilities allow the sprayer to achieve a significant spray throw, with some models capable of spraying up to 20 feet high.

- **Field capacity:** A foot sprayer can cover a large area per day, suitable for small to medium-sized landholdings, depending on the operator's speed and working conditions.

ROCKER SPRAYER

The process continues until the pump operator is unable to push the piston forward due to the downward pressure created by the entrapped compressed air in the pressure vessel and until the entire suction pipe, ball valve assembly, delivery hose, and a portion of the pressure vessel are filled with spray fluid. Thereafter, the trigger cut off valve will be opened to allow the spray fluid to rush through the nozzle and get atomized.

Fig.5.Rocker Sprayer

The pressure chamber typically has the capacity to build pressures of 14 to 18 kg/cm2, making it convenient for free spraying.



Fig.5.Rocker Sprayer

SPECIFICATION

- **Average working pressure:** Around 6 bar (600kPa).
- **Minimum discharge:** Approximately 1,200 ml per minute, which can vary based on nozzle type.
- **Spray range/height:** Can reach up to 20–25 feet (6–7.5 meters).

Conclusion

Hand sprayers are useful tools for applying liquids accurately and effectively in a variety of applications, including cleaning and pest control, agriculture, gardening, and agriculture. While they all share the basic function of dispersing liquid as a spray, they are best understood through their distinct categories, each suited to different scales and applications. The most suitable hand sprayer ultimately depends on the size of the area to be treated, the type of liquid being sprayed, and the required spray precision.

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HETEROTIC GROUPING IN MAIZE: UNLOCKING THE POWER OF HYBRID BREEDING

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Abstract

Maize (*Zea mays* L.) is one of the most important cereal crops worldwide and hybrid breeding has played a crucial role in increasing its productivity. The concept of heterosis or hybrid vigor, underpins the success of modern maize improvement programs. Heterotic grouping, which classifies inbred lines into genetically distinct groups, is a vital strategy for maximizing heterosis and achieving consistent yield gains. By identifying and exploiting genetic divergence between groups, breeders can develop superior hybrids that combine traits such as high yield potential, stress tolerance and nutritional quality. Advances in molecular markers, genomics and statistical models have refined grouping methods, allowing more precise classification compared to traditional morphological and pedigree-based approaches. Heterotic grouping not only ensures sustained genetic gains but also strengthens breeding efficiency and resilience in the face of climate change. It remains an indispensable tool in developing high-performing maize hybrids for global food and nutritional security.

Keywords: Maize, Heterosis, Hybrid breeding, Genetic diversity, Molecular markers and Crop improvement.

Introduction

Maize (*Zea mays* L.) is a cornerstone of global agriculture, cultivated across diverse environments and serving as food, feed and industrial raw material. Its remarkable yield potential

largely stems from the exploitation of heterosis, also known as hybrid vigour, wherein crosses between genetically distinct parents produce superior offspring. Hybrid maize varieties have consistently outperformed open-pollinated varieties, revolutionizing productivity in both developed and developing countries.

At the heart of successful hybrid breeding lies the concept of heterotic grouping, a systematic classification of inbred lines into genetically distinct groups. The rationale is simple yet powerful: crossing inbred lines from different groups tends to produce higher heterosis than within-group crosses. Traditionally, breeders relied on pedigree information, morphological traits, and test-cross performance to assign lines to heterotic groups. While effective, these methods often lacked precision, especially when breeding programs expanded and inbred lines became increasingly diverse (Fan *et al*., 2009).

Modern breeding tools have transformed heterotic grouping. Molecular markers such as SSRs, SNPs and high-throughput sequencing technologies provide more accurate insights into genetic relationships among inbreds. Marker-assisted and genomic selection approaches now complement conventional methods, enabling breeders to predict heterotic groupings with greater confidence. Furthermore, advances in bioinformatics and statistical models allow efficient analysis of genetic distance and heterotic patterns across large breeding populations.

The importance of heterotic grouping extends beyond yield enhancement. It contributes to the development of hybrids with resilience to biotic and abiotic stresses, improved resource-use efficiency and enhanced nutritional traits such as quality protein maize. In the era of climate change, strategic grouping is essential for designing hybrids that can withstand unpredictable weather and sustain global food security (Hallauer *et al*., 2010).

Thus, heterotic grouping remains a cornerstone of maize breeding, combining classical concepts with cutting-edge genomics to ensure that hybrid maize continues to feed a growing world population.

Methods of Heterotic Grouping

The identification and classification of inbred lines into heterotic groups is fundamental to maximize heterosis in maize breeding. Over the years, several methods have been developed, ranging from traditional to modern genomic approaches:

1. **Pedigree and Morphological Methods:** Early attempts at heterotic grouping were largely based on pedigree information (ancestry) and visible traits such as plant height,

flowering behavior, kernel colour or ear architecture. While relatively simple, this approach is often less precise because morphological traits are strongly influenced by the environment and pedigree data may not always reflect true genetic relationships.

2. **Combining Ability Tests:** One of the most reliable traditional approaches involves test-crossing inbred lines with standard testers and evaluating the performance of their hybrids. Lines are grouped based on their general combining ability (GCA) and specific combining ability (SCA), which reflect additive and non-additive gene effects, respectively. Although accurate, this method is labour and time intensive, as it requires multiple field evaluations across environments (Betrán *et al*., 2003).
3. **Molecular Marker-Based Methods:** With the advent of DNA technologies, markers such as Simple Sequence Repeats (SSRs), Amplified Fragment Length Polymorphisms (AFLPs) and Single Nucleotide Polymorphisms (SNPs) have been widely used to estimate genetic distances among inbreds. These molecular data provide more robust and environment-independent insights into genetic diversity, leading to more reliable grouping compared to morphological traits alone (Melchinger, 1999 and Xu, *et al.*, 2020).
4. **Genomic Approaches:** Recent advances in high-throughput sequencing, genome-wide association studies (GWAS) and genomic prediction models have transformed heterotic grouping. These methods allow breeders to capture genome-wide variation, identify hidden diversity and predict hybrid performance with high accuracy. Genomic approaches not only refine heterotic grouping but also accelerate breeding cycles by reducing the need for extensive field testing (Technow *et al*., 2014).

Importance in Maize Breeding

Heterotic grouping plays a central role in modern maize improvement programs, offering multiple benefits to breeders, farmers and the seed industry:

- **Enhances exploitation of heterosis for yield improvement:** By systematically crossing inbred lines from contrasting groups, breeders maximize hybrid vigour, resulting in higher yields and improved productivity.
- **Reduces time and resources spent on testing random crosses:** Instead of blindly testing thousands of parental combinations, heterotic grouping provides a strategic

framework that narrows down the most promising crosses, saving valuable time, labour and costs in breeding programs.

- **Helps in developing stress-resilient hybrids for climate-smart agriculture:** Grouping ensures the inclusion of diverse parental lines with complementary traits, enabling the development of hybrids that can withstand drought, heat, pests and diseases, making them better adapted to changing climates.
- **Ensures sustainability by maintaining genetic diversity within breeding programs:** Proper grouping prevents over-reliance on a narrow genetic base, thereby conserving diversity and ensuring long-term genetic gains in maize improvement.

Future Perspectives

The concept of heterotic grouping continues to evolve as breeding programs adopt modern technologies to address emerging challenges in global agriculture. Looking ahead, several promising directions are likely to shape the future of maize improvement:

- **Integration of Artificial Intelligence and Machine Learning:** With the availability of large-scale genomic and phenotypic datasets, AI and machine learning can be applied to predict heterotic groups with higher accuracy. These tools can uncover complex patterns and interactions beyond the scope of conventional statistical models, ultimately improving hybrid prediction and selection efficiency (Reif *et al*., 2005 and **Windhausen *et al*., 2012)**
- **Use of Pan-Genomics and Transcriptomics:** Traditional genomic approaches often rely on reference genomes, which may miss unique genes and alleles present in diverse maize germplasm. (Wen, 2019). Pan-genomics and transcriptomic analyses provide deeper insights into hidden genetic variation and gene expression patterns, offering more refined classification of heterotic groups and revealing novel opportunities for trait improvement.
- **Breeding for Region-Specific Stresses:** Climate change and shifting agro-ecological conditions demand hybrids tailored to specific environments. Incorporating heterotic group information into region-focused breeding strategies will enable the design of hybrids resilient to local stresses such as drought, heat, flooding or nutrient deficiencies, ensuring sustainable production for diverse farming systems (Bernardo, 2020).

In the future, the integration of genomics, big data and advanced computational tools with traditional breeding wisdom will further strengthen heterotic grouping as a pillar of maize improvement and food security.

Conclusion

Heterotic grouping has remained one of the cornerstones of maize breeding, enabling breeders to systematically exploit heterosis and deliver high-performing hybrids. From its beginnings with pedigree and morphological classifications to the present era of genomics and molecular markers, the refinement of heterotic grouping has greatly improved breeding efficiency and accuracy. By helping breeders identify the most promising parental combinations, heterotic grouping accelerates the development of hybrids with superior yield, resilience and nutritional quality. As climate change and global food demands intensify, the integration of advanced genomic tools, big data analytics and predictive models into heterotic grouping will be crucial. Ultimately, the strategic use of heterotic groups ensures not only sustained genetic gain but also the resilience and adaptability of maize, securing its role as a pillar of global food and nutritional security.

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AUTOMATION MEETS AGRICULTURE: THE RISE OF THE INTELLIGENT PADDY THRESHER

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Abstract

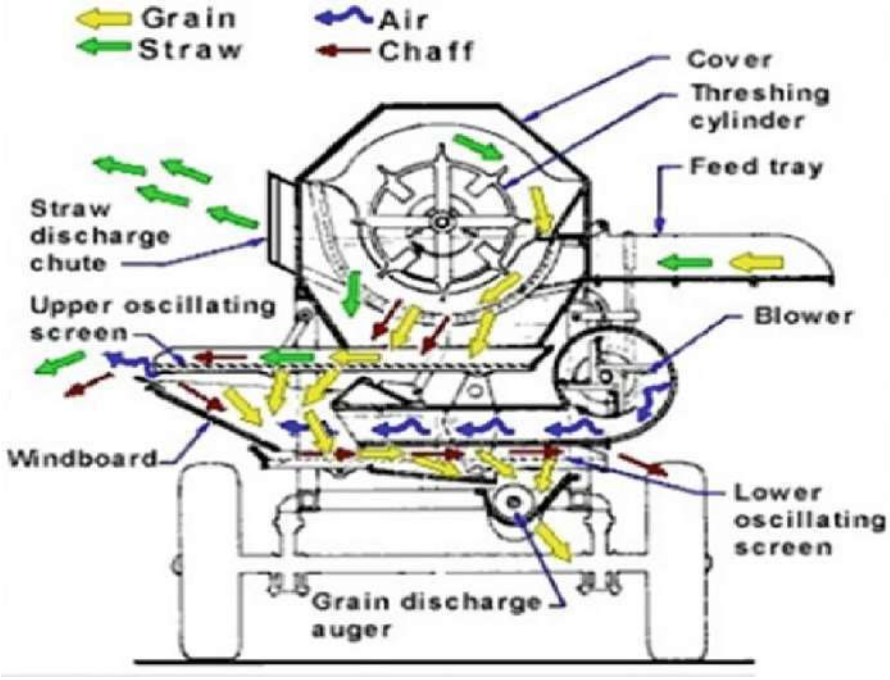
Traditional farming methods are being rewritten in new ways as a result of the incorporation of automation and sensor technology into agricultural machinery. The intelligent paddy thresher is a significant advancement in post-harvest mechanization because it combines real-time data control with mechanical efficiency. This system can automatically adjust drum speed, feeding rate, and blower operation using sensors like infrared, load, and temperature detectors to ensure accurate and efficient grain separation. It increases productivity and operational safety by reducing manual labor, minimizing grain losses, and preventing machine overload. Additionally, farmers can remotely monitor performance with IoT- or microcontroller-based monitoring, bringing digital intelligence to rural farming systems. By optimizing power consumption and operational timing, this innovation not only supports sustainable agriculture but also boosts output and consistency. In the modern agricultural era, the rise of the intelligent paddy thresher is a pivotal step toward smart, automated, and sustainable farming. Traditional paddy threshing methods frequently involve a lot of labor, take more time, and lead to uneven grain separation as well as significant losses after harvest. Grain damage or overload of the machine can also result from manual monitoring of the drum's speed and feeding rate. Using sensors and automation, smart threshing systems have been developed to meet these challenges and guarantee precise control, consistent operation, and increased efficiency. By optimizing power use and reducing waste, these intelligent systems support sustainable farming, reduce the need for human intervention, increase productivity, and make modern agriculture possible.

Keywords: Automation, Drum speed,Intelligent Paddy Thresher, IoT in Agriculture, Post-Harvest Mechanization, Precision Farming, Sensor Technology, Sustainable Agriculture

WORKING PRINCIPLE OF INTELLIGENT PADDY THRESHER:

The intelligent paddy thresher combines sensor-based automation with mechanical threshing. Paddy is fed into a rotating drum, where impact and friction separate the grains from the straw and husk. Clean grains can pass through a concave sieve while chaff and straw are removed. The process is intelligently controlled by sensors and a microcontroller: By keeping an eye on the amount of paddy, load sensors prevent overloading. Crop feed is detected and feeding rate is controlled by infrared (IR) sensors. The drum's optimal rotation speed is maintained by speed sensors. Temperature sensors ensure motor safety by detecting overheating.

The microcontroller automatically adjusts motor speed, feed mechanism, and blower operation by processing sensor data in real time. The threshing procedure is smart and dependable because of this, which ensures uniform grain separation, reduced losses, minimal human effort, and energy-efficient operation.



SENSOR AND CONTROL MECHANISM

The intelligent paddy thresher is built on the sensor and control mechanism, which allows for precise automation and increased operational efficiency. In order to continuously monitor and control every aspect of the threshing process, modern systems combine a variety of sensors with

microcontrollers. To keep the motor and mechanical parts from being put under too much stress and to prevent overloading, load sensors measure the volume of paddy that enters the threshing drum. The presence and flow of paddy in the feed hopper are detected by infrared (IR) sensors, allowing for dynamic feed rate adjustment for continuous and uniform operation. The threshing drum runs at the highest possible RPM thanks to rotational speed sensors, allowing for efficient grain separation while minimizing damage. Temperature sensors keep an eye on important parts and automatically initiate cooling or shutdown procedures to stop mechanical failure and overheating. In order to guarantee the seamless integration of all subsystems, the microcontroller continuously processes sensor inputs and executes commands to control motor speed, feeding mechanisms, and blower operations. In addition to improving grain quality and threshing efficiency, this sophisticated sensor-based control also promotes energy-efficient operation, lessens labor dependence, and minimizes post-harvest losses. The system exemplifies the principles of smart, precise, and sustainable agriculture by incorporating automated feedback and real-time monitoring.

IoT – BASED AUTOMATION FEATURES

Intelligent paddy threshers' functionality, effectiveness, and ease of operation are significantly enhanced when IoT technology is incorporated into them. Farmers can use mobile or web applications to remotely and in real time monitor the thresher's performance if they are connected to the Internet. Continuous monitoring of important parameters like drum speed, feed rate, motor temperature, and load ensures that the machine works best in a variety of crop conditions. In order to lessen the likelihood of equipment damage and downtime, the system is able to instantly send alerts and notifications for potential issues like motor overload, overheating, or the need for maintenance. Data logging and analysis are supported by IoT-enabled threshers, allowing farmers to evaluate operational efficiency, monitor productivity, and anticipate maintenance schedules. By looking at trends in previous sensor data, advanced systems can use predictive maintenance to extend the machine's lifespan and cut operating costs. Additionally, cloud integration improves the efficiency of large-scale or cooperative farming by providing centralized control over and access to performance data from multiple machines. The intelligent paddy thresher is positioned as a transformative tool in modern farming practices because IoT-based features not only promote precision, smart, and sustainable agriculture but

also improve grain quality and reduce losses by providing real-time insights, automated adjustments, and actionable data.

ADVANTAGES FOR USING INTELLIGENT PADDY THRESHER

1. Saves time and labor by reducing manual labor.
2. Ensures efficient and uniform grain separation.
3. Minimizes grain damage and loss.
4. Prevents motor overheating and overloading.
5. Increases operational reliability and safety.
6. Encourages energy-saving operation.
7. Enables IoT-enabled models' remote monitoring.
8. Supports farming methods that are precise and long-lasting.

FUTURE SCOPE OF INTELLIGENT THRESHING

Advanced automation, Internet of Things (IoT) integration, and AI-driven decision making are the future of intelligent paddy threshing. These systems can be enhanced to include predictive maintenance, which analyzes sensor data to anticipate motor or component failures ahead of time, in response to the growing demand for precision farming. Farmers will be able to remotely monitor multiple machines, track performance trends, and optimize operational schedules thanks to integration with cloud platforms and big data analytics. The thresher can automatically adjust operational parameters based on crop variety, moisture content, and field conditions thanks to emerging technologies like artificial intelligence (AI) and machine learning. This will further enhance grain quality and reduce losses. Solar-powered threshers, in particular, can make these machines more sustainable and suitable for rural off-grid settings. In addition, harvesting, cleaning, and storage systems can be coordinated with future intelligent threshers so that they can be incorporated into fully automated smart farms. These innovations will not only boost productivity and efficiency, but they will also help to modernize rural farming practices, support sustainable agriculture, and reduce labor dependence. As a result, the intelligent paddy thresher has the potential to become an essential component of the next generation of agricultural automation.

Conclusion

The intelligent paddy thresher revolutionizes post-harvest farming by combining automation, sensors, and IoT technology. It reduces manual labor, minimizes grain losses,

ensures uniform threshing, and enhances safety. With real-time monitoring and adaptive control, it supports efficient, sustainable, and smart farming practices. Future integration of AI and renewable energy will further improve productivity, making the intelligent thresher a key tool in modern agriculture.

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JOURNEY OF STRAW-IMPLEMENT FOR CROP RESIDUE MANAGEMENT

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Abstract

Crop residue management plays a vital role in sustainable agriculture by turning farm waste into valuable resources. This e-magazine, *"Journey of a Straw – Implements for Crop Residue Management,"* highlights modern implements like Mulchers, Happy Seeders, Balers, and Straw Reapers that help farmers manage residues efficiently. It explains their working, benefits, and impact on soil health, environment, and income. The magazine also showcases farmer success stories, government schemes, and future innovations that promote the vision of "Residue to Resource" for a cleaner, greener, and more productive farming future.

Chapter 1: The Residue Challenge in Indian Agriculture

Every year, India produces approximately **500 million tonnes of crop residues**. Major contributors include:

- Paddy (~120–150 million tonnes)
- Wheat (~90–100 million tonnes)
- Maize (~70–80 million tonnes)
- Cotton and pulses (~50–60 million tonnes combined)

Despite this abundance, **residue mismanagement** is a major problem. Farmers often burn paddy stubble immediately after harvest in Punjab, Haryana, and Uttar Pradesh. The consequences are severe:

1. Air Pollution and Health Hazards

Smoke from burning residues contains fine particulate matter (PM2.5), carbon monoxide, and

toxic gases. These cause:

- Respiratory illnesses (asthma, bronchitis)
- Cardiovascular problems
- Smog and reduced visibility in cities
- Increased hospitalization rates during harvest season

2. Nutrient Loss

Burning destroys:

- **Nitrogen (N):** 50–60% loss
- **Potassium (K):** 30–40% loss
- **Phosphorus (P):** 10–20% loss
- **Organic Carbon:** 2–3% reduction per year

This reduces soil fertility, forcing farmers to rely heavily on chemical fertilizers.

3. Soil Degradation

Repeated residue burning leads to:

- Reduced soil organic matter
- Damage to beneficial soil microorganisms
- Compacted soil structure
- Reduced water retention capacity

4. Climate Impact

Residue burning releases **methane (CH4)** and **nitrous oxide (N2O)**, both potent greenhouse gases.

5. Economic Loss

- Loss of nutrients → increased fertilizer costs
- Air pollution → health-related expenses
- Loss of fodder and biomass → missed income opportunities

The solution: Implement proper crop residue management using modern farm implements that **recycle residues** into soil, fodder, or energy, reducing environmental impact while increasing farmer profit.

Chapter 2: Implements That Transform Residues

2.1 Mulcher / Shredder

Working Principle: A Mulcher or Shredder is a tractor-attached machine that chops crop

residues such as paddy straw, maize stalks, or cotton stalks into small pieces. The machine spreads the residue uniformly over the field, leaving a **mulch layer** on the soil surface.

Technical Details:

- Working Width: 1.5–3.0 meters
- Tractor HP Requirement: 35–50 HP
- Operation Speed: 3–5 km/hr
- Maintenance: Blade sharpening every 50–60 hours; regular lubrication

Benefits:

- Conserves soil moisture and reduces evaporation.
- Enhances decomposition, adding **organic carbon** and nutrients back to the soil.
- Reduces weed growth and protects soil from erosion.
- Minimizes pest and disease habitats.



Fig:2.1 Mulcher

Case Study:

Farmers in Tamil Nadu who mulched maize residues reported **20% higher soil moisture retention** and improved earthworm activity after two seasons.

2.2 Rotary Slasher

Function: Cuts tall stubble, weeds, and unwanted vegetation close to the ground.

Technical Specifications:

- Working Width: 1.2–2.5 meters
- Tractor HP: 25–40 HP
- Speed: 4–6 km/hr

Benefits:

- Prepares the field quickly for the next crop.
- Prevents pest and disease problems by removing residues that harbor pests.
- Reduces fire hazards.



Fig: 2.2 Rotary slasher

Application: Orchards, sugarcane fields, pastures, harvested wheat/paddy fields.

2.3 Straw Reaper

Function: Cuts, collects, and cleans straw for storage or sale.

Technical Details:

- Working Width: 1.5–2.5 meters
- Tractor HP: 40–60 HP
- Residue Type: Wheat, barley, oats



Fig: 2.3 Straw reaper

Benefits:

- Collected straw can be sold as fodder or biomass.

- Reduces residue burning, improving air quality.
- Provides an additional income stream for farmers.

Case Study:

In Haryana, farmers earn **₹2000–3000 per acre** by selling wheat straw to biomass plants and dairy farms.

2.4 Happy Seeder / Super Seeder (Zero-Till Drill)

Function: Sows wheat or pulses directly into fields full of paddy residue without burning or removal.

Technical Details:

- Working Width: 3 meters
- Tractor HP: 50–70 HP
- Cutting Mechanism: Rotary discs lift residue and create a seedbed simultaneously
- Mulching: Residue left on top acts as mulch



Fig :2.4 Happyseeder

Benefits:

- Prevents burning and air pollution.
- Saves labor and fuel costs.
- Improves soil fertility and moisture retention.
- Allows immediate sowing after paddy harvest.

Case Study:

In Punjab, 75% of farmers adopting the Happy Seeder reduced stubble burning incidents by 80% during 2022–23. Wheat yields improved by 5–7% due to better moisture and soil conditions.

2.5 Baler (Round/Square)

Function: Compresses loose residue into compact bales for transport, storage, or sale.

Technical Details:

- Working Width: 2.0–2.5 meters
- Tractor HP: 40–60 HP
- Bale Size: Round (1.2 m diameter) / Square (0.8 × 0.8 m)



Fig : 2.5 Square Baler



Fig : 2.6 Round Baler

Benefits:

- Straw can be sold for fodder, paper, or biomass energy.
- Reduces field clutter and fire hazards.
- Creates additional income for farmers.

Case Study:

Biomass power plants in Haryana source bales from local farmers, offering **₹1,200–1,500 per tonne**, converting residues into renewable energy.

2.6 Rotavator / Harrow

Function: Incorporates residue into soil while preparing seedbed.

Benefits:

- Enhances decomposition, improving soil organic carbon.

- Reduces fertilizer need over time.
- Creates a fine seedbed for next crop.

Technical Details:

- Working Width: 1.5–3.0 meters
- Tractor HP: 40–50 HP
- Residue Type: Wheat, maize, pulses, vegetables



Fig : 2.7 Disc harrow



Fig : 2.8 Rotavator

2.7 Chisel Plough/ Disc Harrow

Function: Breaks compact soil layers and mixes residues into deeper layers.

Benefits:

- Improves water infiltration and aeration.
- Useful for heavy clay soils with dense residues.
- Enhances microbial activity.



Fig : 2.9 Disc harrows with chisel plough

Technical Details:

- Working Width: 2–4 meters
- Tractor HP: 50–70 HP
- Depth: 15–20 cm

2.8 Super SMS & IoT Implements

Super Straw Management System (SMS): Attachments for combine harvesters that chop and spread straw while harvesting.

IoT Implements: Smart sensors monitor residue density and adjust chopping/spreading automatically.



Fig : 2.10 Super SMS

Benefits:

- Reduces fuel and labor costs.
- Ensures uniform residue distribution.
- Minimizes field burning.

Case Study:

In Punjab and Haryana, pilot programs with IoT-enabled SMS showed **30% reduction in stubble burning** and **15% improvement in wheat yields**.

Chapter 3: Environmental Benefits of Residue Management

Proper crop residue management has significant **environmental benefits**, from improving soil health to reducing air pollution.

3.1 Reduction in Air Pollution

Burning residues releases harmful **PM2.5 particles**, carbon monoxide, and greenhouse gases. Implementing mechanical management like Happy Seeder, Mulcher, and Straw Reaper:

- Reduces air pollution drastically during post-harvest season.
- Prevents smog formation in urban areas near farms.
- Improves public health by reducing respiratory illnesses.

Example: In Punjab, large-scale adoption of Happy Seeder and Mulchers decreased stubble burning by 75% over five years, improving local air quality during winter.

3.2 Soil Health Improvement

Residues left on the field or incorporated into the soil improve:

- **Organic carbon content** → increases from 0.5–0.8% to 1.2–1.5% over 2–3 seasons.
- **Microbial activity** → supports nitrogen-fixing bacteria and earthworms.
- **Water retention** → mulch layer reduces evaporation, maintaining soil moisture.

Example: Mulching maize stalks in Tamil Nadu increased earthworm population by 20–25% and reduced irrigation needs.

3.3 Nutrient Recycling

Residues are rich in NPK and micronutrients:

- Wheat straw: ~0.5% N, 0.1% P, 1.0% K
- Paddy straw: ~0.3% N, 0.05% P, 0.5% K

  Incorporating residues saves chemical fertilizers and enhances long-term soil fertility.

3.4 Reduction in Greenhouse Gas Emissions

- Controlled incorporation reduces methane (CH_4) and nitrous oxide (N_2O) emissions compared to burning.
- Contributes to climate change mitigation efforts and aligns with **sustainable agriculture goals**.

3.5 Ecosystem Preservation

- Residues act as habitat for beneficial insects and earthworms.
- Reduces erosion and prevents nutrient runoff during rains.

- Enhances biodiversity in agricultural landscapes.
- Average earning: ₹2,000–3,500 per acre for wheat or paddy residues.

Case Study: In UP, cooperative FPOs buy straw bales from farmers and supply biomass plants, increasing farmer income while reducing environmental damage.

Chapter 4: Future Perspectives & Research

- **Precision Agriculture:** GPS-enabled implements for accurate residue management.
- **AI & Robotics:** Autonomous machines for residue collection and mulching.
- **Hybrid Machines:** Combines mulching, sowing, and baling in a single pass.
- **Bio-Residue to Energy:** Direct link between balers and biomass power plants.
- **Research Areas:** Crop varieties producing easier-to-manage residues, IoT for monitoring decomposition rates.

Example: Pilot programs with AI-powered SMS in Haryana reduced stubble burning by 30% and improved wheat germination rates by 10%.

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MISSION FOR AATMANIRBHARTA IN PULSES

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Introduction

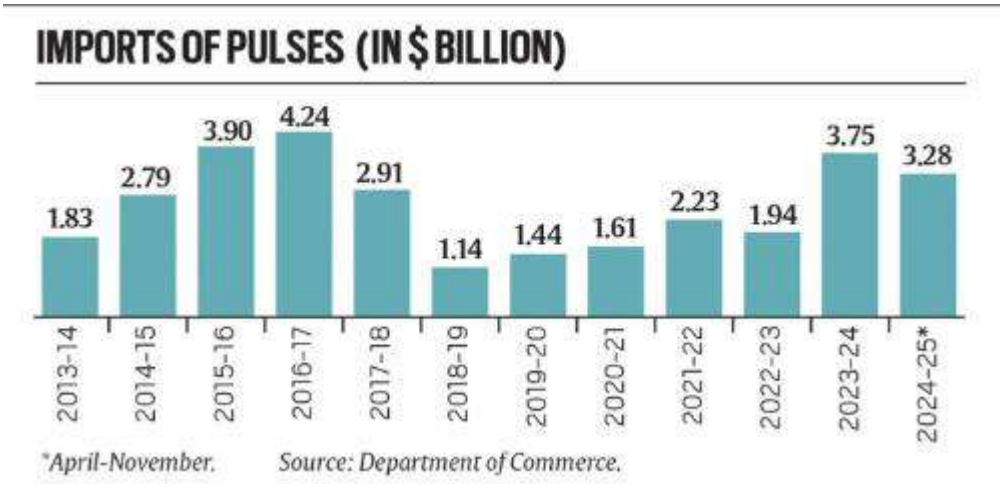
Agriculture continues to be the backbone of India's economy, providing livelihood to nearly 46.1% of the population. However, its share in the country's Gross Domestic Product (GDP) remains limited at about 16.6%. Within this sector, pulses play a crucial role as a major source of protein in the Indian diet and as an essential component of sustainable farming systems. India holds the distinction of being the largest global producer of pulses, contributing close to 25% of the world's total output. Yet, despite this strong production base, the nation still faces a supply-demand imbalance, leading to heavy dependence on imports. Recognizing the need to reduce this gap and strengthen domestic production, the Government of India has launched the *Mission for Atma Nirbharta in Pulses*. The program seeks to achieve self-sufficiency by concentrating on three vital crops—pigeonpea (tur/arhar), black gram (urad), and red lentil (masoor)—through targeted interventions in research, cultivation, and market support.

India's Path to Atmanirbharta in Pulses

India occupies a distinctive place in global agriculture as both the largest producer and the biggest consumer of pulses. These crops are central not only for ensuring dietary protein and nutritional security but also for strengthening public health and sustaining eco-friendly farming systems that contribute positively to soil fertility and the environment.

In 2015–16, domestic production fell sharply to just 16.35 million tonnes (MT), creating a pressing need to import nearly 6 MT of pulses to meet demand. Responding to this challenge, the government rolled out targeted measures that transformed the sector. By 2022–23, production had risen impressively to 26.06 MT—a jump of 59.4%—while productivity saw a 38% increase.

As a result, India's dependence on imports was drastically reduced from nearly 29% to only 10.4%. Building on this progress, the Union Budget 2025–26 introduced the **"Mission for Atmanirbharta in Pulses"**, a dedicated six-year strategy designed to achieve self-reliance in three focus crops: pigeonpea, black gram, and lentil.



The report emphasizes that India's diverse agro-climatic conditions make it possible to grow as many as twelve pulse varieties across the kharif, rabi, and summer seasons. However, production remains uneven across the country. States like Madhya Pradesh, Maharashtra, and Rajasthan together account for around 55% of total output, while more than 91% of production comes from the top ten states. Reducing this geographical imbalance is crucial not only for minimizing imports but also for ensuring nutritional security for the entire population and realizing the national aspiration of self-sufficiency in pulses.

To address these gaps, a comprehensive roadmap has been charted to align demand with supply. This strategy rests on two central pillars aimed at ensuring long-term sustainability of pulse farming:

(i) Horizontal Expansion, which focuses on increasing the cropped area by utilizing underused lands such as rice fallows and encouraging intercropping with high-yield systems

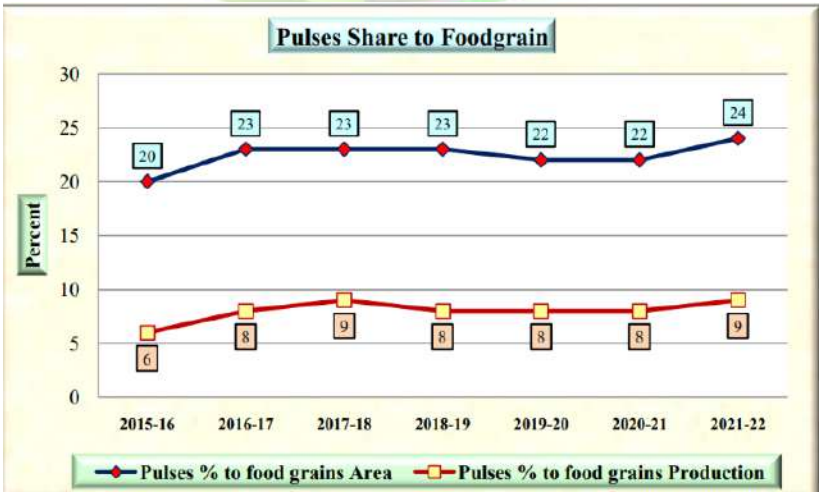
(ii) Vertical Expansion, which seeks to maximize productivity through better farming practices and technology-led solutions. The latter includes the adoption of improved and climate-resilient varieties, ensuring the availability and treatment of quality seeds, adding value through processing, adopting timely and scientific sowing techniques, and integrating advanced nutrient, pest, weed, and water management practices. In

addition, a **district-level quadrant analysis** will serve as a guiding framework to implement interventions more effectively within selected clusters, ultimately accelerating the nation's journey toward complete *Atmanirbharta* in pulses.

Key Objectives of the Mission

The *Mission for Atma Nirbharta in Pulses* has been launched with a clear vision of attaining self-reliance in the pulse sector. Its central objectives are as follows:

1. **Enhance Domestic Production:** To steadily scale up the country's annual pulse output so that the growing national requirements can be met internally, thereby reducing heavy dependence on imports and strengthening food security.
2. **Improve Crop Productivity:** To raise per-hectare yields by promoting the adoption of superior crop varieties, mechanization, precision farming tools, and other modern agricultural innovations that can maximize returns from available land resources.
3. **Promote Environmentally Friendly Farming:** To encourage pulse cultivation practices that conserve natural resources, maintain soil fertility, reduce chemical dependency, and safeguard ecological balance, ensuring that pulse farming remains sustainable for future generations.
4. **Build Strong Market and Supply Systems:** To create a well-integrated infrastructure for storage, processing, and transportation, along with a fair and transparent marketing network that guarantees both price stability for consumers and profitable returns for farmers.



Key Components of the Mission

To fulfill its goals, the mission is structured around several core elements:

1. **Research and Innovation:** The mission emphasizes the development of improved pulse varieties that are high-yielding, tolerant to climate stress, and resistant to pests and diseases. It promotes partnerships with agricultural research bodies to generate and share innovative technologies.
2. **Farmer Training and Extension:** It aims to strengthen extension services by equipping farmers with knowledge on advanced cultivation methods. This includes training on soil health management, effective pest and disease control, and efficient use of water resources.
3. **Infrastructure Strengthening:** The mission supports the creation of modern irrigation facilities, scientific storage solutions, and improved logistics to facilitate both production and smooth movement of pulses to markets.
4. **Financial Assistance:** Farmers are provided with access to subsidies, crop insurance, and affordable credit options to reduce uncertainties and financial risks in pulse farming.
5. **Market and Policy Support:** The mission also seeks to implement market reforms by ensuring a fair minimum support price (MSP) for pulses and establishing direct marketing avenues so that farmers can secure better returns.

Conclusion

The Aatmanirbharta in Pulses Mission stands as a vital step toward making India self-sufficient in pulse production. It addresses key challenges in cultivation while ensuring market stability and empowering farmers, thereby paving the way for a resilient and sustainable pulse sector. For the mission to achieve long-term success, continuous efforts and adaptive strategies will be essential to effectively tackle emerging challenges.

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INNOVATION IN FOOD PACKAGING: THE EMERGENCE OF SMART MATERIALS THAT ARE STARCH-BASED AND NANOTECHNOLOGY-BASED

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Introduction

Think of wasting less food as your packaging informs you of when your food goes bad and you get to be environmentally friendly. That is what starch-based smart packaging fortified with nanomaterials promises to deliver: a state-of-the-art option proving to be an eye catcher in the food sector. As food waste around the world reaches unprecedented levels (some 1.3 billion tons a year!), plastic stuffing up our oceans, there has been that move by innovators to seek out a more natural, more biodegradable product such as starch. Starch is produced using simple materials that can be easily found, like corn, potatoes, or cassava, so it is very abundant, very low cost, and eco-friendly. When infused with tiny nanomaterials, it can be made smart killing bacteria, sensing spoilage, and prolonging shelf-life without impacting the environment. This paper plunges into the details of how this technology operates, the advantages it provides, and what is ahead based on the recent scientific discoveries.

The Rising Issues of Food Wastes and Plastic Wastes

Food waste is not only a kitchen problem, but a worldwide crisis that is costing the world almost a trillion dollars a year and causing 8 percent of greenhouse gas emissions. A lot of this is based on bad packaging which does not help protect perishable goods such as fruits, meats, and dairy against spoilage. Conventional plastic packaging, although good at creating an airtight seal and locking out moisture, can take centuries to be naturally more biodegradable and only 14% of plastic used in packaging is recycled. Step up starch-based products: these products break down naturally, sometimes within months, alleviating the loads of landfills and trash in the ocean.

Recent research singles out the potential to incorporate nanomaterials into starch that would enable packaging which would not only be sustainable but also interactive producing signals to warn against, say, bacterial growth or a drop in temperature. An example is the fact that nano-enhanced starch films can completely break down in the soil in less than 180 days not to mention the plastics which take 450 years and above before they degrade.

How is Packaging Made Smart, and Why Starch?

Smart packaging is not just a wrapping but it is living and smart. Active components add on to keep food fresh, such as antimicrobials that fry bacteria, whereas smart components would check to see what is going on, such as a food freshness indicator that changes color. Starch glows as it is renewable, non-toxic, and versatile. When combined with polymers, such as polyvinyl alcohol (PVA), it produces flexible films that are reminiscent of the durability of plastic and disappear harmlessly after usage. Recent developments indicate that starch nanocrystals (SNCs) which can be treated as nano particles obtained by extracting starch increase the mechanical strength by up to 60 percent compared to starch films, and are tougher against tear and puncture. It is not sci-fi; this is already happening in labs, and we have already seen patents on films created with anthocyanins in them that identify spoilage in real-time, and change colors as to mark off whether it is "eat now" or "toss it."

The Nanomaterials of Power: Big Tech, Little Tech

Nanomaterials are those that are below 100 nanometers in size, which is unseen by the naked eye but all-transforming in packaging. Added to starch they form superpowered composites with enhanced impediments to oxygen and moisture, both of which lead to oxidation and dampness. As an example, nanoclays such as montmorillonite provide a tortuous conduit to gases, reducing oxygen permeability by 50-90%. Antimicrobial punch is supplied by silver or zinc oxide nanoparticles that destroy bacterial cells such as *E. coli* or *Salmonella*, and they can add days to shelf life. The use of bioactive additions, like berry-derived anthocyanins encapsulated in nanocomplexes, make pH-sensitive colour changes possible; blue to pink in the event of food turning sour. A study predicted in 2023-2025 highlights the advantages of these hybrids in staying transparent and flexible and are fully biodegradable as opposed to synthetic alternatives. It can even be considered as incorporating a mini-lab in your food wrap.

How It All Works: The Most Important Technologies Working

The production of these materials includes the combination of starch with the nanomaterials through a process such as the process of an acid hydrolysis or an electrospinning analysis in order to produce a combination of nanocrystals or nanofibers. In another configuration, starch-PVA films will include free or nanocomplexed plant anthocyanins, such as *Lycium ruthenicum*. Nanocomplex yields denser structures with higher bond strength, better water vapor block, and increased mechanisms but free anthocyanins are best blocking light and antioxidants. More technology involves edible nano-coatings: polysaccharide layers on fruits that give gas barriers and only release the antimicrobials when required. Recent reviews have described the use of zinc oxide or titanium dioxide nanoparticles to provide new protection against UV and self-cleaning surfaces to prevent biofilms. The packaging is designed to change with these innovations such as self-healing as the packaging reseals in case of piercing or odor absorbing to maintain the aroma of the food.

Real-Desire Applications: Lab to Fridge

The potential of this tech is proven by case studies. Nano-clay starch were used in the packaging of yogurt, decreased the amount of oxygen entering them by half and created shelf life increase of 3-5 days and 15% reduction in the mechanical material used. In the case of meat, films that contained silver nanoparticles reduced bacteria populations by 99.9 percent and inhibited wastage of meat by 30 percent. Nano-films of chitosan and starch with essential oils are useful with fruits to reduce decay by 70-85 percent and retained vitamins, e.g., strawberries lasted 28 days coated versus 7 uncoated. New examples are barley-based plastic biodegrading within two months, suitable to snacks and Israeli sugar-free binding technology to bars. They are used in Asia and Europe as environmentally friendly cups by dairy giants and intelligent labels with nano-inks trace supply chains through QR codes or RFID to provide a farm-to-table traceability guarantee.

Profits to People and the Planet

To the consumer this is longer-lasting fresh food, less store visits, and security- color indicators help avoid the ingestion of spoiled foods and have an impact on the number of cases of foodborne illnesses. It is a win environmentally: biodegradable starch is reduced plastic waste with nano-composites made of agricultural byproducts such as seaweeds or fungi improving soil when they compost. In economic terms, initial cost is up to 3 times higher, but once it is scaled it

can lower the price, and billions saved by cutting waste. Natural antimicrobials such as essential oils are healthier alternatives to chemicals and migration of nanoparticles has been demonstrated to be minimal during normal usage, however regular safety tests are essential.

Obstacles and the path to tomorrow

Problems remain: regulation varies by jurisdiction- in Europe they require labeling of products as nano, the US considers each case individually. Fears that nanoparticles will end up in food need additional information on their toxicity, and upsized lab operations to manufacturing plans needing investment. Consumer doubts about terms in nano require more education about the benefits. In the future, the forecast trend consists of self-responsive packaging which will not only vary in permeability according to temperature, but also entirely edible packaging which releases nutrients via nanocapsules. Nano-ink printable electronics may print in additional displays of up-to-date information, and improvement is growing rapidly through collaborations between auxiliary, industry and regulators. The global smart packaging market might reach 70 billion by 2029, and it will be the starch-nano hybrids to drive the market.

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COMMON DISEASES OF ONION AND THEIR MANAGEMENT

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Introduction

Onion (*Allium cepa* L.) is a globally important vegetable crop known for its culinary versatility, nutritional value, and commercial significance. India ranks among the top onion-producing countries, yet the crop is highly vulnerable to a range of diseases caused by fungal, bacterial, and viral pathogens. These diseases not only compromise crop yield and bulb quality but also reduce storability and marketability, posing serious challenges to both farmers and supply chains. Epidemiological studies and field observations have shown that diseases such as damping-off, purple blotch, Stemphylium blight, basal rot, and downy mildew can lead to yield losses ranging from 20% to 70%, depending on disease severity, environmental conditions, and management practices. For instance, purple blotch alone has been reported to cause 30–50% yield loss in favorable weather, while damping-off can result in 60–75% seedling mortality during the nursery stage. Such high-impact diseases are often aggravated by monoculture, poor drainage, high humidity, and delayed disease diagnosis. Therefore, early detection and implementation of integrated disease management (IDM) strategies—combining cultural, biological, and chemical control methods—are vital to safeguarding onion production.

1. Damping-Off

Pathogens: *Fusarium oxysporum* f.sp. *cepae*, *Pythium* spp., *Sclerotium rolfsii*, *S. cepivorum*, and *Colletotrichum* spp.

Season: Prevalent during the ***kharif*** season, causing 60–75% damage.

Favourable Conditions: High soil moisture, moderate temperatures, and high humidity during the rainy season.

Symptoms:

- **Pre-emergence damping-off:** Seeds fail to germinate, or seedlings die before emerging from the soil. The infected seed area becomes soft, discoloured, and decays rapidly, often leaving gaps in seedling rows.
- **Post-emergence damping-off:** The disease manifests as softening and rotting of the collar region at soil level. Seedlings become water-soaked, topple over, and collapse. Fungal mycelium may be visible around the base of affected plants.

Management:

- Use healthy seeds treated with Thiram @ 2g/kg.
- Avoid repeated use of the same nursery bed.
- Treat nursery soil with Thiram @ 5g/m² and drench with 2g/L solution fortnightly.
- Employ soil solarization using 250-gauge polythene sheets for 30 days.
- Incorporate *Trichoderma viride* @ 1.2 kg/ha into the soil.

2. Purple Blotch

Pathogen: *Alternaria porri*

Season: More common during ***kharif*** under hot and humid conditions (21–30°C, 80–90% RH).

Symptoms:

- Small, circular, water-soaked lesions appear on older leaves and flower stalks.
- These lesions expand and develop purplish centres with yellow halos.
- Under severe infection, lesions enlarge, coalesce, and girdle the leaves or stalks, leading to tissue death and wilting.
- Infected tissues may curl or become brittle and dried, especially under dry conditions.
- Affected plants often fail to develop marketable bulbs due to reduced photosynthesis.

Management:

- Use disease-free seeds.
- Rotate crops every 2–3 years with unrelated species.
- Spray Mancozeb (0.25%), Chlorothalonil (0.2%), or Iprodione (0.25%) fortnightly starting one month after transplanting.
- Add sticker agents like Triton or Sandovit.

3. Stemphylium Blight

Pathogen: *Stemphylium vesicarium*

Region: Predominantly affects seed crops in northern India.

Symptoms:

- Initial symptoms appear as tiny, yellow to orange flecks or streaks, primarily on the middle of older leaves.
- These spots elongate and form spindle-shaped, sunken lesions with a characteristic pinkish to reddish border.
- In humid conditions, black spores may be observed on the lesions.
- Infection progresses toward the tip and base of the leaves, leading to extensive blight, shriveling, and eventual collapse.
- On flower stalks, lesions lead to breakage and significant yield loss in seed crops.

Management:

- Practice field sanitation and remove crop residues.
- Spray Mancozeb (0.25%) + Monocrotophos (0.05%) with a sticker at 15-day intervals.

4. Basal Rot

Pathogen: *Fusarium oxysporum* f.sp. *cepae*

Favourable Temperature: 22–28°C

Symptoms:

- Leaves exhibit premature yellowing starting from the tips and progressing downward.
- Infected plants show stunted growth and wilt prematurely.
- Roots become pinkish in early stages and later rot entirely.
- Bulb decay begins from the basal plate and spreads upward, causing softening and discoloration.
- In severe cases, bulbs collapse when squeezed, emitting a foul odor.

Management:

- Use crop rotation and mixed cropping.
- Apply soil solarization for 30 days during summer.
- Treat seed with Thiram (2g/kg).
- Soil application or seedling dip with Carbendazim, Thiophanate Methyl, or Benomyl (0.1%).

- Use biocontrol agents like *Trichoderma viride* and *Pseudomonas cepacia*.

5. Downy Mildew

Pathogen: *Peronospora destructor*

Region: Affects humid areas, particularly hilly northern regions.

Symptoms:

- Pale green to yellow elongated patches form on the upper surface of leaves.
- A grayish-violet, downy fungal growth appears on the underside during humid mornings.
- Lesions may expand, causing leaf twisting, curling, and necrosis.
- Infected flower stalks turn pale and collapse.
- Severely infected fields appear blighted with patches of yellow and dead plants.

Management:

- Expose seed bulbs to sunlight for 12 days before planting.
- Spray with Zineb (0.2%), Karathane (0.1%), or Tridemorph (0.1%).

6. Onion Smut

Pathogen: *Urocystis cepulae*

Favourable Conditions: Cooler climates (<30°C)

Symptoms:

- Elongated dark lesions near the base of the cotyledons and first leaves of young seedlings.
- Lesions appear slightly raised, blistered, and thickened.
- Affected tissue ruptures to expose black, powdery spore masses.
- Older plants may develop dark blisters near the base of leaves, with curling and downward bending of foliage.
- Severely infected seedlings often die, reducing plant stand.

Management:

- Seed treatment with Captan or Thiram (2.5g/kg).
- Soil fumigation with Methyl Bromide (1kg/25m^2).

7. Onion Smudge

Pathogen: *Colletotrichum circinans*

Target: Primarily white onion varieties.

Symptoms:

- Small, dark green to black smudgy spots form on the outer dry scales of harvested bulbs.
- Spots may enlarge into smudges, giving the bulbs a dirty appearance.
- Affected bulbs lose market appeal though internal quality may remain intact.
- The disease is cosmetic but leads to economic losses due to reduced market value.

Management:

- Cure bulbs thoroughly post-harvest.
- Store in well-ventilated rooms.

8. Black Mould

Pathogen: *Aspergillus niger*

Favourable Temperature: 30–45°C

Symptoms:

- Appearance of black, powdery fungal growth between the outer and inner bulb scales.
- Infection is often seen first at wounds or areas of bruising.
- The black spores may also penetrate deeper scales under high humidity and poor ventilation.
- Bulbs develop soft spots, and storage life is significantly reduced.
- Often accompanied by a musty odour in storage areas.

Management:

- Dry bulbs in the field for 2 days and then in shade for 10–15 days.
- Avoid mechanical injuries during handling.
- Spray Carbendazim (0.2%) 10–15 days before harvest.

9. Bacterial Brown Rot

Pathogen: *Pseudomonas aeruginosa*

Symptoms:

- Infection typically begins at the neck of the bulb and progresses downward.
- Affected tissue softens, turns brown, and emits a foul odour upon pressure.
- Internal tissues become water-soaked and discoloured.
- In severe cases, bacterial ooze may be seen at the neck when squeezed.
- Rot continues during storage, leading to collapse of entire bulbs.

Management:

- Ensure rapid drying and proper curing after harvest.
- Discard affected bulbs.
- Spray Streptocycline (0.02%) if rain occurs at maturity.

10. Onion Yellow Dwarf (Viral)

Cause: Onion Yellow Dwarf Virus (OYDV)

Transmission: Mechanical and insect vectors

Symptoms:

- Plants are stunted and show overall dwarfism.
- Leaves become yellow, twisted, and flattened.
- Leaf tips may crinkle and bend over, forming a fan-like appearance.
- Flower stalks are also shortened and twisted, resulting in poor seed set.
- Symptoms are systemic and affect the entire plant uniformly.

Management:

- Remove and destroy infected plants.
- Use healthy bulbs for seed production.

Control vectors with Malathion (0.1%) or Metasystox (0.1%).

11. Anthracnose

Pathogen: *Colletotrichum gloeosporioides* / *C. circinans*

Symptoms:

- Small, pale yellow, water-soaked lesions appear first on the leaf surface.
- These lesions rapidly elongate into spindle or elliptical shapes.
- Lesions may turn brown with a concentric ring structure and develop black fruiting bodies (acervuli) in the center.
- Severely infected leaves become shriveled, dry, and break off easily.
- Infection may spread to flower stalks, affecting seed production.

Management:

- Practice crop debris sanitation.
- Spray Mancozeb (0.25%), Carbendazim (0.1%), or Thiophanate Methyl (0.1%).

12. White Rot

Pathogen: *Sclerotium rolfsii*

Symptoms:

- Initial yellowing and dieback of older leaf tips.
- Roots and stem plates become soft, decayed, and disintegrate.
- Bulbs soften and exude a foul-smelling, watery sap.
- White, cottony fungal growth covers infected tissue, with small black sclerotia (resting structures) that resemble mustard seeds.
- Infected bulbs collapse in storage and leave behind fungal mats in the soil.

Management:

- Avoid monocropping onions.
- Rotate with cereals.
- Seed treatment with Thiram (4g/kg).
- Drench soil with Mancozeb (0.25%) and apply *Trichoderma viride*.

13. Neck Rot

Pathogen: *Botrytis allii*

Symptoms:

- Infection starts in the field but symptoms become evident during storage.
- Scales around the neck soften and appear water-soaked.
- Under moist storage conditions, grayish fungal growth appears on infected tissues.
- Affected bulbs may develop a "slippery" neck and emit a musty odor.
- The rot often remains confined to the neck initially but later spreads throughout the bulb

Management:

- Dry bulbs in the field for 2 days, then shade-dry for 10–15 days.
- Handle carefully post-harvest.
- Spray Carbendazim (0.2%) 10–15 days prior to harvesting.

Onion crops are highly prone to a variety of destructive diseases that can cause severe yield and quality losses, often ranging from 20% to 70%. Timely identification and adoption of integrated disease management (IDM) practices such as crop rotation, seed treatment, biocontrol agents, and targeted fungicide use are essential for effective control. By combining preventive and curative strategies, farmers can reduce dependency on chemicals, enhance crop health, and ensure higher productivity and profitability. Strengthening awareness and field-level disease surveillance remains crucial for sustainable onion cultivation.

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AI ASSISTED IN HARVESTING CROPS

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Introduction

Agriculture has always been the backbone of human survival. For centuries, farmers have depended on traditional tools and manual labour to grow, maintain and harvest crops. However, with the world population increasing rapidly, there is a constant demand for higher food production and more efficient farming practices. Modern agriculture is now turning to advanced technologies to meet these demands. One of the most promising approaches is the use of Artificial Intelligence (AI) in farming.

AI is a computer-based technology that can “think,” “learn” and “make decisions” like humans. In agriculture, AI is now being applied in many areas such as soil testing, irrigation management, pest control and harvesting of crops. AI-assisted harvesting uses smart machines and robots to pick, cut or collect crops with minimal human effort. This paper focuses on explaining how AI helps in harvesting, its benefits and its future in farming.

AI-Assisted Harvesting in Crops

Harvesting is the process of gathering crops from the fields when they are mature. Traditionally, harvesting is done either by hand or by using simple machines. Manual harvesting requires a lot of labour and time while, machines may sometimes damage harvest of fruits and vegetables. AI-assisted harvesting uses robots, drones, sensors and computer systems that are guided by AI to identify ripe crops and harvest them carefully. For example, a robotic arm with a camera can identify ripe tomatoes and gently pick them without damaging the plant, AI-powered

drones can scan large fields to detect which crops are ready for harvest and smart harvesting machines can separate ripe fruits from unripe ones. Thus AI helps machines "see" the crops, "decide" which ones are ready and "act" to harvest them efficiently.

are ready and "act" to harvest them efficiently.

Technologies Used in AI Harvesting

1. **Computer Vision**

   Cameras and sensors capture images of crops. The AI system analyzes these images to detect ripeness, size and colour of the produce.

2. **Robotics**

   Robots with arms and claws are designed to pluck fruits, cut grains or collect vegetables with care.



3. **Drones**

   Unmanned aerial vehicles (UAVs) fly over fields to monitor crop maturity and send real-time data to farmers.

4. **Machine Learning**

   AI learns from past data, such as crop growth stages, harvesting time and quality to improve its accuracy.

5. **Sensors and IoT**

   Smart sensors measure crop moisture, firmness and environmental conditions to guide harvesting decisions.

Advantages of AI-Assisted Harvesting

- **Reduces Labour Shortage**: In many countries, there is a lack of farm workers. AI robots can fill this gap.



- **Faster Harvesting:** AI machines can work continuously, day and night, unlike humans.
- **Better Quality Produce:** By picking only ripe crops, AI ensures that the produce is fresh and uniform.
- **Lower Wastage:** AI reduces crop damage and prevents overripe crops from being wasted.
- **Cost-Effective in the Long Term:** Though the initial cost of AI machines is high, farmers save money in the future due to reduced labour and increased efficiency.
- **Data Collection:** AI not only harvests but also collects valuable data about crop health and yield, helping farmers make better decisions.

Challenges in AI Harvesting

- **High Initial Cost:** Purchasing AI robots and machines requires big investment.
- **Maintenance and Training:** Farmers need training to use and maintain AI equipment.
- **Suitability:** AI robots may work well for certain crops like tomatoes, apples, or strawberries, but may not be effective for all crops.
- **Dependence on Technology:** If there is a technical failure, it may delay harvesting and affect the yield.

Future of AI in Harvesting

AI is still developing in agriculture, but its future looks very bright which could lead to, more affordable AI robots for small farmers, multi-purpose harvesting machines that can handle different crops, integration with smart farming where irrigation, pest control and harvesting are all controlled by AI, higher yields and sustainable farming thus reducing food shortages globally.

AI-assisted harvesting will not replace farmers but will act as a helping hand. Farmers can focus on decision-making and management, while machines take care of the heavy work.

Conclusion

AI-assisted harvesting is a revolution in agriculture. By combining artificial intelligence with robotics, sensors and drones, farming is becoming faster, smarter and more sustainable. While there are challenges such as cost and training, the advantages are far greater. AI can solve the problems of labour shortage, reduce wastage and improve the quality of produce.

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PERFORMANCE EVALUATION OF KNAPSACK SPRAYER

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Abstract

A knapsack sprayer is a portable and efficient agricultural implement used for applying liquid fertilizers, pesticides, herbicides, and other crop protection chemicals. It is made up of a tank that is carried by the operator on their back, a pump that can be operated by hand or by a battery, a spray lance, and a nozzle that makes a uniform spray. The sprayer ensures effective pest and disease control, ensures precise application, and cuts down on chemical waste. It is designed for ease of use, flexibility, and mobility, making it suitable for small and medium-scale farms, gardens, and plantations. Controlled liquid discharge is made possible by the knapsack sprayer's use of hydraulic pressure generated manually or by a motorized pump. Its lightweight design and adjustable straps make it more comfortable for the user to use for a long time. Overall, the knapsack sprayer enhances agricultural productivity by ensuring uniform chemical distribution, minimizing human exposure to chemicals, and promoting sustainable and cost-effective crop management practices

Key words: Knapsack sprayer, pesticide, fertilizer, crop protection, portable, agriculture, uniform spraying, efficiency.

Introduction

A knapsack sprayer is a widely used agricultural tool designed for the efficient application of liquid chemicals such as pesticides, herbicides, and fertilizers. It consists of a tank carried on the operator's back, a pumping system, a spray lance, and a nozzle for controlled spraying. This sprayer is especially useful for small and medium-sized farms, gardens, and

nurseries where large machinery cannot be used. It provides uniform distribution of chemicals, helping to protect crops from pests and diseases while improving yield and quality. Knapsack sprayers can be manually operated or battery-powered, offering convenience and ease of handling. They are comfortable to use for a long time because of their light weight and ergonomic design. Overall, the knapsack sprayer plays a vital role in modern agriculture by ensuring effective crop management, reducing labor effort, and promoting safe and efficient chemical usage.

COMPONENTS OF KNAPSACK SPRAYER:

The essential components of a knapsack sprayer work together to ensure effective spraying. The main components include:

1. Tank: The container that holds the chemical solution and has a capacity of 10 to 20 liters. It is typically made of plastic or fiberglass.
2. Pump: Creates pressure to force the liquid through the nozzle; it can be manually operated or battery-powered.
3. Agitator: Helps mix the solution in the tank to keep the concentration consistent.
4. Delivery Hose: Connects the pump to the spray lance, allowing smooth flow of liquid.
5. A long tube used to precisely direct the spray to the desired area is referred to as a spray lanyard (or wand).
6. Spray pattern and droplet size are controlled by the nozzle for uniform application.
7. Pressure Regulator: Maintains consistent spraying pressure.
8. Shoulder Straps: These straps let the operator comfortably carry the sprayer on their back.
9. Trigger Valve: Controls the start and stop of spraying.

WORKING PRINCIPLE OF KNAPSACK SPRAYER:

The knapsack sprayer works by forcing liquid through nozzle in the form of fine droplets by creating pressure.



Fig:1.**Knapsack sprayer**

The operator carries the sprayer on back, and by manually operating a lever or using a battery-powered pump, pressure built up inside tank.

The chemical solution is pushed through a delivery hose and into the spray lance by this pressure. The fine mist or spray produced by the nozzle at the end of the lance ensures uniform application on crops. In manual sprayers, the operator pumps air into the tank to generate the required pressure. This is done automatically by a small motorized pump in battery-operated sprayers. The spray intensity can be changed by adjusting the pressure. This controlled spraying ensures effective coverage, reduces chemical wastage, and protects crops efficiently against pests and disease.

SPRAYING MECHANISM OF KNAPSACK SPRAYER:

1. Preparation: Choose the Right Nozzle: Consider the desired spray pattern (such as mist or stream). Mixing the Solution: Dilute chemicals as per manufacturer instructions to ensure effective application.
2. Filling the Tank: Open the Tank Lid: Ensure the lid is clean before opening. Pour the Prepared Solution: Fill the tank up to the recommended level, avoiding overfilling.
3. Making the Straps: Fit Adjust the shoulder straps of the sprayer to achieve a comfortable fit by placing it on your back.
4. Pressurizing the Tank: Manual Sprayers: Pump the handle 6–8 times to build pressure. Battery/Motorized Sprayers: Ensure the power source is activated and functioning.
5. Spraying: To activate the trigger, release the solution by pressing the trigger valve. Maintain Pressure: Continue to pump (manual) or monitor battery/fuel levels (powered) to maintain consistent pressure.
6. Post-Application :Close the valve or turn off the power to the sprayer .Clean the Equipment: To get rid of any residue, rinse the tank, hoses, and nozzles with clean water.

MAINTENANCE OF KNAPSACK SPRAYER:

Daily Maintenance

1. Purify the Tank: After each use, rinse the tank thoroughly with clean water to remove any chemical residues.
2. Clean Hoses and Nozzles: Remove and flush hoses, nozzles, and filters to prevent clogging.
3. Fluidize the Moving Parts: Apply light oil to the pump handle, trigger, and other moving

parts for smooth operation.

4. Examine for Damage: Examine the seals, nozzles, and hoses for wear, cracks, and leaks. If necessary, replace it.

Long-Term or Seasonal Maintenance

1. Check before the Season: Before the spraying season begins, check each component to make sure it works as intended.
2. Post-Season Storage: Remove any remaining chemicals, clean thoroughly, and store the sprayer in a dry, cool place away from sunlight.
3. Protect Components: Keep rubber parts like gaskets and hoses away from heat or chemicals to prevent deterioration

APPLICATION OF KNAPSACK SPRAYER IN AGRICULTURAL:

1. Spraying pesticides and insecticides to control pests.
2. Utilizing fungicides to control and prevent fungal diseases. 3. Spraying herbicides for weed control.
4. Applying liquid fertilizers for faster nutrient absorption.
5. Spraying growth regulators onto plants to control their size, fruit, or flowering.
6. Use for small-scale crops in nurseries, greenhouses, and gardens.
7. Treatments for specific plants or areas that are applied specifically.
8. Suitable for orchards and plantations where machinery cannot reach.

Conclusion

The knapsack sprayer is a useful and effective tool for applying fertilizers, pesticides, and herbicides in contemporary agriculture. Its portability, ease of operation, and ability to deliver uniform spray make it ideal for small and medium-scale farms, gardens, and plantations. Proper operation and regular maintenance enhance its effectiveness, reduce chemical wastage, and ensure safety for the user. The knapsack sprayer not only protects crops from pests and diseases but also contributes to increased productivity and sustainable farming practices by allowing for precise and controlled application. Overall, it is a cost-effective and reliable implement that plays a vital role in promoting efficient crop management and healthy agricultural production.

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LIDAR IN AGRICULTURE: TRANSFORMING FARMING THROUGH PRECISION TECHNOLOGY

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Abstract

Light Detection and Ranging (LiDAR) is emerging as a transformative technology in modern agriculture, offering high-precision data for enhancing productivity, sustainability, and resource management. By generating detailed three-dimensional models of farmland, LiDAR enables accurate mapping of terrain, soil, and crop conditions. Its applications range from monitoring crop growth, canopy density, and biomass to optimizing irrigation, soil conservation, and water management. LiDAR also supports forestry and plantation agriculture by assessing tree height, density, and carbon storage potential. Furthermore, it strengthens disaster preparedness by predicting flood zones, drought risks, and erosion-prone areas. Integrated with drones, autonomous machinery, and AI-driven platforms, LiDAR empowers farmers with real-time, data-rich insights for precision farming. Despite challenges such as high costs and technical expertise requirements, the technology is becoming increasingly accessible. As adoption grows, LiDAR is poised to play a vital role in ensuring food security, improving farm efficiency, and advancing sustainable agricultural practices worldwide.

Keywords: LiDAR, Precision Agriculture, Remote Sensing, Crop Monitoring, Digital Elevation Models (DEMs)

Introduction

Agriculture has always been at the heart of human civilization, and with the growing demand for food security, the industry is turning to innovative technologies to increase efficiency, productivity, and sustainability. One such breakthrough is Light Detection and Ranging (LiDAR), a remote sensing technology that uses laser pulses to create highly detailed three-dimensional (3D) maps of landscapes. While initially developed for aerospace and defense applications, LiDAR is now finding widespread use in agriculture, where it is revolutionizing the way farmers manage crops, soil, and resources.

What is LiDAR?

LiDAR works by emitting rapid laser pulses toward a target and measuring the time it takes for them to bounce back. By calculating these return times, LiDAR creates highly accurate spatial models of terrain and vegetation. Mounted on drones, aircraft, satellites, or ground-based vehicles, LiDAR sensors can cover large areas quickly and provide farmers with precise, data-rich insights.

Mapping Farmlands with Precision

Traditional land surveys often require manual work and lack accuracy over large terrains. LiDAR technology, however, can generate high-resolution topographic maps that highlight slopes, soil variations, and micro-elevations. This information helps farmers plan irrigation systems, drainage networks, and planting strategies more effectively. For example, detecting uneven terrain ensures that water and fertilizers are distributed uniformly, reducing waste and increasing yields (Eitel *et al.*, 2016).

Crop Health and Growth Monitoring

LiDAR allows farmers to monitor crop height, canopy density, and biomass distribution throughout the growing season. By identifying variations in crop growth, farmers can detect early signs of stress caused by pests, diseases, or nutrient deficiencies. Such data supports precision agriculture practices, enabling targeted interventions rather than broad, resource-heavy approaches (Mathews et al., 2013).

Soil and Water Management

Efficient water use is critical for sustainable agriculture. LiDAR-derived digital elevation models (DEMs) help farmers understand watershed patterns, soil erosion risks, and irrigation needs. By integrating LiDAR with Geographic Information Systems (GIS), farmers can optimize

irrigation schedules, design contour farming systems, and conserve water while maintaining soil fertility (Pishgar *et al.*, 2021).

Forestry and Plantation Crops

In forestry and plantation agriculture, LiDAR plays a vital role in analyzing tree canopy height, density, and overall biomass. It helps plantation managers monitor crop maturity, estimate timber volumes, and assess carbon storage potential. For crops like coffee, tea, and orchards, LiDAR data supports both productivity and sustainability goals.

Disaster Preparedness and Risk Management

Floods, droughts, and soil erosion present major challenges to agriculture. LiDAR's ability to model terrain at high resolution helps farmers and policymakers predict flood zones, identify drought-prone areas, and assess erosion risks. This predictive capacity enables better preparedness and resilience against climate change impacts (Farhan *et al.*, 2024).

Integration with Smart Farming

Modern agriculture increasingly relies on automation and smart technologies. LiDAR integrates seamlessly with drones, autonomous tractors, and AI-driven platforms. By combining LiDAR data with multispectral imaging and satellite observations, farmers gain a holistic view of their fields. This fusion of data supports real-time decision-making, reducing input costs and improving yields (Wang *et al.*, 2019).

Challenges and Limitations

Despite its many advantages, LiDAR adoption in agriculture faces challenges. High equipment and operational costs can be a barrier for small and medium-sized farmers. Additionally, processing and analyzing LiDAR data require technical expertise. However, as technology advances and costs decline, LiDAR is expected to become more accessible to a broader farming community(Wallace *et al.*, 2012).

The Future of LiDAR in Agriculture

The future of LiDAR in agriculture looks promising. With increasing integration into drone-based farming, smart irrigation systems, and AI-powered analytics, LiDAR will play a crucial role in sustainable agriculture. Governments and research institutions are also exploring LiDAR for monitoring large-scale agricultural landscapes, ensuring food security while addressing environmental concerns.

Conclusion

LiDAR technology is transforming agriculture by providing farmers with the tools to monitor crops, optimize resources, and build resilience against environmental challenges. From soil management to disaster prediction, LiDAR is making farming smarter, more efficient, and sustainable. As costs decrease and accessibility improves, LiDAR has the potential to become a cornerstone of modern agriculture worldwide.

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PAH IN SMOKED FISH: SOURCE, OCCURRENCE AND HEALTH RISKS

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Abstract

Smoking is a widely used method for fish preservation and processing, with approximately 15% of fish consumed in Europe being smoked. Traditional smoking involves salting and exposing fish to wood smoke in kilns, while modern smokehouses employ controlled airflow and external smoke generation. Depending on the technique, smoking temperatures range from cold (12–25 °C) to hot (up to ~100 °C). Beyond imparting flavor and extending shelf-life, smoking also introduces contaminants, notably polycyclic aromatic hydrocarbons (PAHs), which are of toxicological concern. Studies consistently report PAHs in smoked fish, with concentrations influenced by species, fat content, wood type, smoking duration, and kiln design. Levels frequently exceed European Union limits of 5 µg/kg for benzo[a]pyrene and 30 µg/kg for PAH4. Traditional methods, particularly those using sawdust or resin-rich woods, produce the highest contamination, whereas improved kilns, liquid smoke, and controlled ovens significantly reduce PAHs. Risk assessments suggest that chronic consumption of heavily smoked fish elevates cancer risk, though exposure levels vary regionally. Mitigation strategies include optimizing smoking parameters, selecting low-resin fuels, using modern technologies, and applying pre-treatments to reduce PAH uptake. Advancing safer smoking practices and expanding monitoring, particularly in developing regions, remain crucial for striking a balance between cultural traditions and public health.

Introduction

Smoking is one of the oldest methods for preserving food and remains a major technique in processing fish. In Europe, approximately 15% of fish sold for human consumption is either cold-smoked or hot-smoked. Traditional methods involve salting the fish first, either whole, gutted, or filleted, then exposing them to wood smoke. The smoke is generated by slowly burning wood or wood shavings/sawdust in a firebox, with the fish placed either hanging above or laid on mesh trays. Natural drafts, shaped by the kiln's geometry and weather conditions, govern the flow and distribution of smoke. In contrast, modern smokehouses often generate smoke in external units under controlled temperature and airflow, using forced circulation to ensure uniform exposure. During cold smoking the smoke temperature is kept between about 12-25 °C; warm smoking uses 25-45 °C. Hot smoking typically involves staged heating, with smoke temperatures rising from ~40 °C up to about 100 °C, with the inner part of the fish sometimes reaching temperatures up to ~85 °C. The rate at which various smoke components deposit on the fish depends on many factors: smoke temperature, humidity, flow rate and density; the chemical nature (water solubility, volatility) of smoke constituents; and surface properties of the fish (e.g. skin, fat). More recently, smoke condensates or "liquid smoke" solutions or aerosols have been used as alternatives to direct smoking.

Electrostatic smoking has also been explored: applying a high voltage (~30 kV) can enhance the directed deposition of smoke particles, droplets, and vapours. The composition of the smoke, as well as the smoking conditions, significantly affect the product's flavour, appearance, safety, and shelf-life. One concern is the presence of carcinogenic substances in wood smoke, especially polycyclic aromatic hydrocarbons (PAHs), as well as their derivatives (nitro-PAHs, oxygenated PAHs), with smaller contributions from N-nitroso compounds and heterocyclic amines. In many cases, the levels of N-nitroso compounds in hot-smoked fish remain relatively low (micrograms per kilogram), lower than in several other food sources. Some studies of heavily smoked or dried fish report heterocyclic aromatic amines also in low microgram/kg levels.

Occurrence of PAH in smoked fish

PAH are consistently reported in smoked fish, though the concentrations vary widely depending on species, smoking method, type of fuel used, and duration of processing. In many cases, the levels found are well above international food safety standards, especially those

established by the European Union (EU), which sets maximum allowable limits of 5 µg/kg for benzo[a]pyrene (BaP) and 30 µg/kg for the sum of four marker PAHs (BaP, chrysene, benzo[a]anthracene, and benzo[b]fluoranthene) (Iwu et al., 2024). A recent study in Nigeria compared smoked mackerel and catfish to grilled counterparts and found that smoked mackerel contained total PAHs of 1.618 ± 0.102 mg/kg, while smoked catfish contained 1.718 ± 0.129 mg/kg, far above safe limits (Iwu et al., 2024). The same study reported that carcinogenic PAH sums (PAH7 and PAH8) also exceeded guideline thresholds, suggesting that frequent consumption of these products could contribute substantially to cancer risk. By contrast, grilled samples from the same study contained significantly lower PAH concentrations, highlighting the role of direct smoke exposure in PAH accumulation.

The influence of wood type and fish species has also been investigated. Savin et al. (2024) demonstrated that smoking with woods high in lignin or resin content resulted in higher PAH deposition compared to less resinous woods. Species differences were also clear: oily fish such as carp or sturgeon accumulated more PAHs than leaner species like trout, due to their higher fat content, which facilitates the absorption of lipophilic PAHs. This pattern is reinforced by the finding that fish skin accumulates higher concentrations of PAHs than muscle tissue. In rainbow trout smoked with cherry tree sawdust, the concentration of 17 PAHs in the skin was 32.79 µg/kg, while the flesh contained only 5.59 µg/kg (Uiuiu et al., 2025). Studies from West Africa show similar patterns. Diop et al. (2023) investigated several smoked fish species in Senegal, including *Sardinella aurita* and *Ethmalosa fimbriata*, and reported measurable PAH contamination across all samples.

In many cases, levels of BaP and PAH4 approached or exceeded EU thresholds. Likewise, a Nigerian study comparing different fuels reported extremely high PAH concentrations in fish smoked with sawdust, reaching 2058 µg/kg in *Arius heudelotii* and 1395 µg/kg in *Sardinella* species. In the same study, firewood produced somewhat lower PAH levels (e.g., 1320 µg/kg in *Arius heudelotii*), while charcoal produced the lowest concentrations, though contamination was still present (Academia.edu, 2023). These findings suggest that the choice of smoking fuel is one of the most critical determinants of PAH formation.

In another Nigerian market survey, Borno State samples showed lower concentrations, with chrysene detected at 3.54 µg/kg and naphthalene at 4–7 µg/kg, values that are still relevant for dietary exposure though they fall closer to international safety limits (Academia.edu, 2023).

The discrepancy between these lower results and the very high levels reported in traditional smoking contexts underscores the role of smoking intensity, kiln design, and handling practices in determining final contamination levels. The use of improved kilns has been shown to significantly reduce PAH contamination. For example, fish smoked using the FAO-Thiaroye Technique (FTT) in Ghana had BaP and PAH4 concentrations below EU maximum limits, whereas fish smoked with traditional kilns in the same region exceeded them. In traditional kiln samples, BaP reached 70 µg/kg and PAH4 levels were as high as 395 µg/kg, while the improved FTT kilns consistently produced fish within regulatory safety margins (Academia.edu, 2022). These results demonstrate that technology upgrades can be highly effective in mitigating PAH occurrence in smoked fish.

In traditional, uncontrolled smoking using sawdust, total PAHs in fish often exceed 1–2 mg/kg (1000–2000 µg/kg), many times higher than regulatory limits (Iwu et al., 2024). By contrast, when fish are smoked using modern kilns or portable smoking ovens with controlled airflow and selected fuels, PAH concentrations can be reduced to single- or low double-digit µg/kg values. For example, rainbow trout smoked in a controlled oven showed only 5.6 µg/kg of PAHs in the flesh, demonstrating that with proper controls, smoked fish can be produced safely (Uiuiu et al., 2025). Despite these improvements, challenges remain. Many studies in the Global South report that smoked fish continues to carry high PAH burdens, reflecting both cultural smoking practices and limited access to improved smoking technology. Furthermore, while most research focuses on BaP and PAH4 as regulatory markers, the broader mixture of 16 priority PAHs, including heavy PAHs and oxygenated or nitrated derivatives, is less frequently quantified. This gap limits the ability to fully characterize the health risks posed by smoked fish consumption.

Health Risk Assessments

The health risks associated with PAHs in smoked fish are primarily carcinogenic. Risk assessments often rely on measures such as the Margin of Exposure (MOE), Incremental Lifetime Cancer Risk (ILCR), or Toxic Equivalent (TEQ) calculations. Evidence from recent studies indicates that frequent consumption of smoked fish can increase long-term cancer risk, particularly when PAH7 or PAH8 levels are elevated. Although non-carcinogenic hazard quotients (HQ) and hazard indices (HI) often fall below critical thresholds, there remains concern

over chronic exposure to low levels of PAHs, which may contribute to immune system impairment or genotoxicity over time.

Determinants of PAH Formation

The generation of PAHs during smoking is shaped by multiple factors. High smoking temperatures, particularly during hot smoking, increase the formation of heavier PAHs, whereas carefully controlling smoke temperature and avoiding flare-ups can reduce deposition. The choice of wood also matters, with less resinous or pre-dried woods producing fewer harmful compounds. Additionally, fat drippings that fall into flames can generate PAH-rich smoke, which then deposits back on the fish. Other determinants include the duration of smoking, the density of smoke exposure, and the proximity of fish to the smoke source. Optimizing these conditions is key to minimizing PAH formation while still achieving desired sensory qualities.

Strategies for Mitigation

Efforts to reduce PAH levels in smoked fish have centered on both technological and processing innovations. The use of liquid smoke offers a practical alternative, as it allows controlled application of smoke flavoring while removing harmful compounds. Modified kilns with filtering systems, including activated carbon, can further reduce PAH concentrations. Selecting appropriate wood types, drying fuel properly, and avoiding resinous materials are also effective. Pre-treatments such as marination with acidic or antioxidant-rich solutions, or protective coatings that reduce direct smoke contact, have been shown to lower PAH uptake. Adjusting smoking protocols by lowering smoke temperatures, managing humidity, and shortening exposure times also contribute to safer products. Regulatory guidelines, such as those in the EU, emphasize these good practices to ensure compliance and consumer safety.

Conclusion

Recent years have seen greater emphasis on advanced methods to identify the sources of PAHs in smoked fish, using statistical models and chemical fingerprinting to distinguish between environmental contamination and smoke-related deposition. Research has also revealed species-specific variations, with fattier fish often accumulating more PAHs than leaner varieties. Despite this progress, significant gaps remain, particularly in regions of the Global South where traditional smoking is widespread and regulatory oversight is limited. Expanding monitoring, improving awareness among producers, and adopting safer smoking technologies will be critical to reducing health risks associated with smoked fish in the coming years.

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TURNING WEEDS INTO WEALTH: THE HIDDEN TREASURE OF HERBAL REMEDIES

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Abstract

Weeds are often regarded as unwanted plants that interfere with agriculture and reduce productivity. Yet, hidden within this “green nuisance” lies a vast treasure of medicinal wealth. Many common weeds that grow abundantly in backyards, farmlands, and roadside patches possess remarkable healing properties and have been used in traditional medicine systems for centuries. Plants such as Eclipta alba (karisalankanni), Phyllanthus niruri (keelanelli), Centella asiatica (vallarai), and Tridax procumbens (thatha poochi keerai) are not only resilient survivors of harsh environments but also reservoirs of bioactive compounds with antimicrobial, anti-inflammatory, hepatoprotective, and memory-enhancing effects. These “medicinal weeds” can play a vital role in affordable primary healthcare, support the discovery of novel drugs, and open new avenues for sustainable livelihoods through herbal product development. Despite their potential, medicinal weeds remain neglected due to poor awareness, negative perceptions, and limited scientific validation. Harnessing their value requires a blend of traditional knowledge and modern research, along with policy support for cultivation,

conservation, and commercialization. As the demand for herbal remedies and natural healthcare grows globally, it is time to reimagine weeds not as enemies of agriculture but as forgotten green pharmacies waiting to be rediscovered.

Key words: Bioactive Compounds, Medicinal benefits, Policy support, Value addition

Introduction

Most of us consider weeds to be unwanted invaders plants that compete with our crops, spoil the beauty of our gardens, and reduce yields in fields. Farmers spend huge amounts of money and effort every year to control weeds. But what if we told you that some of these so-called "troublemakers" are actually healers in disguise? Many weeds that grow freely in backyards, roadside patches, and farm fields have been used for centuries in traditional medicine systems like Ayurveda, Siddha, Unani, and folk practices (Garud *et al.*, 2024). They are rich in bioactive compounds with properties ranging from anti-inflammatory and antimicrobial to antidiabetic and anticancer. Yet, they remain largely neglected. These "medicinal weeds" represent a hidden green pharmacy that could contribute to low-cost healthcare, drug discovery, and even sustainable livelihoods if harnessed properly.

What Are Medicinal Weeds?

Medicinal weeds are plants that are usually unwanted in agriculture or horticulture but possess medicinal and therapeutic value. They are hardy, adaptive, and rich in phytochemicals such as alkaloids, flavonoids, tannins, terpenoids, and glycosides. While some weeds are harmful, a surprising number of them are natural remedies for health issues (Choudhary and Singh, 2017).

Examples:

Eclipta alba (False Daisy / Karisalankanni) – Used for liver disorders and hair growth.

Phyllanthus niruri (Stonebreaker / Keelanelli) – Known for its role in treating kidney stones and hepatitis.

Tridax procumbens (Coat Buttons / Thatha poochi keerai) – Traditionally used for wound healing.

Centella asiatica (Gotu Kola / Vallarai) – A brain tonic used to enhance memory and concentration.

Achyranthes aspera (Prickly Chaff Flower / Nayuruvi) – Used in treating cough, asthma, and snakebites.

Why Medicinal Weeds Matter Today

1. Affordable Healthcare for All In rural areas where access to modern healthcare is limited, medicinal weeds can provide simple, effective remedies at no cost. For instance, Acalypha indica is a common weed but valued in folk medicine as a cure for respiratory problems. **2.** Rich Source of Bioactive Compounds Modern research has shown that medicinal weeds contain compounds with antimicrobial, antioxidant, anti-inflammatory, and anticancer properties. They are potential sources for new drug development in the pharmaceutical industry (Azeez *et al.*, 2025).

3. Supporting Sustainable Agriculture Instead of being seen only as enemies of crops, some weeds can be integrated into farming systems for herbal value addition (Bhattacharya, 2018). For example, Azolla, though often seen as a paddy weed, is used both as a green manure and as a source of medicinal properties.

4. Cultural and Traditional Importance Traditional healers have used weeds as home remedies for generations. For example, Alternanthera sessilis (Ponnanganni) is consumed as a green leafy vegetable in South India for improving eyesight and cooling the body. **5.** Turning Weeds into Wealth With the growing popularity of herbal medicines, nutraceuticals, and organic products, medicinal weeds could become a new avenue for rural entrepreneurship. Collecting, processing, and marketing weed-based herbal products can create livelihood opportunities (Serdiati *et al.*, 2024).

Examples of Common Medicinal Weeds and Their Uses

Weed Name (Scientific)	Common Name	Medicinal Uses
Eclipta alba	Karisalankanni	Liver tonic, hair growth promoter
Phyllanthus niruri	Keelanelli	Treats kidney stones, hepatitis
Tridax procumbens	Thatha poochi	Wound healing, antibacterial
Centella asiatica	Vallarai	Improves memory, reduces anxiety
Achyranthes aspera	Nayuruvi	Cough, asthma, snakebite

Alternanthera sessilis	Ponnanganni	Improves eyesight, reduces body heat
Acalypha indica	Kuppaimeni	Skin diseases, respiratory ailments

Challenges in Promoting Medicinal Weeds

Negative Perception: Farmers see weeds as enemies, not allies. **Lack of Awareness:** Many people are unaware of their medicinal value. **Scientific Validation Needed:** Though traditional use is strong, clinical trials are limited. **Overexploitation Risk:** Uncontrolled harvesting may lead to biodiversity loss (Abbas *et al*., 2024).

The Way Forward

- To unlock the potential of medicinal weeds, the following steps are needed: Awareness programs to educate farmers, students, and communities.
- Scientific research to validate traditional claims and identify new medicinal compounds.
- Value addition through processing and marketing of weed-based herbal teas, powders, and extracts.
- Policy support to integrate medicinal weeds into sustainable agriculture and rural development programs.

Conclusion

Medicinal weeds are no longer just the "green enemies" of farmers. They are unsung heroes of nature, offering health, nutrition, and income opportunities. By blending traditional knowledge with modern science, we can transform these neglected plants into valuable resources for society. In the journey towards sustainable healthcare and agriculture, medicinal weeds could indeed become the forgotten green pharmacies in our backyards.

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SALTMARSH ECOSYSTEM

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Abstract

Salt marshes are intertidal, salt-tolerant ecosystems that develop in sheltered coastal zones where sediments are stabilized by halophytic vegetation. In India, they occupy about 1600 km², mainly along the Gujarat coast. These habitats exhibit distinct plant zonation influenced by tidal and salinity gradients. Salt marshes provide vital ecosystem services, including shoreline protection, carbon sequestration, nutrient filtration, and serving as nursery grounds for marine fauna, making them ecologically and economically invaluable.

Keywords: Saltmarsh, halophytes, mudflat

Introduction

Salt marshes are salt tolerant rooted vegetation and present in a low-energy transition zone between submerged and emerged environments, occupying the upper margins of the inter-tidal landscape. These plants are able to withstand high salinity and regular submersion due to regular or occasional immersion by the tides. They are the major blue carbon ecosystems, with a greater latitudinal extent than mangroves, and are dominated by herbaceous and halophytic shrubs rather than trees. However, there are confusions in defining halophytes regarding which species should be considered as a true salt marsh species among the coastal vegetations. Salt marshes provide a unique habitat for a large number of species that cannot survive in other habitats. Therefore, they are an essential element in our ecological structure.

DISTRIBUTION IN INDIA

In India salt marshes are distributed in seven coastal districts/UTs, viz. Gujarat, Daman and Diu, Maharashtra, Tamil Nadu, Puducherry, Andhra Pradesh and Andaman & Nicobar

Islands, covering an approximate area of 1600 km2. Gujarat has the highest area cover of 89.5% of total cover, followed by Tamil Nadu (3.8%), Andaman & Nicobar Islands (3.7%), Andhra Pradesh (2.5%), Maharashtra (0.4%), Puducherry (0.04%) and Daman and Diu (0.04%). There is hardly any species level mapping in India, 15 major salt marsh species have been reported so far from general biodiversity studies. Common species are *Arthrocnemum indicum, Cressa cretica, Fimbristylis ferruginea, Heliotropium curassavicum, Myriostachya wightiana, Porteresia coarctata, Phragmites karka, Salicornia brachiate, Scirpus littoralis, Sesuvium portulacastrum, Suaeda maritime, Suaeda nudiflora, Suaeda monoica, Suaeda fruticosa and Urochondra setulose*.



Salicornia brachiate



Phragmites karka



Scirpus littoralis

FORMATION OF SALTMARSH HABITAT

Saltmarshes are intertidal wetlands formed in sheltered coastal areas where fine sediments are deposited and stabilized by vegetation (Boorman, 1995). Once vegetation becomes established, it enhances sediment accumulation (accretion) by trapping more particles and reducing their resuspension (Stumpf, 1983; Stevenson et al., 1988). Organic matter from plant litter and roots further contributes to the build-up and stability of the marsh surface (Allen and Pye, 1992).

For a saltmarsh to develop, four key conditions are necessary:

1. A stable sediment surface that is covered by tides for shorter periods than it is exposed.
2. A continuous sediment supply during tidal inundation.
3. Low water velocity to allow sediment deposition.
4. Availability of seeds or propagules for vegetation establishment.

Initial colonization occurs on intertidal mudflats by pioneer plants such as *Salicornia, Suaeda,* and *Spartina* species, which tolerate long tidal submergence. As sediment accumulates and the

surface elevates, flooding frequency decreases, allowing less salt-tolerant species to establish. Over time, a mature saltmarsh with complex vegetation and stable soil develops—typically within 40 to 80 years.

During this progression, soil structure and microbial communities (bacteria and fungi) develop, facilitating biogeochemical processes like nutrient cycling and organic matter decomposition. The mature saltmarsh functions as a dynamic system, exchanging organic matter and nutrients with adjacent terrestrial and marine environments.

ZONATION OF SALTMARSH PLANT

Key plant species defining saltmarsh zonation vary with tidal elevation and salinity tolerance, creating distinct zones from low to high marsh areas.

Low Marsh Zone

The lower marsh zone, located closest to the sea, is regularly flooded by tides and experiences high salinity and waterlogging. This harsh environment supports highly salt-tolerant species such as *Spartina alterniflora*, *Salicornia europaea*, and *Suaeda maritima*, which possess adaptations like succulent leaves, salt glands, and specialized air tissues (aerenchyma) for oxygen transport**.**

Middle Marsh Zone

Slightly higher up lies the middle marsh zone, which is flooded only during high tides and has moderate salinity. Species such as *Spartina patens*, *Limonium vulgare*, and *Atriplex portulacoides* dominate here, showing moderate salt tolerance and competitive ability.

High Marsh Zone

The **upper marsh zone** is less frequently inundated and has lower salinity, allowing less salt-tolerant but more competitive plants like *Juncus gerardii*, *Festuca rubra*, and *Plantago maritima* to thrive.

Beyond this lies the **transition zone** or high marsh–upland area, which is rarely flooded and supports semi-terrestrial plants like *Phragmites australis* and *Carex* species. In Indian saltmarshes, a similar zonation pattern is observed — with *Salicornia brachiata* and *Suaeda maritima* in the seaward zone, *Aeluropus lagopoides* and *Sporobolus virginicus* in the middle marsh, and *Phragmites karka* and *Cyperus malaccensis* dominating the landward regions. This gradual change in plant communities reflects the influence of tidal gradients, salinity levels, and ecological competition within the saltmarsh ecosystem.

ECOSYSTEM SERVICES OF SALT MARSH

Ecosystem services are the benefits that humans derive from ecological systems and are generated directly from the processes that sustain ecosystems, or ecosystem functions (UNEP, 2006). Salt marshes provide some of the highest and most valuable ecosystem services among other natural ecosystems (Costanza et al., 2007; Gedan et al., 2009) which lead to one of the primary needs for protecting salt marshes.

Provide raw material and food

Direct provisioning of raw materials and food from salt marshes are known (Davy et al., 2009) as in different parts of the world's marsh lands are used as pasture land (Bromberg-Gedan et al., 2009).

Providing a buffer against wave and storm surges

Marsh vegetations help to stabilize the coast by trapping sediment from the runoff. In due course, increased intertidal height and vertical leaf blades provide a form of sea defense by reducing wave energy, velocity, height and duration (Morgan et al., 2009; Moller et al., 2014; Roner et al., 2015). At times, marshes support to reduce the storm surge duration and height by providing extra water uptake (Barbier et al., 2011).

Nursery areas for coastal biota

Salt marsh ecosystems play a major role in maintaining fisheries by providing nursery ground (MacKenzie and Dionne, 2008). The complex and dense plant structure of marshes provide safe habitat for commercially important young fishes, shrimp and shellfish, as this area is mostly inaccessible to large fishes. Sometimes, they act as high tide refuges for birds feeding on adjacent mudflats and acts as a source of food for marsh dependant birds (Greenberg et al., 2014).

Filters for nutrients and pollutants

Marshes are called natural filters as they effectively purify water entering the estuary (Mitsch and Gosselink, 2008). As water from upstream passes through marshland, it looses its velocity due to friction with marsh vegetation and suspended particles slowly get deposited on the marsh surface. This natural filtration mechanism facilitates nutrient and pollutant uptake and recycling process.

Facilitates carbon sequestration

Salt marshes are known as one of the most productive ecosystems in the world, as they

effectively sequester atmospheric carbon and serve as an organic carbon sink (sequester millions of tons of carbon annually) (Mitsch and Gosselink, 2008).

Enhances cultural values

The aesthetics of salt marsh and high diversity of migratory and passerine birds found within marshes draws attention to many tourists and bird watchers, giving a scope for recreational activities. Salt marsh and other associated ecosystems provide wide possibilities for research.

Conclusion

Saltmarsh habitats are vital coastal ecosystems that form through the interaction of tidal processes, sediment deposition, and vegetation growth. They play a crucial role in shoreline stabilization, nutrient cycling, and supporting diverse wildlife. Over time, saltmarshes evolve into highly productive and resilient environments that act as natural buffers against coastal erosion and flooding. Protecting and conserving these ecosystems is essential for maintaining ecological balance and coastal sustainability.

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TRICLOSAN IN FISH: SOURCE, TOXICITY, AND HUMAN HEALTH RISKS

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Abstract

Triclosan (TCS) is a man-made antimicrobial that has quietly worked its way into everyday life, appearing in soaps, toothpastes, fabrics, and even plastics. It is now recognized as a contaminant that lingers in the environment long after use. Wastewater treatment plants remove only part of TCS, allowing the rest to escape into rivers and lakes or bind to sludge that eventually returns to farmland. Over time, TCS and its by-products settle in sediments and enter aquatic food webs. Fish and shellfish can accumulate both triclosan and its more persistent form, methyl-triclosan (MTCS). Research has linked triclosan to hormone disruption, antibiotic resistance, and even the potential formation of toxic by-products like dioxins when exposed to sunlight. With seafood serving as a staple food worldwide, understanding how triclosan travels from daily human life into oceans and back into human diets is essential for protecting public health.

Introduction

Triclosan (TCS), formally known as 5-chloro-2-(2,4-dichlorophenoxy) phenol, is a chemical that has quietly become part of our everyday lives. First created more than forty years ago, it has since found its way into a surprising variety of products. From the soap we use at the sink, to the toothpaste we squeeze onto our brushes, to the shampoo and deodorants lining our bathroom shelves, TCS is everywhere. Beyond personal care, it has also been added to detergents, disinfectants, fabrics, plastics, and even some veterinary and household products. Its

appeal lies in one key trait: it is a powerful, broad-spectrum antimicrobial. The way TCS works is both fascinating and troubling. Once it comes into contact with bacteria, it can pass through the cell wall and interfere with vital processes inside. It disrupts the production of RNA and other macromolecules necessary for cell survival. More importantly, it blocks the enzyme enoyl reductase, which bacteria need to produce fatty acids. Without fatty acids, bacterial cell membranes cannot be built or maintained, eventually leading to cell death. However, it does have its limits—bacterial spores, for instance, are unaffected by it.

TCS is part of a family of halogenated aromatic hydrocarbons, and its structure resembles that of several well-known, and sometimes notorious, compounds like polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), and even dioxins. These similarities have raised concerns among scientists, as many of these chemicals are linked to serious health and environmental issues. The 1990s marked a boom in triclosan's popularity. Studies show that, by the late 1970s, hundreds of consumer products—up to 700—contained it as an active ingredient. Companies marketed it under brand names like Irgasan DP300, Aquasept, and Ster-Zac, while consumer materials embedded with TCS carried labels such as Microban, Sanitized, and Ultra-Fresh. At one point, there was even discussion of adding it to food packaging, but in 2010, the European Union decided against it, removing triclosan from its list of provisional additives allowed in materials that touch food. One reason triclosan spread so widely is that it was considered safe. It has low acute toxicity, meaning it doesn't cause immediate harm in small doses, and its concentrations in consumer products are generally modest—usually between 0.1% and 0.3% of the product's weight. For years, this led many to assume there was little to worry about. But the story doesn't end there.

Every time we rinse off soap or toothpaste containing triclosan, tiny amounts of it travel down the drain and into wastewater treatment plants. From there, it can make its way into rivers, lakes, sediments, soils, and even the tissues of fish, birds, and humans. Researchers have detected it in surface waters around the world, as well as in biosolids, sludge, and living organisms. This environmental persistence has sparked growing concern, especially since its use continues to rise in tandem with consumer demand for "antibacterial" products. Health experts are now paying closer attention. While some reviews suggest that triclosan is unlikely to cause harm at the levels found in typical consumer products, others have raised serious questions. Possible risks include the development of antibiotic-resistant bacteria, irritation of the skin,

disruption of the body's endocrine system, higher rates of allergies, and the formation of potentially cancer-causing by-products. These aren't abstract worries—scientists have already begun linking triclosan exposure to measurable biological changes in both animals and humans. Despite these concerns, independent research into the long-term effects of triclosan remains relatively limited. This article focused on toxicity in laboratory animals, environmental pathways, and their role in bacterial resistance.

TCS in Aquatic Environment

TCS is frequently detected in aquatic systems because wastewater treatment plants (WWTPs) do not fully eliminate it. Its removal efficiency depends on treatment type: while aerobic processes degrade a large portion of TCS, anaerobic conditions allow it to persist. Field studies have shown that although most of the compounds can be biologically broken down, a measurable fraction passes into the final effluent, while another significant portion becomes bound to sewage sludge. Since biosolids are often applied to agricultural lands, this creates two major environmental release pathways—direct discharge into waterways and land application of sludge. Reported concentrations range from micrograms per liter in effluents to hundreds of micrograms per kilogram in sediments, highlighting its widespread distribution. Once in the environment, TCS is influenced by water chemistry, organic matter, sediment density, and even seasonal variations, but it often accumulates and persists under oxygen-poor conditions. Sediment core studies have traced its presence back decades, showing fluctuations in use patterns over time and confirming its environmental persistence. Even more concerning is its transformation under sunlight, where photolysis generates chlorinated dioxins, including toxic derivatives that can further degrade into higher-order dioxins with long-lasting ecological impacts. Together, these findings underscore triclosan's resilience, its ability to partition into sediments, its role as a long-term contaminant in aquatic ecosystems, and its potential to form hazardous by-products (Chalew & Halden, 2009).

Toxicity to fish

Triclosan (TCS) and its main transformation product, methyl-triclosan (MTCS), have been detected in a variety of aquatic organisms, with fish showing the most consistent evidence of accumulation. One of the earliest studies, conducted in Japan in the 1980s, identified MTCS in both freshwater fish and shellfish collected from the Tama River and Tokyo Bay, with concentrations ranging from a few to several dozen micrograms per kilogram of whole-body

weight. Later, a well-documented investigation in Sweden exposed rainbow trout (Oncorhynchus mykiss) to effluents from a wastewater treatment plant. The results demonstrated clear accumulation of TCS in bile fluid, with levels in exposed fish exceeding 100 mg per kilogram, far higher than those in reference or control groups. These findings provided strong evidence that TCS concentrates in the bile of exposed fish. Subsequent European studies have consistently confirmed the presence of TCS and MTCS in wild fish. In Switzerland, MTCS was detected in juvenile brown trout (Salmo trutta fario) living in rivers influenced by wastewater discharges, with tissue concentrations ranging from 130 to over 2000 ng per gram of lipid weight. Similarly, lake fish were found to contain MTCS at lower levels, reflecting the lower exposure typically observed in systems without direct wastewater inputs. Long-term monitoring in Germany using archived bream (Abramis brama) tissue revealed a rising trend of MTCS concentrations from the mid-1990s through the early 2000s, while TCS itself was present at only low or sporadic levels. The study concluded that MTCS is more environmentally persistent than its parent compound and has the capacity to bioaccumulate in fish muscle tissue. Data from North America are more limited, but available evidence also points to widespread contamination. A study on the Detroit River detected TCS in the plasma of multiple fish species at picogram-to-nanogram levels, with MTCS present at lower concentrations.

In contrast, an investigation in Nevada reported strikingly high levels of MTCS in common carp (Cyprinus carpio), with mean concentrations exceeding 500 µg per kilogram wet weight. Researchers suggested that the sediment-foraging behavior of carp likely explains their elevated exposure, since MTCS, being lipophilic, readily partitions into sediments where it can persist. Beyond biota, both TCS and MTCS have been identified in freshwater and marine sediments, reinforcing their potential for long-term persistence in aquatic systems. A U.S. national survey further highlighted the ubiquity of pharmaceutical and personal care products, including triclosan, in fish sampled from effluent-dominated rivers near major urban centers. While trace amounts of TCS were detected in fillets, the consistent presence of its transformation product in tissues across multiple studies highlights the compound's environmental persistence and its capacity to bioaccumulate within aquatic food webs (Ramirez et al., 2009).

Toxicity to humans

Seafood provides a direct route of human exposure to triclosan and MTCS. People consuming fish or shellfish harvested from effluent-impacted waters may ingest residues that

have accumulated in tissues. While estimated intake levels are generally lower than those encountered through the use of personal care products, the concern lies in chronic exposure and bioaccumulation. Unlike exposure from soaps or toothpaste, dietary intake bypasses dermal barriers and delivers triclosan directly to the digestive system, where absorption efficiency can be higher. Regular seafood consumers, particularly in regions where wastewater effluent contaminates fishing grounds, may face sustained intake levels that increase the likelihood of toxicological effects over time. Monitoring data from urban waterways in Europe and North America suggest that seafood harvested from contaminated habitats can contain nanogram to microgram levels of triclosan per gram of tissue, enough to raise questions about long-term human safety (Ramirez et al., 2009).

Triclosan has been linked to endocrine-disrupting effects, interfering with thyroid hormone homeostasis and potentially altering reproductive and developmental processes. Laboratory studies have shown that exposure can affect the expression of thyroid hormone–related genes, which play critical roles in metabolism, growth, and neurological development. Because MTCS is more stable, it may extend these endocrine impacts by persisting longer in tissues. Chronic intake through seafood consumption, even at low levels, may contribute cumulatively to hormonal disturbances over time (Rodricks et al., 2010). One of the most widely debated consequences of triclosan exposure is its potential to promote antibiotic resistance. By interfering with bacterial fatty acid synthesis, triclosan can create selective pressure favoring resistant strains. While much of the concern has focused on environmental and medical settings, dietary exposure represents another avenue where resistant bacteria could transfer resistance genes to the human gut microbiota (Adolfsson-Erici et al., 2002). Consuming seafood contaminated with triclosan could indirectly contribute to this global health challenge. Because triclosan is lipophilic, dietary intake via seafood may result in accumulation in human adipose tissue over long periods.

This raises the possibility of systemic effects such as immune dysregulation, altered liver enzyme activity, and oxidative stress. Although blood concentrations measured in population studies are typically low, the additive contribution from seafood consumption is concerning in regions with high dietary dependence on fish and shellfish. Sensitive populations—such as pregnant women, infants, and individuals with pre-existing endocrine disorders—may be at greater risk. Another indirect concern is the formation of chlorinated dioxins from triclosan

breakdown. When exposed to sunlight in aquatic environments, triclosan can photodegrade into dioxin-like compounds, some of which are carcinogenic. If these derivatives accumulate in sediments and are transferred into seafood species, consumers may be exposed to far more toxic compounds than triclosan itself. This highlights the importance of considering transformation products, not just the parent chemical, when assessing risks from dietary exposure (Singer et al., 2002).

Current risk assessments suggest that the levels of triclosan typically found in seafood do not pose immediate, acute toxicity to humans. However, regulatory agencies increasingly recognize the importance of considering chronic exposure, bioaccumulation, and mixture effects with other contaminants. The U.S. Food and Drug Administration and the European Union have already restricted triclosan use in certain consumer products, reflecting broader concern over its safety profile. Yet, seafood remains a largely unmonitored source of triclosan exposure for many populations. Establishing maximum residue limits, improving wastewater treatment technologies, and conducting more comprehensive biomonitoring studies are essential steps to reduce uncertainty. Public health recommendations may also need to consider dietary contributions when evaluating overall triclosan exposure.

Conclusion

Seafood consumption represents a significant but often overlooked pathway for human exposure to triclosan and its more persistent metabolite, methyl-triclosan. Once released into aquatic environments, triclosan accumulates in fish and shellfish, allowing it to move up the food chain and into the human diet. While current evidence suggests that acute risks are low, the potential for endocrine disruption, promotion of antibiotic resistance, bioaccumulation, and dioxin formation highlights the need for continued vigilance. Considering the global reliance on seafood as a protein source, understanding and mitigating triclosan contamination is critical for safeguarding both environmental and human health. Future research should prioritize long-term monitoring, mechanistic toxicology, and policy frameworks that address dietary exposure alongside other sources of triclosan intake.

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SMART AQUATIC MANAGEMENT: ROLE OF AI, DRONES, AND GIS IN WATER OUALITY MONITORING

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Abstract

Water quality monitoring has evolved significantly with the integration of Artificial Intelligence (AI), unmanned aerial vehicles (drones), and Geographic Information Systems (GIS). Traditional methods are time-consuming, labor-intensive, and spatially limited. The convergence of AI algorithms, drone-based remote sensing, and GIS spatial analysis offers unprecedented opportunities for real-time, comprehensive aquatic ecosystem management. AI-powered predictive models enable early detection of water quality deterioration, drones provide rapid data collection across vast water bodies, and GIS facilitates spatial pattern recognition and decision-making support. Together, these technologies create an integrated framework for sustainable water resource management, addressing critical challenges in pollution detection, ecological conservation, and public health protection.

Keywords: Water quality monitoring, Artificial Intelligence, Unmanned Aerial Vehicles, Geographic Information Systems, Remote sensing, Smart water management

1. Introduction

Water quality monitoring is fundamental to environmental sustainability and public health. Traditional assessment methods relying on manual sampling present significant limitations including high costs, temporal delays, and inadequate spatial coverage (Glasgow et al., 2004; Strobl & Robillard, 2008). The emergence of smart technologies has ushered in a new era of aquatic management. Artificial Intelligence offers computational capabilities for pattern recognition and predictive modeling (Chen et al., 2020), drones enable rapid data acquisition

(Koparan et al., 2018), and GIS provides platforms for spatial analysis (Khatri & Tyagi, 2015). This article examines how these technologies are collectively transforming water quality monitoring practices toward sustainable, intelligent management systems.

2. Artificial Intelligence in Water Quality Assessment

AI has emerged as a game-changing technology in water quality monitoring. Machine learning algorithms process vast datasets to identify patterns, predict parameters, and detect anomalies with remarkable accuracy (Hadjisolomou et al., 2021). AI-powered predictive models utilize historical data to forecast water quality conditions, with neural networks predicting dissolved oxygen levels, pH variations, and pollutant concentrations (Ahmed et al., 2019). Support Vector Machines and Random Forest algorithms effectively model complex relationships between environmental variables and water quality indicators (Chen et al., 2020). AI systems excel at real-time anomaly detection, with CNNs analyzing sensor streams to detect sudden changes and trigger immediate alerts (Xu et al., 2021). Computer vision algorithms enable automated analysis of aquatic imagery for algal bloom detection and pollution identification (Zhang et al., 2020).

3. Drone Technology in Aquatic Monitoring

Unmanned Aerial Vehicles have revolutionized water quality data collection by providing flexible, cost-effective platforms for remote sensing. Drones equipped with specialized sensors offer unprecedented access to difficult-to-reach water bodies while maintaining high spatial and temporal resolution (Koparan et al., 2018). Multispectral cameras capture data across multiple wavelength bands, enabling detection of chlorophyll concentrations, suspended sediments, and dissolved organic matter (Su & Chou, 2015). Thermal infrared cameras detect temperature variations crucial for monitoring thermal pollution and identifying groundwater discharge points (Dugdale et al., 2015). Drones offer rapid deployment for emergency response situations including industrial spills and harmful algal blooms, with their ability to quickly survey affected areas significantly enhancing response coordination (Klemas, 2015).

4. Geographic Information Systems for Spatial Analysis

GIS technology provides the spatial framework for integrating, analyzing, and visualizing water quality data from diverse sources, transforming raw data into actionable intelligence (Khatri & Tyagi, 2015). GIS enables identification of spatial patterns revealing pollution sources and impact zones through spatial interpolation techniques (Nas et al., 2010). The platforms

integrate topographic data, land use information, and hydrological models to assess watershed-scale impacts, with digital elevation models delineating catchment boundaries while land use analysis correlates anthropogenic activities with downstream conditions (Pratt & Chang, 2012). GIS-based decision support systems combine spatial analysis with optimization algorithms, using multi-criteria evaluation to assess trade-offs between competing objectives (Rahmati et al., 2015).

5. Integrated Systems and Applications

The true transformative potential emerges when AI, drones, and GIS operate as integrated systems, creating intelligent monitoring networks capable of adaptive, real-time water quality management (Barzegar et al., 2020). Integrated systems combine fixed sensors, drone surveys, and AI analysis within GIS frameworks. Drones conduct AI-optimized surveys, collecting data that feeds into GIS databases where machine learning algorithms process information, updating predictive models and generating spatial risk maps automatically (Johansen et al., 2019). AI algorithms dynamically adjust monitoring strategies based on patterns and conditions, with GIS visualization displaying adaptive plans ensuring optimal resource deployment (Tiyasha et al., 2020). When AI detects potential deterioration, the system triggers drone deployments for assessment, with GIS visualizing threatened areas and facilitating rapid response (Hafeez et al., 2019).

Successful implementations demonstrate practical value across diverse environments. Coastal regions utilize drone-based assessment combined with AI analysis for monitoring coral reef health and marine pollution, with GIS integrating findings with oceanographic data (Klemas, 2015). Drinking water reservoirs employ drones for weekly multispectral surveys, with AI models predicting algal bloom development and GIS identifying optimal water intake locations (Bresciani et al., 2018). Large river systems utilize drone swarms coordinated by AI algorithms, with GIS platforms integrating data to reveal pollution relationships (Johansen et al., 2019).

6. Challenges and Future Perspectives

Despite significant advantages, several challenges must be addressed for widespread adoption. Regulatory frameworks often restrict drone flight permissions over water bodies (Koparan et al., 2018). Technical limitations include battery life restrictions, weather vulnerability, and AI model requirements for extensive training datasets (Tiyasha et al., 2020).

Cost considerations remain barriers for resource-limited organizations, with initial investment and ongoing maintenance requiring sustained financial commitments.

Emerging technological advances promise more sophisticated capabilities. Autonomous underwater vehicles combined with aerial drones will enable three-dimensional water quality assessment. Advanced AI architectures including transformer models will improve prediction accuracy (Ahmed et al., 2019). Internet of Things integration will create vast sensor networks feeding real-time data to AI processing centers. Edge computing will enable on-board data processing on drones, while digital twin technology will create virtual representations of water bodies for scenario testing (Barzegar et al., 2020). Citizen science initiatives leveraging smartphone applications and consumer drones will democratize monitoring, vastly expanding networks.

Conclusion

The integration of AI, drone technology, and GIS represents a transformative advancement in water quality monitoring and aquatic management. These technologies address fundamental limitations of traditional approaches, providing real-time, comprehensive, and cost-effective solutions. AI delivers powerful analytical capabilities enabling predictive modeling and automated decision-making. Drones offer flexible, rapid data collection with unprecedented resolution. GIS provides the spatial framework for data integration, pattern recognition, and visualization. The synergistic application creates intelligent monitoring systems capable of proactive, adaptive water quality management. While challenges including regulatory constraints, technical limitations, and cost considerations persist, ongoing technological development continues to address these barriers. As these technologies become more accessible and affordable, they will play an increasingly central role in global water quality management efforts, contributing to sustainable development goals and environmental protection objectives.

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PROMOTION OF IMPROVED MUNG BEAN VARIETIES THROUGH SEED HUB

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Introduction

Quality seed production is one of the most critical components for ensuring quality seed supply of pulses at the doorstep of farmers. Provision of quality seeds is an important step in enhancing the yield and production of pulses. To ensure the availability of location specific high yielding varieties and quality seed, the Ministry of Agriculture and Farmers welfare, Government of India implemented the project entitled 'Creation of seed hubs for increasing indigenous production of pulses in India' during 2016-17 and provided funds for seed multiplication and infrastructure facilities across the country. Under this project pulses seed hub has been sanctioned to Krishi Vigyan Kendra, Nagaur-I. The seed hub project was allotted to KVK, Nagaur-I, during 2016-17 and a one-time grant of Rs. 50 lakh was sanctioned in the first year for creating infrastructure such as seed processing plant and storage facility. In addition to this, Rs. 1 crore has been allocated to the seed hub as revolving fund to meet expenses form production, procurement and processing of seeds. At KVK, Nagaur-I, the seed production was implemented on farmer's fields across different villages of Nagaur districts. The main objective of this project was to ensure supply of quality seed and maintain sustainability with profitability to the farmers locally by developing suitable infrastructure for seed quality enhancement, safe storage and seeds development.

Problems:

(1) Lack of Seed production Knowledge and lesser availability of pulse seeds in the market due to higher demand and much lesser research activities is an important challenge faced by farmers.

(2) Lesser wide adaptive varieties and diversity of varieties in a local areas is an issue that limits pulse production.

(3) Lack of quality and improved seed availability

(4) Limited availability of short duration verities and short duration cultivars which escape terminal drought.

(5) Farmers do not get benefit from the higher market prices of pulses. Market prices are largely controlled by local buyers irrespective of minimum support price (MSP), and procurement of pulses by the government agency is very limited. The government has suggested procuring pulses at MSP whereas local market trends show that the rate offered by local dealers is much below the MSP.

(6) Major constraints for the cultivation of pulses include the availability of desired quality and quantity of high yielding varieties of pulses. Lack of high yielding varieties, low harvest index, high susceptibility to diseases and insect pests, flower drops, lack of short duration varieties, intermediate growth habits, poor response to inputs and instabilities in performances are the few varietal constraints that need immediate attention.

(7) Lake of technical knowledge such as improper sowing time, seed treatment, seed rate, defective sowing method, insufficient irrigation, inadequate intercultural practices, insect pest and diseases management are major constraints

(8) Poor knowledge of farmers regarding seed treatment, Rhizobium inoculation, adaption of proper cropping sequence/crop management to meet any contingent situation.

(9) Lack of seed production knowledge and lesser availability of pulse seeds in the market due to higher demand and much lesser research activities is an important challenge faced by farmers. Lesser wide adaptive varieties and diversity of varieties in local areas is an issue that limits pulse production.

(10) Due to the slow initial growth, pulse crops face severe crop–weed completion at early growth stages and effective chemical measures are limited due to non-availability of post-emergence herbicides.

(11) Unawareness and difficult access to warehouse, heavy storage loss (20-30%) of pulses, is major market associated constraints.

(12) Lack on guidance for proper certified seed production/variety identification, insect pest/diseases identification and management phases, importance and procedure of seed treatment/rhizobium inoculation, lack of information/knowledge on current advances in technology, also poor or no knowledge about seed production and its protection for succeeding crop. Poor knowledge base on nutrient use efficiency (NUE), IPM, method of preparation of spray solutions etc.







Intervention of KVK:

(1) Farmers were selected based on prior experience in pulse seed production and availability of adequate irrigation facility and fertile soil and had good knowledge and skills for undertaking quality seed production. Their fields were equipped with appropriate irrigation, infrastructure and assured irrigation.

(2) Farmers were trained by KVK scientist staff in seed certification procedures viz., rouging, isolation distance, field inspection, seed processing and geo-tagging. The KVK also conducted trainings in quality seed production.

(3) Field visits were organized by scientific staff of KVK, Nagaur-I at farmer fields and inspections by certification officers of Rajasthan State Seeds & Organic Certification Agency (RSSOCA), Jodhpur and Agriculture University, Jodhpur consultants during cropping period to create awareness of production technologies of pulses and quality seed production.

(4) Subsequently, foundation seeds of different varieties of Mung bean were distributed by the KVK to seed producing farmers for producing certified seed in farmer's fields during the last four years (2020-2023) with the support of KVK, Nagaur-I.

(5) Seed treatment with Carbendazim (50% WP) @ 2.5 g /kg seed.

(6) Line sowing in 30x10 cm row and plant spacing.

(7) Use of Recommended nitrogen (N) @ 20 kg/ha and Phosphorus (P) @ 40 kg/ha.

(8) Application of Zinc sulphate (33%) @ 12.5 kg/ha, Sulphur (80% WDG) @ 2.5 kg/ha and NPK (18:18:18) @ 2.5 kg/ha for nutrient management.

(9) Application of Fipronil (0.3% GR) @ 12.5 kg/ha for termite management.

(10) Application of Imazethapyr (10% SL) @ 625 ml/ha at 15-18 day after sowing for weed management.

(11) Use of Imidacloprid (17.8%SL) @ 250 ml/ha for management of sucking pest.





Table-1: Details of seed production under seed hub as farmer participatory mode during 2020-2023

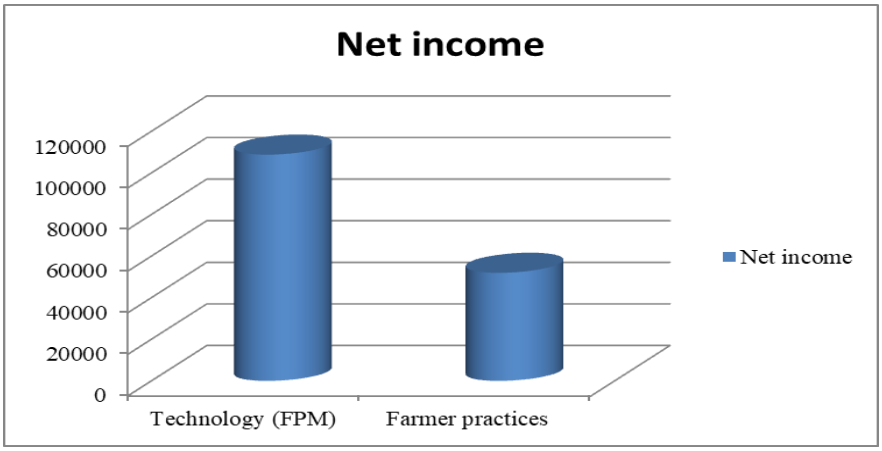
S. No.	Year	Season	Crop	Variety	Category	Production (qtls.)	Income (Rs.)	Horizontal spread in district (ha)
1.	2020-21	Kharif-2020	Mung bean	IPM 2-14	CS	352.90	49,40,600	9750
2.	2021-22	Kharif-2021	Mung bean	MH-421	CS	50.00	7,50,000	955
3.	2022-23	Kharif-2022	Mung bean	MH-1142	CS	225.36	33,80,400	4120
4.	2023-24	Kharif-2023	Mung bean	GM-7	CS	139.88	20,98,200	2250
Total						**768.14**	**1,11,69,200**	

Table-2: Economics performance of technology in farmer participatory mode (FPM) and Farmer practices

Specific Technology	**Yield (q/ha)**	**Gross cost (Rs/ha)**	**Gross income (Rs./ha)**	**Net income (Rs./ha)**	**Additional income (Rs./ha)**	**B:C ratio**
Technology (FPM)	13.55	27500	136286	108785.9	56830.2	4.96
Farmer practices	9.15	26350	78305.7	51955.7	-	2.97
% Increase/different	48.09 %	1150	57980.2	56830.2		1.98

Technology (FPM):-Selling rate Rs. 8558/- (MSP) + Rs. 1500/- (Subsidy) = Rs. 10058/ quintal

Farmer practices: - Selling rate Rs. 8558/quintal (MSP)



Impact of quality pulses seed produced and supplied to farmers:

(1) Crop failure risk minimization due to resistance/tolerance of improved varieties against biotic & abiotic stress.

(2) Decrease in yield gap.

(3) Upliftment in socio-economic status of farm families.

(4) Quality seed availability builds faith & creates rapport of the KVK in the area.



नागौर पत्रिका 08 राजस्थान पत्रिका

केवीके ने तैयार किया मूंग का उन्नत बीज

अधिक उत्पादन का दावा

सोमवार से किसानों के लिए कृषि विज्ञान केंद्र अठियासन रहेगा उपलब्ध

Conclusions

(1) Establishment of such seed hub centre may play a major role in production of quality seed at local level which helps in timely supply of seed to the farmers.

(2) Required seed replacement rate (SRR) especially in pulses for recently released improved varieties can be meeting out only by production of sufficient quantity of quality seed at local level & KVK can play a major role in this.

(3) To achieve the target of doubling farmer's income, quality seed availability of pulses at local level at right time may play a vital role.

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ROLE OF EDNA IN THE CONSERVATION OF THREATENED AND ENDANGERED FISH SPECIES

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Abstract

Environmental DNA (eDNA) has emerged as a transformative tool in the conservation of threatened and endangered fish species. By detecting trace genetic material shed by organisms into their environment, eDNA enables non-invasive, efficient, and highly sensitive monitoring of aquatic species. This method has revolutionized how scientists and conservationists assess species presence, distribution, and population dynamics, especially in habitats where traditional survey methods are costly, labor-intensive, or pose risks to sensitive species. eDNA facilitates early detection of rare or elusive fish, aiding in timely conservation actions and habitat management. Moreover, it supports long-term monitoring programs that track the effectiveness of conservation interventions and detect shifts in biodiversity due to environmental changes. The technique also plays a crucial role in identifying critical habitats, informing protective regulations, and guiding species recovery plans. Despite challenges such as potential contamination, DNA degradation, and the need for standardized protocols, eDNA continues to expand its applicability through advancements in sequencing technology and bioinformatics.

Overall, eDNA represents a powerful, innovative approach that enhances our capacity to protect and restore vulnerable fish populations, contributing significantly to global biodiversity conservation efforts.

Keywords : Environmental DNA (eDNA)**,** Fish conservation**,** Endangered Species, Threatened species, Aquatic biodiversity**,** Non-invasive monitoring

Introduction

Aquatic ecosystems globally are under increasing pressure from anthropogenic activities such as pollution, climate change, overfishing, habitat degradation, and the introduction of invasive species. These pressures have led to the decline of numerous freshwater and marine fish species, many of which are now classified as threatened or endangered by the IUCN Red List (IUCN, 2023).Traditional methods for fish monitoring—such as gill netting, electrofishing, or visual surveys—are often invasive, expensive, labor-intensive, and sometimes ineffective, especially when targeting rare or elusive species. Moreover, these methods can stress or harm already vulnerable species and habitats. Consequently, there is an urgent need for innovative, non-invasive techniques to monitor fish biodiversity and inform conservation strategies.Environmental DNA (eDNA) is one such innovation. eDNA refers to genetic material shed by organisms into their environment through excretion, skin cells, gametes, or mucus. By collecting and analyzing samples of water (or sometimes sediment), researchers can detect the presence of a species without ever seeing or capturing it (Taberlet et al., 2012). This approach is transforming the field of conservation biology, offering a powerful tool to monitor aquatic biodiversity with precision, safety, and cost-efficiency.

Understanding eDNA Technology

eDNA analysis typically involves the following key steps:

1. **Sample Collection:** Water samples are taken from the target habitat. Special care is taken to avoid contamination, which could lead to false positives.
2. **Filtration and DNA Extraction:** The water sample is filtered to collect particles that may contain DNA. The DNA is then extracted using laboratory protocols.
3. **Amplification:** Specific DNA fragments are amplified using polymerase chain reaction (PCR) or quantitative PCR (qPCR). For multi-species surveys, metabarcoding is used with universal primers.
4. **Sequencing and Analysis:** The amplified DNA is sequenced and compared to genetic databases to identify the species present.

Unlike traditional surveys, eDNA methods allow for the detection of organisms based on trace genetic signals, making it possible to detect species at low densities or those that are difficult to sample directly (Goldberg et al., 2016).

Applications of eDNA in Fish Conservation

Species Detection and Monitoring

The most common use of eDNA is to confirm the presence or absence of a species in a specific location. This is crucial for threatened and endangered species, many of which exist in small, fragmented populations.For example, researchers used eDNA to detect the presence of the endangered giant Japanese salamander (*Andrias japonicus*) in river systems where physical sightings were rare (Fukumoto et al., 2015). Similarly, eDNA has helped monitor populations of Chinook salmon (*Oncorhynchus tshawytscha*) and bull trout (*Salvelinus confluentus*), both of which are declining in parts of North America (Wilcox et al., 2016).eDNA enables rapid assessment over large spatial scales, allowing conservationists to identify priority areas for protection and restoration.

Mapping Habitat Use and Migration Routes

Another important application is identifying critical habitats such as spawning grounds, feeding areas, or migratory corridors. For instance, Klymus et al. (2017) used eDNA to track the movements of the endangered pallid sturgeon (*Scaphirhynchus albus*) in the Missouri River. Such data are invaluable for implementing habitat protections and designing effective conservation corridors.Because eDNA sampling is non-intrusive, it is particularly useful in protected areas or fragile ecosystems where traditional sampling would be disruptive.

Early Detection of Invasive Species

Invasive species are one of the greatest threats to native aquatic fauna. eDNA enables early detection of invasive fish, even before their population becomes large enough to be caught by conventional methods. Jerde et al. (2011) successfully detected silver carp (*Hypophthalmichthys molitrix*) DNA upstream of physical barriers in the Great Lakes region, raising alarms for possible spread into Lake Michigan. This early detection led to targeted management efforts, showcasing the preventive power of eDNA.

Population and Community-Level Monitoring

With advances in metabarcoding and next-generation sequencing (NGS), eDNA can also provide a snapshot of entire fish communities. This is particularly useful for ecosystem-level assessments and biodiversity monitoring programs.In European rivers, Valentini et al. (2016) demonstrated that eDNA metabarcoding could detect more species than traditional electrofishing, including many that were previously unrecorded. Such data help track the

effectiveness of conservation interventions over time.

Case Studies

Case Study 1: Pacific Northwest Salmon

In the Pacific Northwest, native salmon species are declining due to habitat degradation and overexploitation. Traditional surveys are logistically challenging, especially in remote or seasonal habitats. Laramie et al. (2015) used eDNA to detect multiple salmonid species across a watershed, enabling efficient identification of critical habitats.

Case Study 2: Lake Biwa (Japan)

In Lake Biwa, Japan, eDNA was used to monitor the endemic and endangered Biwa trout (*Oncorhynchus masou subsp.*) and identify suitable habitats for its conservation (Minamoto et al., 2012). The findings were used to develop habitat restoration projects.

Case Study 3: European River Monitoring

eDNA has also been adopted in European environmental policy frameworks. For example, in France and the UK, eDNA monitoring is used to meet requirements under the EU Water Framework Directive by assessing fish biodiversity in river systems (Pont et al., 2018).

Advantages of eDNA-Based Monitoring

Non-Invasive and Ethical

eDNA does not require capturing or handling organisms, which is particularly important for species under stress or in declining populations.

Cost-Effective and Scalable

A single technician can sample multiple locations in a day, and lab costs continue to decrease as sequencing technologies advance. This allows for large-scale, repeatable surveys that are financially viable for conservation agencies.

High Sensitivity and Specificity

eDNA can detect species present at very low abundances, often before they are observable by traditional methods. With species-specific primers, researchers can distinguish between closely related taxa.

Minimizes Habitat Disturbance

By avoiding physical habitat disruption (e.g., dragging nets or using electrofishing), eDNA sampling helps preserve fragile ecosystems.

Challenges and Limitations

Contamination and False Positives

Due to its high sensitivity, eDNA workflows are susceptible to contamination from equipment, researchers, or laboratory settings. Rigorous protocols are necessary to avoid false detections (Rees et al., 2014).

DNA Degradation and Environmental Factors

DNA degrades over time, especially in warm, acidic, or UV-exposed environments. This can affect detection reliability. Temporal resolution is also limited—eDNA indicates recent presence, but not necessarily real-time abundance.

Quantifying Abundance

Although some studies suggest that eDNA concentration correlates with biomass or abundance, the relationship is often non-linear and affected by shedding rates and water flow (Yates et al., 2019).

Lack of Standardization

Methods vary widely between studies, limiting cross-site comparisons. There is a need for standardized sampling protocols and analytical pipelines to ensure reproducibility and data sharing.

Future Perspectives

The future of eDNA is promising. Key developments include:

- **Automated Samplers and Real-Time Detection:** Devices like autonomous underwater eDNA samplers are being developed to collect and analyze samples in situ.
- **Portable DNA Sequencers:** Field-based sequencing (e.g., Oxford Nanopore) allows for near real-time results in remote areas.
- **AI and Machine Learning:** Advanced algorithms can enhance data analysis, pattern detection, and predictive modeling for species distributions.

Global Reference Databases:

Expansion of genetic databases will improve species identification and support conservation in under-studied regions. eDNA is also gaining policy traction. Some governments have begun integrating it into national biodiversity monitoring and management frameworks.

Conclusion

Environmental DNA has become a critical tool in the conservation of threatened and endangered fish species. Its ability to detect elusive or rare species non-invasively offers unprecedented advantages for monitoring, management, and policy-making. While technical challenges remain, ongoing improvements in field protocols, laboratory methods, and data analysis are rapidly addressing these limitations. As the technique becomes more accessible and standardized, eDNA will undoubtedly play an increasingly central role in global conservation efforts, helping protect aquatic biodiversity in the face of accelerating environmental change.

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TOWARD SEAMLESS SENSING: AN OVERVIEW OF WEARABLE TECHNOLOGIES

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Abstract

Wearable technologies are body worn systems that capture physiological, biomechanical, behavioural, and environmental signals in everyday settings. This article organizes the field by form factor, sensing modality, and system role, and explains key categories including epidermal patches, smart textiles, wrist and finger devices, ear and head systems, and nearables. It surveys applications in cardiometabolic monitoring, rehabilitation, occupational safety, sports performance, human computer interaction, and population research. Major challenges include rigorous and representative validation, energy and comfort constraints, privacy and security, interoperability and stewardship, and durable design. The discussion highlights multimodal fusion, on device inference, and workflow integration as priorities for reliable and equitable impact.

Introduction

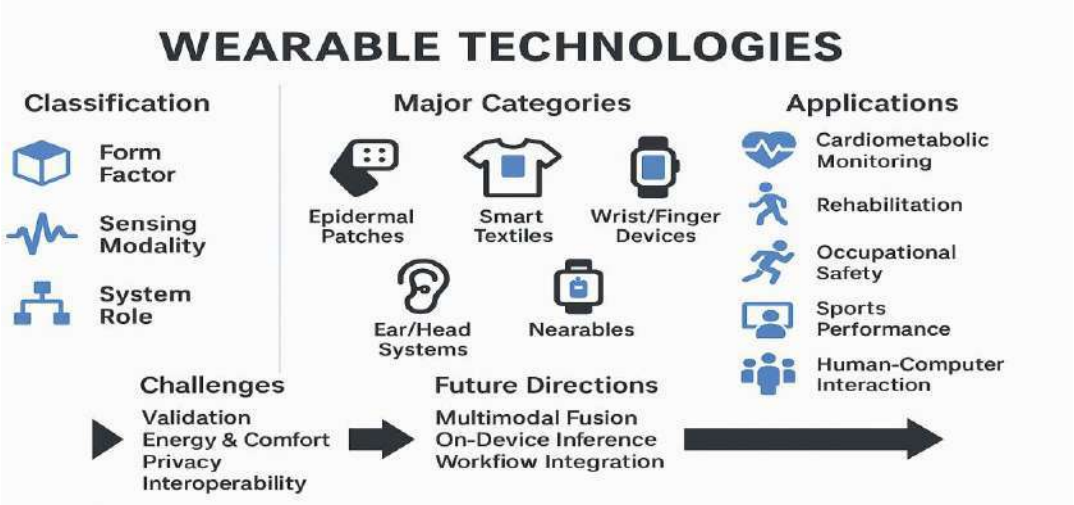
Wearable technologies integrate sensors, computation, and communication into artifacts designed to be worn on or near the human body. Their defining promise is the ability to observe physiology and behaviour continuously in naturalistic settings, thereby bridging the long-standing gap between carefully controlled laboratory assessments and the complex variability of daily life. Early systems in ambulatory ECG and activity recognition established feasibility by pairing low-power sensing with compact storage and simple classifiers. Subsequent waves of innovation drew on advances in microelectronics, flexible substrates, and edge networking to expand sensor repertoires and to reduce the burden of wearing devices for extended periods [1–

4]. The last decade brought a dramatic expansion in consumer adoption via smartwatches, rings, and earbuds that perform step counting, sleep staging, and optical heart-rate monitoring alongside notifications and navigation [6,8]. This consumerization increased scale and lowered barriers for data collection, but it also exposed structural issues. Optical measurements are sensitive to motion and skin tone. The model performance can drift outside validated operating envelopes and proprietary data formats impede reproducibility and meta-analysis [5,8,10].

In parallel, research in epidermal electronics and smart textiles demonstrated that matching device mechanics to the skin or embedding sensors into garments can substantially improve comfort and signal fidelity, enabling biopotential, thermal, and biochemical measurements during vigorous movement with reduced motion artifact [2–4]. Industrial and occupational deployments capitalized on edge/IoT integration to support safety and productivity analytics, while clinical trials explored remote monitoring pathways for arrhythmia detection, rehabilitation, and chronic-disease management [1,5,7].

Across these domains, the field is converging on a set of shared requirements like population-representative validation, transparent performance reporting, secure and privacy-preserving data stewardship, and interoperability that allows signals to flow into clinical and enterprise systems without excessive friction [5,7,8,10]. The sections that follow provide a structured classification of the landscape, elaborate the principal device categories, and synthesize the growing portfolio of applications and the challenges that must be met for reliable, equitable impact.

Fig.1. Overview of Wearable Technologies



Classification of Wearable Technologies

A practical way to organize the wearable ecosystem is to consider three intertwined axes—form factor, sensing modality, and system role—because together they shape signal quality, user adherence, and achievable outcomes.

Form Factor

Form factor captures how a device inhabits the body. Accessories such as watches, bands, rings, glasses, and clip-on badges package sensors, within rigid or semi-rigid housings that benefit from familiarity, mature batteries, and robust radios. They succeed in everyday adoption but can suffer when optical paths are perturbed by motion or when anatomical placement is suboptimal for certain measurements [6,8]. Epidermal or skin-mounted patches, by contrast, use ultrathin, compliant substrates and serpentine interconnects to match the mechanical modulus of the skin, producing intimate electrode-skin contact and low-noise capture of biopotentials and temperature. These patches excel for longitudinal studies yet must solve adhesion durability, skin compatibility, and energy delivery to sustain multi-day operation [2,3].

A third form factor embeds sensing fibers and electrodes directly into textiles, distributing the interface across garments to capture respiration, ECG vectors, posture, and joint kinematics with high comfort. Here, washability, connector fatigue, and calibration drift across laundering cycles are dominant engineering constraints [4]. Head- and ear-worn devices occupy a distinct niche, earbuds and head-mounted displays sit near richly perfused vasculature and neural activity, enabling stable photoplethysmography (PPG), kinematics, and eye tracking while providing natural audio/visual feedback, although thermal comfort, occlusion pressure, and social acceptability set practical bounds [1,6]. Finally, nearables—badges and belt clips—do not rely on a precise anatomical site but contribute rich environmental and contextual signals that become most valuable when fused with body-mounted measurements [7].

Sensing Modality

The second axis, sensing modality, encompasses electrical, optical, mechanical, biochemical, and environmental channels. Electrical physiological sensing includes ECG, EMG, and EEG-adjacent signals that can characterize rhythm, muscle activation, and cognitive workload with high temporal fidelity when the electrode-skin interface is well engineered [1,2]. Optical and mechanical sensing, exemplified by PPG, inertial measurement units (IMUs), pressure mats, and strain gauges, underpins heart-rate/SpO_2 estimation, gait analysis, posture

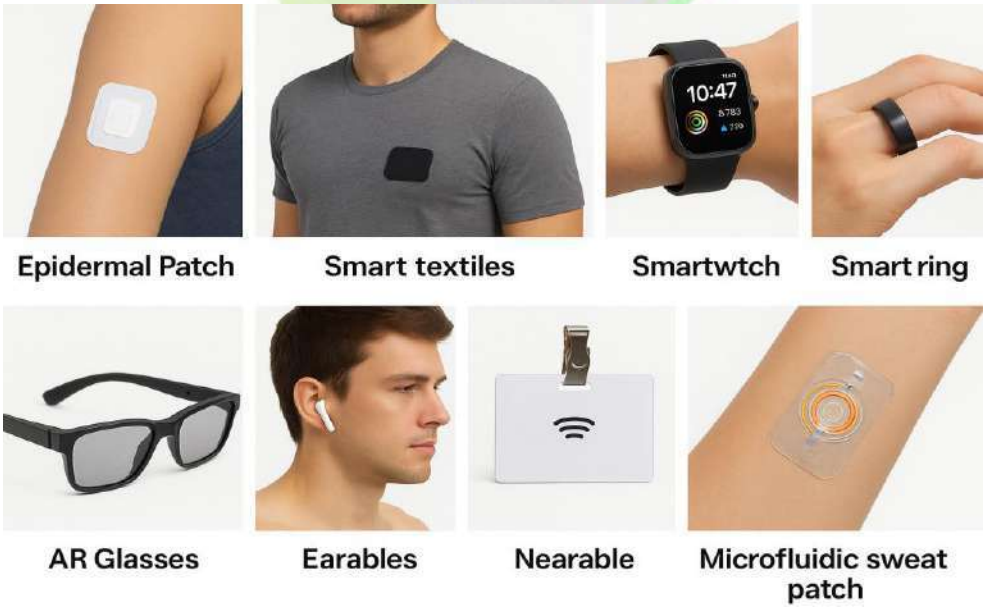
assessment, and gesture recognition, albeit with susceptibility to motion artifacts and perfusion variability that must be controlled through multi-wavelength optics, geometry, and adaptive filtering [1,6,7].

Biochemical sensing in sweat or interstitial fluid expands wearables beyond biophysics to chemistry, offering insights into electrolytes, metabolites, and therapeutic drug levels. This modality requires carefully designed microfluidics, temperature compensation, and standardized protocols to ensure analytical validity across activities and climates [3,5]. Environmental and contextual sensors—temperature, gases, UV, location, and proximity—situate physiological variation within the lived environment, enabling more specific inferences about heat stress, air-quality exposure, and task context [7].

System Role

The final axis, system role, reflects the deployment setting and regulatory posture, which in turn shape requirements for accuracy, documentation, and interoperability. Consumer wellness systems iterate rapidly and optimize for engagement and battery life; they scale globally but often report proprietary metrics with heterogeneous validation. Clinical systems—whether investigational or regulated—anchor to endpoints, protocols, and evidence standards. They demand transparent performance across demographics, rigorous risk management, and data pipelines that integrate with electronic health records and reimbursement frameworks [1,5].

Fig.2. Types of Wearable Technologies



Industrial and occupational systems prioritize safety, ergonomics, and productivity within connected worksites, leveraging edge gateways and IoT standards to provide low-latency alerts and analytics while navigating workforce privacy expectations and governance [7]. The same sensor may therefore behave differently across roles because duty cycles, calibration, and decision thresholds are tuned to their context and recognizing these distinctions is essential for translating findings from one domain to another [5,7,8].

Major Categories of Wearable Technologies

Epidermal Electronics

Epidermal systems exploit soft, ultrathin substrates and meandering interconnects that accommodate skin stretch without delamination, thereby maintaining low-impedance contact for biopotentials and thermal signals during everyday movement. By eliminating the micro-slip that plagues rigid housings, these devices reduce motion artifacts and enable high-quality ECG and EMG at low power budgets, often with on-sensor amplification and filtering to preserve signal integrity before wireless transmission. Practical operation depends on adhesives and encapsulants that tolerate perspiration and repeated flexure, as well as energy strategies—thin-film batteries, inductive coupling, or energy harvesting—that avoid bulk. Longitudinal deployments must address skin irritation, adhesive hydration dynamics, and baseline drift. Robust systems therefore employ adaptive calibration and quality-control flags to maintain validity over multi-day wear. Clinical translation is promising because of measurement fidelity, but standardized protocols and multi-site reproducibility remain prerequisites for regulatory acceptance and widespread adoption [2,3].

Smart Textiles and Garments

Smart textiles weave or embroider conductive yarns, fiber electrodes, or optical/triboelectric sensors into everyday garments. The resulting large-area interface distributes sensing over multiple contact points and allows comfortable, long-duration wear without rigid housings. Respiratory effort, ECG vectors, posture, and joint kinematics can be captured during routine activity and sleep, while detachable “pod” modules concentrate power management, data logging, and radios to preserve washability. Engineering challenges include ensuring stable electrical contact through motion and laundering, designing robust garment-to-pod interconnects, and mitigating calibration drift through automated baseline acquisition. For sports and occupational safety, textile arrays enable pressure mapping to analyze load distribution and

movement quality; in clinical contexts, they enable at-home monitoring without extensive setup. To move from promising prototypes to durable products, materials must meet biocompatibility standards and withstand hundreds of washing cycles without significant performance loss [4].

Wrist- and Finger-Worn Devices

Wrist and finger platforms dominate consumer adoption because they align with familiar jewellery and watch conventions while providing a rich app ecosystem. Typical sensor stacks combine IMUs with optical PPG, sometimes augmented by single-lead ECG electrodes or skin temperature sensors. Algorithmic fusion supports step counting, activity classification, sleep staging, and heart-rate variability estimation, while on-device models increasingly perform inference to conserve battery and protect privacy. Performance varies with motion type, perfusion, ambient light, and skin tone, motivating hardware countermeasures such as multi-wavelength emitters and optimized optical geometry, plus signal-processing approaches that down-weight artifact-prone segments. As these devices encroach on clinical territory—exemplified by atrial-fibrillation notifications—they require clear user guidance, confirmatory pathways, and transparency about operating envelopes and false-positive rates. The strength of this category remains adherence and usability; the challenge is to pair those strengths with rigorous, population-representative validation and interoperable data access for research and care [6,8].

Earables (Ear buds) and Head-Mounted Systems

Earbuds and head-mounted displays position sensors at sites advantageous for stable physiology and rich interaction. The ear canal offers thermal stability and reduced motion coupling compared with the wrist, enabling more reliable PPG-based heart-rate estimation and potentially improved proxies for core temperature. Headsets integrate IMUs and cameras for eye tracking and spatial mapping; when combined with physiological channels, they support context-aware interfaces, neuro-ergonomics research, and industrial AR applications that deliver hands-free guidance. Design constraints include thermal comfort, occlusion pressure, battery size, and form-factor aesthetics that determine social acceptability in public spaces. In safety-critical deployments, low-latency edge processing and robust privacy controls are essential, as is careful consideration of cognitive-state inference and the ethics of monitoring attention or workload at work or school [1,6].

Biochemical Patches and Microfluidic Wearables

Biochemical wearables extend the scope of sensing by moving from physics to chemistry. Microfluidic channels guide sweat or interstitial fluid across electrochemical or colorimetric transducers to quantify electrolytes such as sodium and potassium, metabolites such as lactate and glucose, and sometimes therapeutic agents. These measurements can inform hydration strategies, fatigue assessment, and personalized dosing. However, sample volumes are small and flow rates variable; analyte concentrations are temperature-dependent and can be confounded by cross-sensitivity. State-of-the-art systems incorporate flow control, on-board calibration references, and temperature compensation, and they pair analytics with contextual signals from IMUs and PPG to reduce false interpretations. Clinical deployment requires correlation with gold-standard assays, standardized collection protocols, and rigorous human-subject validation across activity types and climates [3,5].

Nearables and Clip-On Context Devices

Nearables—badges, clips, belt modules—are valuable complements to body-mounted sensors because they capture environmental and contextual features that sharpen physiological interpretation. Equipped with location, proximity, particulate matter, gas, temperature, and sound sensors, nearables help quantify heat stress, hazardous exposure, and ergonomic risk. In connected worksites, they link to edge gateways to support geofencing, incident detection, and safety analytics. Their limitations include reduced physiological specificity and potential privacy concerns, especially in workforce monitoring contexts. These concerns can be mitigated through transparent governance, clear purpose limitation, and aggregated reporting that avoids individual surveillance when medical necessity is absent [7].

Applications of Wearable Technologies

Wearables now span a wide spectrum of application domains, with health and clinical care among the most visible. In cardiometabolic health, devices support rhythm monitoring, heart-rate variability analysis, and activity-linked risk stratification between clinic visits, offering opportunities to detect atrial arrhythmias, track recovery after acute events, and personalize rehabilitation workloads [1,5]. Movement-disorder and rehabilitation programs leverage IMUs and pressure sensors to quantify gait asymmetry, tremor, and therapy adherence in home settings, providing clinicians with objective progress indicators and enabling remote adjustment of protocols [1]. In occupational safety and ergonomics, wearables assess postural load, repetitive

strain, heat stress, and exposure to hazardous environments, generating alerts and coaching that can reduce incidents and improve training. Integration with IoT infrastructure enables streaming analytics and contextual prompts on the factory floor or construction site, with data pipelines tuned for latency and robustness [7].

Sports and human performance represent another major locus of adoption. Athletes and coaches use wrist devices, textile garments, and instrumented insoles to manage training load, assess technique, and guide return-to-play decisions after injury. High-frequency IMU data can reconstruct joint kinematics and detect subtle deviations that precede overuse injuries, while PPG and heart-rate variability indices inform recovery and periodization strategies [6]. In human–computer interaction, wearables extend input and feedback beyond keyboards and screens: inertial and electromyographic signals enable gesture and intent recognition; head-mounted displays layer digital information onto the physical world; and earables provide context-aware audio interfaces capable of adapting to environmental noise and user state [9].

Public-health and population-level research are increasingly using consumer wearables to study sleep, activity, and behaviour across large cohorts. The scale and continuity of these datasets promise new insights into behavioural risk factors and disease trajectories, but they also raise methodological challenges around sampling bias, device heterogeneity, and the interpretability of proprietary metrics [8]. Biochemical patches are beginning to translate into sports medicine and potential therapeutic drug monitoring, offering noninvasive or minimally invasive readouts that complement physical signals and may enable closed-loop interventions for hydration and glycemic control as validation and reliability improve [3]. Across all these domains, the most impactful systems fuse multiple modalities—electrical, optical, mechanical, biochemical, and environmental—so that contextual cues and redundant measurements can suppress artifacts and increase specificity of inference [1–4,7–9].

Challenges

Despite rapid progress, several cross-cutting challenges must be addressed to unlock sustained, equitable impact. Measurement validity remains paramount: optical sensors are sensitive to motion, perfusion, and skin tone, while electrode-based systems must maintain low-impedance contact under sweat and movement. Transparent, population-representative validation across demographics, activities, and environmental conditions is essential to avoid systematic error and to build clinical and public trust [5,8]. Power, size, and comfort are persistent

constraints; energy budgets are divided among sensing, computation, and radios, and while ultra-low-power ICs and duty-cycled communication help, extended operation without frequent charging still requires careful trade-offs that can limit sampling rates or feature richness [2,7].

Security, privacy, and consent present equally significant hurdles. Continuous sensing yields longitudinal datasets rich enough to reveal sensitive attributes; without robust encryption, on-device processing, and privacy-preserving analytics, the risks of re-identification and secondary use are nontrivial. Clear consent frameworks and purpose limitation are crucial, especially in workplaces and schools where power dynamics complicate voluntariness [8,10]. Interoperability and data stewardship also demand attention: device ecosystems remain fragmented, with proprietary formats and application-specific metrics that impede cross-study synthesis and clinical integration. Adoption of open schemas and FHIR-aligned pipelines can reduce friction, but the incentives for standardization remain uneven across consumer and clinical markets [7,10].

Durability and human factors influence long-term adherence. Textile electrodes must endure hundreds of washing cycles without performance degradation; connectors and seams must survive repeated flexure; adhesives must balance secure attachment with skin health across climates and skin types. Social acceptability and aesthetics shape whether devices are worn consistently outside controlled studies, and these factors interact with equity—devices designed around limited anthropometric ranges or cultural assumptions may underperform or discourage use in diverse populations [2,4,6,8]. Finally, regulatory and translational pathways require that wearable-derived endpoints be clinically meaningful, reliably measured, and linked to outcomes, with reimbursement frameworks and clinical workflows able to accommodate device data without overwhelming clinicians [5]. Addressing these challenges calls for coordinated advances in materials, algorithms, user-cantered design, and governance.

Discussion

The trajectory of wearable technologies illustrates how materials science, embedded systems, and data science can converge to produce new measurement infrastructures. Epidermal electronics and smart textiles show that matching device mechanics to the human body can substantially improve comfort and signal-to-noise, while edge AI reduces latency and protects privacy by performing inference on the device itself. At the same time, widespread consumer adoption has revealed that scale without rigor can amplify bias and confusion if metrics are

poorly defined or difficult to interpret. The most promising path forward involves multimodal fusion—combining electrical, optical, mechanical, biochemical, and environmental streams—paired with principled validation across diverse populations and transparent reporting of operating envelopes. Within clinical and industrial settings, integration with existing systems and human workflows remains as important as technical performance; wearables will create value when they close feedback loops, inform timely decisions, and distribute benefits equitably. [1–4,7–10]

Conclusion

Wearable technologies have matured into a versatile measurement and feedback layer for health, safety, and interaction. A structured classification that respects form factor, sensing modality, and system role clarifies the design trade-offs that govern signal quality, adherence, and real-world outcomes. Major categories—from epidermal patches and smart textiles to wrist, ear, and nearable platforms—offer complementary strengths that become most powerful in combination. Realizing the full potential of wearables will depend on rigorous, representative validation, energy-efficient and comfortable designs, robust security and privacy and interoperable data infrastructures that translate signals into actions within clinical and industrial workflows. With these elements in place, wearables can move beyond novelty to become reliable, ethical, and evidence-based infrastructure for personalized health and safer, more efficient work and sport. [1–10]

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A CARBON NEGATIVE REVOLUTION IN YOUR BACKYARD – BIOCHAR AN EMERGING REMEDY FOR CLIMATE CHANGE

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Abstract

Now a days, climate change is a worldwide serious problem that results in the changing atmospheric conditions. The consequences of climate change pose significant challenges to human societies, economies, and ecosystems.The main objective of this paper is to control Carbon emission using a simple and more productive operation for farmers that has to be introduced to the farmers. The solution to overcome climate change at a small scale isby utilization of farm waste organic residues that can in turn providea great natural solution for reduction of Carbon in atmosphere. The core ideais to enhance the view of the household farmers to convert their farm based organic residues into Biochar **(**Biochar is a form of charcoal produced by heating organic materials (such as agricultural waste, wood, or other biomass) in a low-oxygen environment, a process known as pyrolysis). The production and use of biochar have gained attention as a potential strategy for mitigating climate change, primarily due to its ability to sequester carbon for long periods of time. When organic materials are converted into biochar, a significant portion of the carbon in the biomass is "locked" into the char, preventing it from being released back into the atmosphere as CO_2 during decomposition or combustion. This makes biochar a potentially important tool in efforts to reduce atmospheric CO_2 levels and carbon sequestration. Also, biochar has its own benefits for carbon sequestration, soil amendment, waste management, water and nutrient management and reduction in the greenhouse gas emission. This biochar when produced by the farmers in their farm through simpler methods

i.e., Cone pit method, Drum or Trench method, Cone stove or Biochar kiln, Double barrel retort system and Top-Lit Updraft (TLUD) kiln with limited resources and by cost-effective methods. Since a small change can bring a large variation, the production of biochar by utilizingthe own farm resources in a small scale by all the farmers in their own field can in turn become another profitable way to increase soil fertility. Biochar in soil can improve soil fertility by improving microbial activity, erosion prevention, pH regulation, enhanced crop yield and waste to resource. Hence this article provides a new view for the farmers about the prevailing technology of biochar production in abroad countries that should be adapted in their fields based on the resources available. Adapting this technology not only favors an individual farm but also the society and environment as a whole by arresting green house gases (CO_2, CO and other impurities), the reason for pollution and overall climate change.

Key Words: Biochar, carbon sequestration, climate change mitigation, pyrolysis, sustainable agriculture, carbon emission reduction and soil fertility.

Introduction

Biochar, a highly porous form of charcoal, is gaining attention as an effective carbon absorption material with significant environmental benefits. Produced through the process of pyrolysis - where organic materials such as wood, agricultural waste, or biomass are heated in a low-oxygen environment - biochar sequesters carbon that would otherwise be released into the atmosphere as CO_2. This biochar has a very old history as it is produced by our ancestors to be used as soil amendment for the agricultural fields but the use of biochar for Carbon capture is identified and used now by most of the foreign countries. By creating biochar in a backyard setting, individuals can contribute to carbon capture efforts while managing organic waste sustainably. Backyard biochar production offers a practical, low-cost method to repurpose organic material into a soil amendment that improves soil fertility, retains moisture, and fosters beneficial microbial activity. This process not only mitigates carbon emissions but also closes the loop on waste management, making it an accessible tool for both environmental stewardship and personal sustainability practices. So, biochar production reduces carbon footprints and enhances soil health, demonstrate its potential as a practical, grassroots solution to address climate change.

Production methodology of biochar in backyard:

Biochar in backyards can be produced by various simple methods that are very useful to small and marginal farmers with low to medium financial stability in many aspects. The

following methods has been widely used in foreign countries like US, China, Australia, Japan, Bhutan, European Union, Canada., This paper presents major five methods that has been used by the farmers world wide for the production of biochar in the backyard of the house with minimum input costs and higher returns both in the form of economy and social benefits.

1. **Cone pit method**:

Steps:

- **Prepare the Pit**: Dig a cone-shaped pit in the ground. The conical shape helps direct heat and airflow, ensuring efficient combustion. The size of the pit depends on the quantity of biomass available.
- **Layering the Biomass**: Start with a small amount of dry biomass at the bottom, such as wood chips, twigs, or crop residues. Light the biomass to initiate combustion.
- **Add Biomass Gradually**: Once the initial biomass is burning and producing flames, add more biomass in layers. The key is to maintain a controlled, oxygen-limited environment at the base of the fire to produce biochar instead of ash.
- **Quenching**: After the biomass has been reduced to glowing embers and biochar, extinguish the fire by dousing it with water or covering it with soil to cool and stabilize the biochar.
- **Collect Biochar**: Once cooled, collect the biochar from the pit and crush it into smaller particles if needed for specific applications, such as soil amendment.

Advantages:

Low Cost: Requires no expensive equipment.

Simple Design: Easy to implement in rural or backyard settings.

Effective for Carbon Sequestration: Produces biochar that locks carbon in a stable form.

Limitations:

Labor Intensive: Requires manual management of the fire and biomass.

Limited Scale: Suitable for small-scale production, not industrial use.

Inconsistent Quality: The biochar quality may vary based on the type of biomass and combustion control.

The cone pit method is a practical choice for individuals and communities seeking sustainable and affordable ways to produce biochar while managing organic waste and contributing to carbon sequestration efforts.



2. **Drum or Trench method:**

Steps:

- **Prepare the Trench or Drum:** Use a metal drum with a lid or dig a trench with a suitable size to the amount of biochar used.
- **Layer Biomass**: Fill the biomass into the trench or drum as layers till it fills.
- **Ignite the Fire and monitor:** Light a fire beneath the drum or in the trench to heat the biomass. The limited oxygen inside the drum causes pyrolysis, producing biochar instead of ash.
- **Cool and Collect**: Once the pyrolysis is complete, remove the drum from the heat and allow it to cool. Quench the biochar with water to stabilize it or cover it with soil to extinguish the fire.





3. **Cone stove or Biochar kiln:**

- **Design**: The stove is a portable, cone-shaped container made of heat-resistant material. Its shape promotes efficient combustion and heat distribution.

In Biochar kiln method a kiln is kept for production.The only difference of the above methods with cone stove or Biochar kiln method is the design of the stove and set up biochar kiln as base and followed by regular methods of Ignition, monitoring and quenching.

- **Advantages:**

Suitable for larger-scale production.

Provides consistent quality with better emission control.

Can handle diverse types of biomasses.

- **Limitations:**

Higher initial cost due to construction or purchase of the kiln.

Requires careful monitoring during operation.





4. Double barrel retort system:

- **Design and Components**

The double barrel retort system consists of two cylindrical barrels.

Outer Barrel: This is the larger barrel, which acts as an outer shell or combustion chamber. It contains the smaller barrel and allows for heat to be applied from an external source. The outer barrel has openings that facilitate airflow, which is crucial for maintaining combustion and minimizing smoke emissions.

Inner Barrel (Retort): This smaller barrel is where the biomass is placed. It is sealed to restrict oxygen flow, creating a low-oxygen environment where pyrolysis can occur. The inner barrel is typically perforated to allow gases to escape and be partially combusted, contributing to a more efficient process.

The other steps are followed as the same of the above-mentioned methods like loading biomass into the inner barrel, ignition, monitoring and quenching followed by collecting.

- **Advantages:**

Efficient Heat Utilization: The system recycles the volatile gases and liquids from the pyrolysis process by burning them in the outer chamber. This helps maintain the temperature required for pyrolysis while reducing emissions.

Improved Control of Pyrolysis: The sealed inner barrel ensures a more controlled pyrolysis environment, leading to consistent and high-quality biochar.

Cleaner Emissions: By capturing and burning the gases in the outer chamber, this system reduces smoke and air pollution compared to more traditional open-burning methods.

Energy Efficiency: The burning of volatile gases in the outer barrel helps to provide additional heat for the pyrolysis process, reducing the need for external fuel.

Scalability: While it's still primarily a medium-scale system, the double barrel retort can be adapted for larger operations and make it a flexible option for biochar production.

- **Limitations**

Complexity: The double barrel retort system is more complex to build and operate than simpler methods, requiring more attention to detail and control.

Initial Investment: Although the system is efficient, it requires a higher initial investment for the construction or purchase of the barrels and associated components.

Maintenance: Regular maintenance is needed to ensure the barrels are properly sealed, the gas flow is sufficient, and the pyrolysis process remains stable.





5. **Top-Lit Updraft (TLUD) kiln:**

Top-Lit Ignition:The biomass is lit from the top of the kiln. The flames burn downward through the biomass as the pyrolysis process progresses, creating biochar in the lower sections of the kiln. This method allows for better control of the pyrolysis process.

Updraft Flow:The kiln is designed to encourage an upward flow of gases. As biomass burns, the gases rise through the layers of biomass, where they are partially combusted in the process. This results in reduced smoke and more efficient energy use.

Controlled Airflow:TLUD kilns often include an air supply system that helps to regulate the amount of oxygen entering the chamber. Proper airflow is crucial to maintaining the correct temperature and ensuring the partial combustion (pyrolysis) occurs, rather than complete combustion to ash.

Charcoal Production:The bottom layer of biomass in the TLUD kiln undergoes pyrolysis, producing biochar, while the gases produced during pyrolysis exit the top and can be partially combusted to generate additional heat or be used as fuel for other purposes.

- **Advantages:**

Reduced Emissions:By capturing and partially combusting the volatile gases during the process, the TLUD kiln produces significantly less smoke and particulate matter compared to open burning methods.

Efficient Pyrolysis:The top-lit updraft design allows for efficient heat distribution and energy use, making the process faster and requiring less external fuel.

Carbon Sequestration:TLUD kilns are effective in producing biochar, which is an excellent tool for carbon sequestration and improving soil health.

Simple Construction:TLUD kilns can be built with readily available materials like steel or clay, and their design is relatively simple. This makes them affordable and accessible for small-scale producers, especially in rural or agricultural settings.

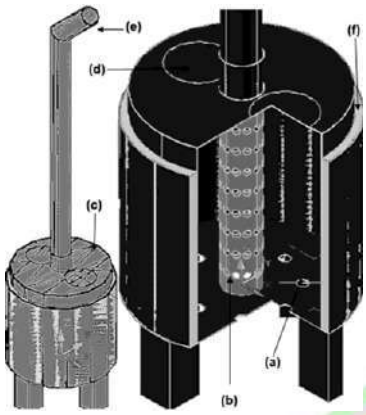
Multi-Use of Gases:The gases produced during the process can be used as a renewable fuel for other applications, such as cooking or heating, which improves the overall energy efficiency of the system.

- **Limitations of the TLUD Kiln**

Smaller Scale:While TLUD kilns are excellent for small- to medium-scale operations, they are not ideal for large-scale commercial production due to their limited capacity.

Continuous Monitoring:The pyrolysis process requires careful monitoring to ensure proper air control and prevent complete combustion, which would result in ash rather than biochar.

Skill and Experience:Operating a TLUD kiln requires some level of experience and knowledge of biomass types, air control, and the pyrolysis process to maximize efficiency and quality.





Conclusion

The production of biochar from farm-based organic residues presents a promising, low-cost, and sustainable solution for mitigating climate change while enhancing agricultural productivity. By converting organic waste into biochar, farmers can effectively sequester carbon, improve soil fertility, reduce greenhouse gas emissions, and promote sustainable farming practices. The various methods for producing biochar, including the Cone Pit, Drum or Trench, Cone Stove or Biochar Kiln, Double Barrel Retort, and Top-Lit Updraft (TLUD) kilns, provide flexible and accessible options for small- to medium-scale farmers, each with its own set of advantages and limitations.

Through simple, backyard biochar production techniques, farmers can contribute significantly to carbon capture efforts while improving their soil quality and increasing crop yields. These methods are cost-effective, require minimal initial investment, and can be adapted to local resources, making them practical solutions for farmers worldwide. Furthermore, the use of biochar can reduce the reliance on chemical fertilizers, improve water retention, and foster beneficial microbial activity in the soil, which supports long-term agricultural sustainability.

Adopting biochar production in small-scale farming systems can create a positive feedback loop, benefiting individual farmers economically while simultaneously addressing larger environmental issues like climate change and carbon emissions. The widespread adoption of these methods has the potential to bring about significant environmental and economic

benefits, contributing to a more sustainable and climate-resilient agricultural sector. Therefore, biochar production, especially at the grassroots level, represents an effective and scalable tool for mitigating climate change and promoting sustainable agriculture practices globally.

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MULCHING IN ORGANIC AGRICULTURE

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Introduction

Mulching is the process of covering the topsoil with plant material such as leaves, grass, twigs, crop residues, straw etc. A mulch cover enhances the activity of soil organisms such as earthworms. They help to create a soil structure with plenty of smaller and larger pores through which rainwater can easily infiltrate into the soil, thus reducing surface runoff. As the mulch material decomposes, it increases the content of organic matter in the soil. Soil organic matter helps to create a good soil with stable crumb structure. Thus the soil particles will not be easily carried away by water. Therefore, mulching plays a crucial role in preventing soil erosion. In some places, materials such as plastic sheets or even stones are used for covering the soil. However, in organic agriculture the term 'mulching' refers only to the use of organic, degradable plant materials.

Use of mulching

- Protecting the soil from wind and water erosion: soil particles cannot be washed or blown away.
- Improving the infiltration of rain and irrigation water by maintaining a good soil structure: no crust is formed, the pores are kept open
- Keeping the soil moist by reducing evaporation: plants need less irrigation or can use the available rain more efficiently in dry areas or seasons
- Feeding and protecting soil organisms: organic mulch material is an excellent food for soil organisms and provides suitable conditions for their growth

- Suppressing weed growth: with a sufficient mulch layer, weeds will find it difficult to grow through it
- Preventing the soil from heating up too much: mulch provides shade to the soil and the retained moisture keeps it cool
- Providing nutrients to the crops: while decomposing, organic mulch material continuously releases its nutrients, thus fertilizing the soil
- Increasing the content of soil organic matter: part of the mulch material will be trans-formed to humus

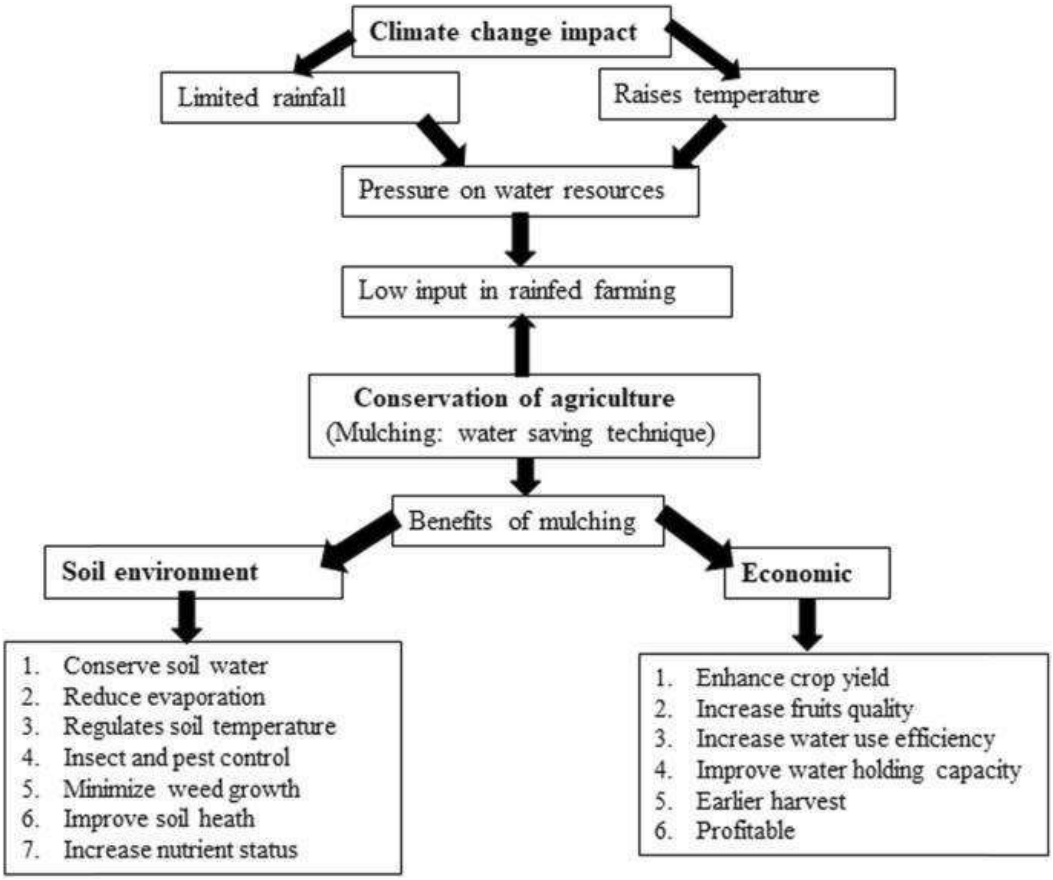


Fig.1. Effects of mulching

Selection of Mulch materials

The kind of material used for mulching will greatly influence its effect. Material which easily decomposes will protect the soil only for a rather short time but will provide nutrients to the crops while decomposing. Hardy materials will decompose more slowly and therefore cover the soil for a longer time. If the decomposition of the mulch material should be accelerated,

organic manures such as animal dung may be spread on top of the mulch, thus increasing the nitrogen content.

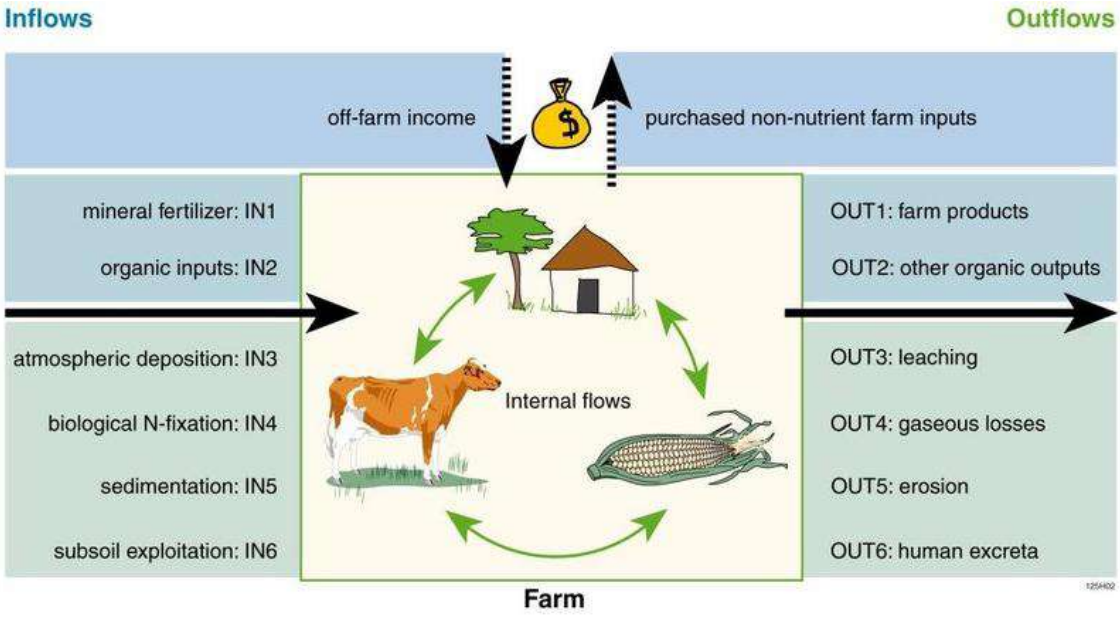


Fig. 2. Inward and Outward resource cycling in Organic Farming

Where **soil erosion is a problem**, slowly decomposing mulch material (low nitrogen content, high C/N) will provide a long-term protection compared to quickly decomposing material.

Sources of mulching material can be the following

- Weeds or cover crops
- Crop residues
- Grass
- Pruning material from trees
- Cuttings from hedges
- Wastes from agricultural processing or from forestry

Recommendation while using mulching

While mulching has a lot of advantages, it can also cause problems in specific situations:

- Some organisms can proliferate too much in the moist and protected conditions of the mulch layer. Slugs and snails can multiply very quickly under a mulch layer. Ants or termites which may cause damage to the crops also may find ideal conditions for living.

- When crop residues are used for mulching, in some cases there is an increased risk of sustaining pests and diseases. Damaging organisms such as stem borers may survive in the stalks of crops like cotton, corn or sugar cane. Plant material infected with viral or fungal diseases should not be used if there is a risk that the disease might spread to the next crop. Crop rotation is very important to overcome these risks.
- When carbon rich materials such as straw or stalks are used for mulching, nitrogen from the soil may be used by microorganisms for decomposing the material. Thus, nitrogen may be temporary not available for plant growth.
- The major constraint for mulching usually is the availability of organic material. Its production or collection usually involves labour and may compete with the production of crops.

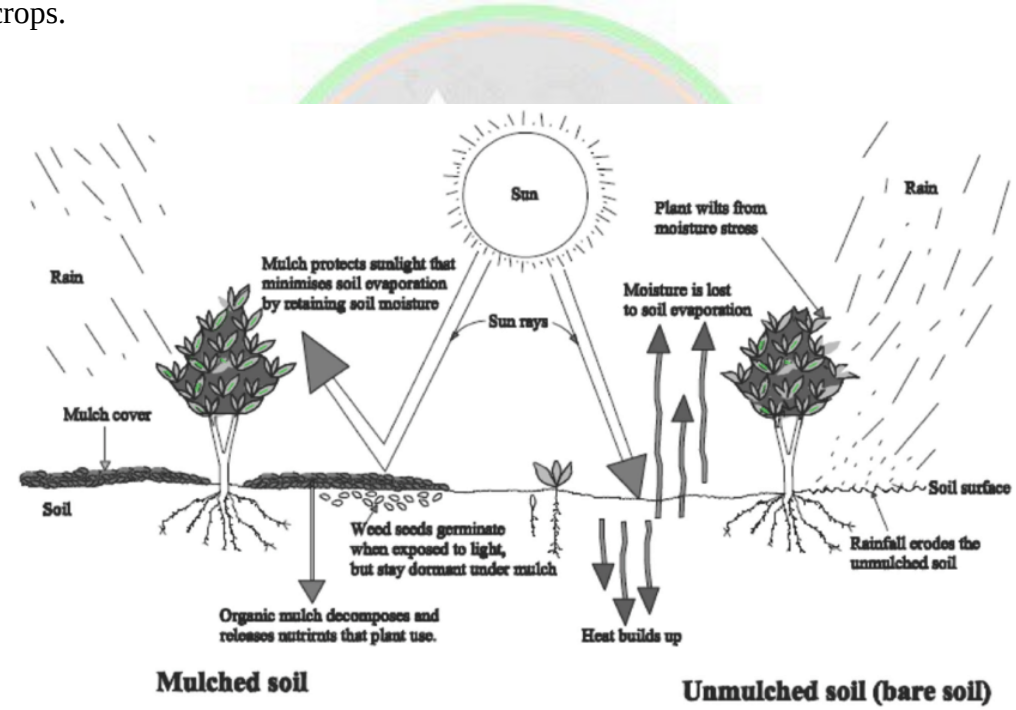


Fig. 3. Potential problems related to mulching

Application of mulch

If possible, the mulch should be applied before or at the onset of the rainy season, as then the soil is most vulnerable.

If the layer of mulch is not too thick, seeds or seedlings can be directly sown or planted in between the mulching material. On vegetable plots it is best to apply mulch only **after** the young plants have become somewhat hardier, as they may be harmed by the products of decomposition from fresh mulch material.



Fig. 4. Protecting the soil with mulch

If mulch is applied **prior** to sowing or planting, the mulch layer should not be too thick in order to allow seedlings to penetrate it. Mulch can also be applied in established crops, best directly after digging the soil. It can be applied between the rows, directly around single plants (especially for tree crops) or evenly spread on the field.

A practical example: The Fukuoka system of mulching rice field

The Japanese organic pioneer Fukuoka developed a system of growing rice which is based on mulching. White clover is sown among the rice one month before harvesting. Shortly thereafter, a winter crop of rye is sown. After threshing the harvested rice, the rice straw is brought back to the field where it is used as a loose mulch layer. Both the rye and the white clover spring up through the mulch which remains until the rye is harvested. If the straw decomposes too slowly, chicken manure is sprinkled over the mulch. This cropping system does not require any tillage of the soil, but achieves satisfying yields.

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INNOVATIVE NUTRITIONAL AND FEEDING STRATEGIES FOR PRODUCING DESIGNER EGGS FROM POULTRY: IMPROVE HUMAN HEALTH AND WELFARE

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Introduction

Eggs are considered one of the most complete, balanced and highly nutritious natural foods with affordable source of high-quality protein, essential fatty acids, vitamins and minerals. However, with advancements in nutritional science, the concept of **designer eggs** has emerged as a way to enhance their nutritional profile to meet specific health needs. Designer eggs are enriched with beneficial nutrients such as omega-3 fatty acids, selenium, vitamin D and antioxidants, providing functional health benefits beyond basic nutrition. These bio-fortified eggs have gained significant attention due to their potential role in preventing lifestyle-related disorders, improving immune function, promoting overall consumers' well-being and welfare.

With the growing prevalence of cardiovascular diseases, obesity, diabetes and micronutrient deficiencies, there is an increasing demand for functional foods. Designer eggs, produced through dietary modifications in laying hens, offer a natural and effective approach to improving human health. Omega-3-enriched eggs, for instance, help reduce the risk of heart disease, while selenium and vitamin E-fortified eggs support antioxidant defence and immune function. Moreover, eggs enriched with folic acid and choline contributes to brain development and cognitive health, making them highly beneficial for pregnant women and growing children.

To produce designer eggs, **innovative nutritional and feeding strategies** are employed in poultry diets. These include supplementation with omega-3-rich sources such as flaxseed, fish oil and microalgae, as well as the inclusion of organic selenium, vitamin D and carotenoid-rich

ingredients. Probiotics, prebiotics and plant secondary metabolites (PSMs) are also incorporated to enhance gut health, nutrient absorption and overall egg quality. Furthermore, the use of **nano-minerals, herbal extracts and fermented feed ingredients** has shown promise in improving egg nutrient composition while maintaining the health and productivity of laying hens.

As consumer awareness about nutrition and functional foods grows, the future of designer eggs lies in further **optimization of poultry nutrition** through precision feeding, nutrigenomics and sustainable feed ingredients. With increasing environmental concerns, efforts to enhance egg nutrition using eco-friendly and locally available feed resources will be crucial. Additionally, advances in biotechnology, such as genetic selection and microbiome modulation, may further enhance the production of nutrient-rich eggs.

However, advancements in poultry nutrition have led to the production of **designer eggs**, which are enriched with specific nutrients that offer additional health benefits beyond basic nutrition of conventional eggs. These modifications cater to growing consumer demand for functional foods that enhance human health. The composition of an egg can be modified through strategic nutritional interventions in layer diets.

Designer eggs can be **enriched with omega-3 fatty acids, vitamins, minerals, antioxidants and other bioactive compounds** through strategic dietary modifications in layer poultry. This article explores **innovative nutritional and feeding strategies** for producing designer eggs, focusing on feed formulation, supplementation techniques and emerging technologies to optimize egg composition that enhance egg quality and health benefits.

Concept of designer eggs

Designer eggs are produced by modifying the diet of laying hens to improve the nutritional profile of egg as well as enrich eggs with specific nutrients beneficial for human health. These eggs may contain:

Enhanced omega-3 fatty acids (Docosahexaenoic acid; DHA, Eicosapentaenoic acid; EPA and α-linolenic acid**; ALA)**

Higher vitamin content (vitamin A, D, E, B-complex, folic acid)

Increased mineral content (selenium, iodine, iron and zinc)

Antioxidants (carotenoids, polyphenols, lutein and zeaxanthin) and

Lower cholesterol levels

These modifications improve egg quality and create functional foods that support heart health, brain function and immunity such as:

Improved cardiovascular health (omega-3, reduced cholesterol)

Enhanced brain function and development (DHA, choline)

Stronger immunity (selenium, vitamin E and polyphenols)

Better bone health (calcium and vitamin D3)

Reduced oxidative stress (antioxidants and carotenoids)

Table 1: Comparison of nutrient composition: Designer eggs vs. conventional eggs

Nutrient	Designer eggs (Enriched)	Conventional eggs	Health benefits of enrichment
Energy (kcal/egg)	70-80	70-80	No significant difference
Protein (g/egg)	6.5-7.5	6.0-7.0	Muscle growth and tissue repair
Total fat (g/egg)	4.5-6.0	5.0-6.0	Essential energy source
Omega-3 fatty acid (mg/egg)	200-600	30-60	Heart health and brain function
Omega-6 fatty acid (mg/egg)	1000-1500	1200-1600	Support skin and cell function
Cholesterol (mg/egg)	150-180	180-200	Reduce cardiovascular risk
Vitamin A (IU/egg)	400-600	300-400	Vision and immune support
Vitamin D (IU/egg)	100-200	18-40	Bone health and immune function
Vitamin E (mg/egg)	5-10	0.5-1.0	Antioxidant protection
Vitamin B_{12} (mcg/egg)	1.5-2.5	0.8-1.2	Nerve function and RBC formation
Folic acid (mcg/egg)	50-100	25-40	Brain development and prevents neural tube defects
Choline (mg/egg)	200-300	120=150	Cognitive function and liver health
Selenium (mcg/egg)	30-50	10-15	Antioxidant and thyroid function
Lutein and zeaxanthin	500-1500	200-300	Eye health and reduced macular degeneration risk

(mcg/egg)			
Iron (mg/egg)	1.2-1.8	0.9-1.2	Oxygen transport and anaemia prevention
Zinc (mg/egg)	1.0-1.5	0.5-1.0	Immune support and wound healing

Nutritional strategies for producing designer eggs

Enriching eggs with omega-3 fatty acids

Omega-3 fatty acids are essential for heart and brain health. Conventional eggs contain minimal omega-3 fatty acids, but **dietary supplementation** can increase their levels in eggs.

Sources of omega-3 fatty acids in layer diets

***Flaxseed (Linseed)* (5-10%)**: Rich in α-linolenic acid (ALA), a precursor for DHA and EPA.

***Fish oil (1-3%)*:** Direct source of DHA and EPA, improving egg omega-3 content.

***Algal oil (0.5-2%)*:** Sustainable DHA source, enhancing egg quality.

Chia seeds (5-10%): High in ALA, improving yolk fatty acid profile.

Perilla seed oil (1-3%): Alternative omega-3 source, improving DHA levels.

Effects on egg quality

Increases **DHA and EPA** content in the yolk,

Reduces **omega-6 to omega-3 ratio**, supporting cardiovascular health,

Enhances **yolk colour and stability** due to improved fat composition,

Challenges:

High levels of flaxseed or fish oil may cause **off-flavours** in eggs.

Balancing **antioxidants (vitamin E)** is necessary to prevent oxidation.

Vitamin-enriched designer eggs

Eggs enriched with vitamins provide superior nutrition for human health.

Key vitamins for enrichment

***Vitamin A (retinol, β-carotene)* (10000-15000 IU/kg diet)**: Improves vision, immunity and skin health.

Sources: Carrots, red pepper, marigold meal and tree leaf meals.

***Vitamin D_3* (3000-6000 IU/kg diet):** Essential for calcium absorption and bone health.

Sources: Fortified feed, fish liver oil, UV-treated yeast.

***Vitamin E* (20-50 mg/kg diet):** Antioxidant, protecting cell membranes.

Sources: Wheat germ oil, sunflower oil, synthetic vitamin E.

***Vitamin B_{12}* (0.01-0.05 mg/kg diet)**: Supports neurological function and red blood cell formation.

Sources: Animal by-products, synthetic supplements.

***Folic acid* (1-4 mg/kg diet)**: Essential for foetal development and heart health.

Sources: Green leafy vegetables, synthetic folic acid.

Effects on egg quality

Higher vitamin concentrations in eggs improve **consumer health benefits**.

Vitamin D enrichment enhances **calcium metabolism**, improving eggshell quality.

Vitamin E supplementation prevents yolk lipid oxidation, extending shelf life.

Mineral-enriched designer eggs

Mineral-enriched eggs contribute to **bone health, immunity, and metabolic functions** in consumers.

Key minerals for enrichment

***Selenium (Se)* (0.2-0.5 mg/kg diet)**: Antioxidant properties, supports thyroid function.

Sources: Selenium yeast, sodium selenite and selenium-enriched algae.

***Iodine (I)* (1-3 mg/kg diet)**: Prevents thyroid disorders.

Sources: Iodized salt and kelp meal.

***Iron (Fe)* (30-60 mg/kg diet)**: Prevents anaemia and supports oxygen transport.

Sources: Ferrous sulphate and organic iron complexes.

***Zinc (Zn)* (50-100 mg/kg diet)**: Supports immunity and skin health.

Sources: Zinc oxide and zinc chelates.

Effects on egg quality

Selenium-enriched eggs have increased antioxidant capacity, protecting against oxidative stress.

Iodine fortification improves **thyroid hormone synthesis**, preventing deficiency disorders.

Iron-enriched eggs help combat **anaemia** in vulnerable populations.

Antioxidant-enriched designer eggs

Antioxidants protect against oxidative stress, improving egg quality and consumer health.

Key antioxidants for enrichment

Lutein and Zeaxanthin **(200-600 mg/kg diet)**: Supports eye health and reduces macular degeneration.

Sources: Marigold petals, spinach and alfalfa meal.

Carotenoids (β-Carotene, Astaxanthin) **(20-100 mg/kg diet)**: Enhance yolk colour and antioxidant capacity.

Sources: Red peppers, algae (*Haematococcus pluvialis*), paprika.

Polyphenols **(50-500 mg/kg diet)**: Reduce oxidative stress.

Sources: Green tea extract, grape seed extract, olive leaf extract and locally available tanniferous tree leaf meals.

Effects on egg quality

Improves yolk colour and stability,

Enhances oxidative stability, reducing egg spoilage,

Provides eye health benefits due to lutein and zeaxanthin,

Cholesterol-reduced designer eggs

High cholesterol in eggs is a concern for some consumers. Reducing yolk cholesterol through dietary strategies improves egg acceptability.

Nutritional strategies to reduce cholesterol

Plant sterols (Phytosterols) **(0.5-2.0 g/kg diet)**: Compete with cholesterol absorption.

Sources: Soybean oil, corn oil and sunflower oil.

Omega-3 fatty acids **(5-10%)**: Improve lipid metabolism, reducing cholesterol synthesis.

Nicotinic acid (Vitamin B_3) **(100-300 mg/kg diet)**: Inhibits hepatic cholesterol production.

Sources: Yeast, fish meal, synthetic B_3.

Soy isoflavones **(100-500 mg/kg diet)**: Modulate cholesterol synthesis.

Effects on egg quality

Reduces **total yolk cholesterol** by 10-30%,

Maintains **egg taste and texture** without adverse effects,

Herbal and phytogenic feed additives for designer eggs

Herbal extracts and phytogenic compounds enhance egg quality naturally.

Key herbal feed additives

Garlic (Allium sativum) **(1-3% in diet)**: Reduces cholesterol, enhances egg antioxidants.

***Turmeric (Curcuma longa)* (0.5-2% in diet)**: Enhances yolk colour and improves lipid metabolism.

***Fenugreek (Trigonella foenum-graecum)* (1-5% in diet):** Improves omega-3 content and reduces cholesterol.

***Green tea extract* (500-1000 mg/kg diet)**: Antioxidant properties, extends shelf life.

Practical considerations for producing designer eggs

Ingredient selection: Ensure high bioavailability of added nutrients.

Nutrient stability: Prevent oxidation of omega-3 fatty acids with vitamin E.

Consumer preferences: Balance nutrient enrichment with taste and texture.

Regulatory compliance: Follow safety guidelines for functional feed additives.

The integration of nano-minerals, precision feeding, nutrigenomics, microbiome modulation and sustainable feed innovations plays a crucial role in optimizing egg nutrition.

Nano-minerals for enhanced bioavailability

Nano-minerals (e.g., nano-selenium, nano-zinc and nano-calcium) improve mineral bioavailability, ensuring better absorption and utilization. They enhance eggshell quality, yolk nutrient density and antioxidant properties while reducing environmental mineral excretion.

Precision feeding for targeted nutrition

Precision feeding uses real-time monitoring of nutrient requirements to minimize wastage and optimize nutrient intake. Customized feeding programs help improve feed efficiency, egg composition and hen health, contributing to cost-effective and sustainable production.

Nutrigenomics for genetic optimization

Nutrigenomics explores gene-diet interactions, allowing targeted dietary modifications to enhance yolk nutrient deposition. It enables genetic selection for superior nutrient metabolism, improving the enrichment of designer eggs with essential fatty acids, vitamins and minerals.

Microbiome modulation for gut health and nutrient absorption

Probiotics, prebiotics and postbiotics enhance gut microbiota balance, improving nutrient absorption, immune function and overall hen productivity. A healthy gut microbiome ensures efficient digestion, better utilization of bioactive compounds and reduced reliance on antibiotics.

Sustainable feed innovations for eco-friendly production

The incorporation of sustainable feed ingredients such as algal omega-3 sources, functional leaf meals, and alternative protein sources reduces the environmental footprint while

maintaining egg quality. Low to moderate level of condensed tannin-rich feed additives improve nutrient utilization and enhance antioxidant status in eggs.

Integrating these advanced strategies ensures optimal egg nutrition, enhances hen welfare, and promotes sustainable designer egg production to meet growing consumer demand for nutritionally enriched eggs.

Conclusion

Designer eggs represent a significant advancement in functional foods, offering enhanced nutrition, health benefits and welfare. Nutritional strategies such as omega-3 enrichment, vitamin and mineral fortification, antioxidant enhancement, and cholesterol reduction can be effectively implemented to produce high-value eggs. With growing consumer demand for **healthier food options**, designer eggs provide an innovative, sustainable and market-driven solution that ensure both economic benefits for poultry farmers and improved health for consumers. Additionally, designer eggs represent a significant innovation in human nutrition, offering a practical and sustainable solution to combat lifestyle diseases and micronutrient deficiencies. Continued research and advancements in poultry nutrition and feeding strategies will be essential to meet the evolving demands of health-conscious consumers while ensuring economic and environmental sustainability in egg production.

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OCEAN-CLIMATE NEXUS: INSIGHTS INTO CARBON STORAGE AND SEQUESTRATION

Article ID: AG-VO5-I10-93

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Abstract

The effects of climate change, exacerbated by the burning of fossil fuels, and the impact of deforestation challenge the health of ecosystems through rising sea levels, increased extreme weather events, and ocean acidification. Oceans provide an ecosystem service carbon sequestration absorbing roughly 25 - 50% of anthropogenic CO_2 emissions and playing an important role in regulating the global carbon cycle through biological, solubility, and carbonate pumps that store carbon over varying timescales. Emerging carbon removal techniques such as ocean fertilization, deep CO_2 injection, and carbon mineralization seek to enhance this natural process. However, ocean warming, acidification, overfishing, and pollution undermine the efficacy of these carbon sinks. Therefore, sustainable climate mitigation will require a combined approach to support climate change mitigation that develops natural ecosystems in conjunction with cautiously researched technical opportunities built on the foundation of strong international cooperation and stewardship of the ocean. Improving the health of the oceans is critical not only for carbon storage, but also for marine biodiversity, and global climate adaptation.

Introduction

Global warming poses a serious threat by driving sea-level rise and increasing the frequency and intensity of wildfires, floods, droughts, and tropical storms. These changes alter the patterns of rainfall, snowfall, and runoff, leading to significant disruptions in coastal, marine, and other ecosystems. Human activities such as the combustion of fossil fuels (coal, oil, and gas) and large-scale deforestation are the primary sources of carbon dioxide (CO_2) and other

greenhouse gas emissions (Lee et al., 2023). The Intergovernmental Panel on Climate Change (IPCC) has emphasised that to limit global warming to 1.5 °C, as outlined in the Paris Agreement, large-scale carbon dioxide removal (CDR) of 100-1000 gigatons will be required. On land, CDR can be achieved through practices like forest restoration, agroforestry, integrated crop-livestock systems, and conservation tillage, which enhance carbon capture in terrestrial ecosystems. At the same time, the oceans have absorbed nearly 30-50% of anthropogenic CO_2 emissions, serving as a critical buffer against climate change and contributing more global carbon uptake than forests, which account for about 20%. However, increasing atmospheric CO_2 levels have also driven higher absorption by seawater, resulting in ocean acidification with severe consequences for marine plankton, coral reefs, and overall ecosystem health. To mitigate these impacts, ocean sequestration techniques such as injecting CO_2 into deep waters (up to 1 km depth), where it dissolves and disperses due to density differences have been proposed. This approach has the theoretical capacity to store about 40,000 gigatons of CO_2, equivalent to roughly 90% of current global emissions (Boyd & Bressac, 2016).

Methods of ocean carbon storage

The oceans are a key regulator of the global carbon cycle, acting as a major carbon sink. Atmospheric CO_2 is transported to deeper layers through physical, chemical, and biological processes, where it can be stored for decades to millennia. Both natural mechanisms, such as the biological and solubility pumps, and engineered approaches, like ocean fertilization and CO_2 injection, contribute to oceanic carbon storage and climate change mitigation (Sabine & Tanhua, 2010).

I. Natural ocean carbon storage

a) Biological Carbon Pump (from decades up to centuries)

- Phytoplankton capture CO_2 from the atmosphere via photosynthesis.
- This organic carbon moves through the marine food web and eventually sinks to the deep ocean as particulate organic matter (POM).
- The vertical migration of zooplankton and the transport of dissolved organic carbon (DOC) further promote carbon sequestration (Gattuso et al., 2020)..

b) Physical (Solubility) Pump (Centuries to millennia)

- CO_2 enters the ocean by dissolving into surface waters, particularly in cold regions at high latitudes.

- The dense, carbon-rich water then sinks and is carried to the deep ocean through thermohaline circulation.

c) Carbonate Pump (Inorganic Carbon Storage) - (Thousands to millions years)

- Marine organisms such as corals and shellfish build shells from calcium carbonate ($CaCO_3$).
- After they die, their remains contribute to the formation of carbonate-rich sediments on the seafloor (Nellemann et al., 2009).

II. Engineered / Artificial Ocean Carbon Storage

a. Ocean Fertilization

- Supplying nutrients (such as iron) to promote phytoplankton growth.
- Strengthens the biological pump, increasing CO_2 uptake.

b. Direct Injection/ Deep Ocean Storage

- Captured CO_2 is released into deep ocean layers.
- It dissolves and can remain stored for centuries.

c. Mineralization in Seawater

- CO_2 interacts with naturally present ions in seawater, forming stable carbonate minerals
- Ensures long-term carbon storage.

Innovative ideas for boosting ocean carbon storage

a. Sea weed farming: Seaweed farming involves cultivating large marine macroalgae in coastal or offshore waters using lines, ropes, or rafts for commercial and ecological purposes. The species selected vary by region; red algae such as *Kappaphycus* and *Gracilaria* are commonly grown for carrageenan and agar, while brown algae are utilised for polysaccharides, bioactive compounds, and other products, depending on local ecological conditions. In India, *Kappaphycus* and *Gracilaria* are among the principal species cultivated (Duarte et al., 2013).

b. Iron Fertilization: Iron fertilisation is a geoengineering approach that involves introducing iron, typically as iron sulphate or other soluble forms, into iron-limited ocean regions to stimulate phytoplankton growth. Because phytoplankton absorb atmospheric CO_2 during photosynthesis, this method aims to strengthen the ocean's biological carbon pump by transferring carbon to deeper waters as phytoplankton die and sink. Field trials such as IronEx,

SOFeX, and LOHAFEX have demonstrated short-term increases in phytoplankton biomass and carbon uptake; however, uncertainties remain regarding the long-term effectiveness, stability of carbon sequestration, and potential ecological risks, including harmful algal blooms, food web disruptions, and oxygen depletion.

c. Restoring Blue carbon Ecosystems: Blue carbon ecosystems including mangroves, seagrass meadows, and salt marshes are vital coastal habitats that capture and store significant amounts of carbon within their biomass and sediments. Their restoration is increasingly recognized as a nature-based strategy for both climate change mitigation and adaptation. Restoration approaches includes such as:

- ✓ **Mangroves**: Replanting or promoting natural regeneration through hydrological interventions, such as re-establishing tidal flows, reducing erosion, limiting pollution, and safeguarding seedlings.
- ✓ **Seagrass meadows**: transplanting shoots, sowing seeds, controlling nutrient inputs, and improving water clarity.
- ✓ **Salt marshes**: restoring tidal exchange by breaching embankments, planting native halophytic vegetation, and managing invasive species.

Key benefits of restoration:

- Enhanced carbon sequestration in biomass and sediments.
- Coastal defence against erosion carbon sequestration, storms, and sea-level rise.
- Increased biodiversity, offering critical habitats and nurseries for marine organisms.
- Improved water quality through nutrient cycling and sediment trapping.
- Strengthened livelihoods, supporting fisheries, tourism, and other ecosystem services.

Challenges and limitations:

- High financial and technical demands for large-scale restoration.
- Sensitivity of restored ecosystems to climate stressors such as sea-level rise, warming, and ocean acidification.
- Competing land-use pressures in coastal regions.
- The need for sustained governance and community involvement to ensure long-term success.

Global momentum: Initiatives such as the *Blue Carbon Initiative*, the *UN Decade on Ecosystem Restoration*, and regional programmes across Asia, Africa, and the Americas are advancing large-scale efforts to conserve and restore blue carbon ecosystems.

Marine Carbon Sequestration at Risk: The Ocean is a key regulator of the global carbon cycle, absorbing an estimated 25-30% of anthropogenic CO_2 emissions. Yet, this natural equilibrium is increasingly threatened by climate change and human activities (Sabine & Tanhua, 2010).

Warming: Higher sea surface temperatures reduce CO_2 solubility, diminishing the ocean's ability to absorb atmospheric carbon. Additionally, increased thermal stratification restricts vertical nutrient mixing, limiting phytoplankton growth organisms vital for carbon fixation and weakening the biological carbon pump.

Ocean Acidification: CO_2 dissolved in seawater forms carbonic acid, lowering pH and creating more acidic conditions. This poses a threat to calcifying species, including corals, shellfish, and certain plankton, which are essential for marine food webs and carbon storage. Acidification thus undermines both biodiversity and the ocean's long-term carbon sequestration capacity.

Human Impacts: Anthropogenic pressures such as overfishing, pollution, and plastic accumulation further disrupt marine ecosystems. Overfishing alters food webs, nutrient pollution can cause harmful algal blooms, and plastics physically and chemically harm marine organisms. These factors collectively reduce the ocean's efficiency as a carbon sink, exacerbating climate change effects.

Protecting and restoring ocean health is therefore essential for maintaining its carbon sequestration role and supporting ecosystem resilience under ongoing environmental stress

The Way Forward

- **Protect and Restore Natural Ocean Ecosystems:**
    - Conserve and rehabilitate mangroves, seagrass meadows, salt marshes, and coral reefs.
    - Implement restoration measures: replanting, hydrological restoration, pollution control, and invasive species management.
    - Enhance carbon sequestration, biodiversity, and coastal protection.
- **Integrate Conservation with Innovative Approaches:**

  - Complement nature-based solutions with carefully tested technologies (e.g., iron fertilisation, artificial upwelling).
  - Evaluate environmental impacts, ecological safety, and long-term effectiveness to avoid unintended consequences.
- **Strengthen International Cooperation:**
  - Coordinate globally through UN, IPCC, and other frameworks.
  - Set standards, monitor carbon fluxes, and support funding for restoration and conservation.
  - Promote knowledge-sharing, collaborative research, and sustainable policy enforcement.
- **Promote Ocean Stewardship as Climate Security:**
  - Recognise oceans as essential for food, livelihoods, and climate protection.
  - Integrate stewardship into climate policies and public awareness to ensure ecological and societal resilience.

Conclusion

Global warming and human pressures are weakening the ocean's role as a vital carbon sink, while also driving sea-level rise and biodiversity loss. Large-scale carbon removal is essential, combining land-based strategies, blue carbon ecosystem restoration, and cautiously tested innovations. Strengthened global cooperation and ocean stewardship are critical to achieving climate resilience and mitigation.

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SCIENTIFIC APPROACHES TO WHEAT SEED PRODUCTION IN THE PENINSULAR ZONE OF INDIA

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Abstract

Based on the climatic and geographical requirements of different wheat-growing zones, the ICAR–Indian Institute of Wheat and Barley Research, Karnal, along with several agricultural universities, develops and releases suitable varieties to supply farmers with quality seeds. Farmers can also produce quality seeds on their own farms by selecting improved varieties and following recommended cultivation practices suited to their sowing conditions.

Introduction

Wheat is one of the most important crops in India. A cool and dry climate is ideal for its growth. In the country, wheat is mainly cultivated in Punjab, Haryana, Rajasthan, Uttar Pradesh, Madhya Pradesh, Bihar, West Bengal, Uttarakhand, Himachal Pradesh, Karnataka, and Maharashtra. Depending on climate, the wheat-growing regions of India are classified into five zones: North-Western Plains, North-Eastern Plains, Northern Hills, Central Zone, and Peninsular Zone. During 2024-25, wheat occupied 32.76 million hectares in India, with a total production of 117.5 million tonnes and an average productivity of 35.87 quintals/ha (ICAR–IIWBR 2025).

The Peninsular Zone includes Maharashtra, Andhra Pradesh, Karnataka, Goa, and Tamil Nadu (excluding Nilgiris and Palani Hills). In this region, sarbati wheat (*Triticum aestivum*), bansi wheat (*Triticum durum*), and khapli wheat (*Triticum dicoccum*) are predominantly grown, as the climate is favorable for these types. However, wheat crops here often face high

temperatures, particularly at the stalk elongation and flowering stages. Hence, short-duration and heat-tolerant varieties are crucial for this zone.

Although yields in this region are slightly lower compared to the north-western plains (Punjab and Haryana), the quality of wheat from the central and peninsular regions is considered superior and has strong export potential. Additionally, Karnal Bunt, a seed-borne disease, is not commonly found here, further enhancing the international market value of wheat from this region.

Wheat Species Cultivated in India

A) Sarbati Wheat (*Triticum aestivum*)

Best suited for chapatis, breads, biscuits, and cookies due to its strong gluten and high protein content. Suitable regions include Madhya Pradesh, Gujarat, Maharashtra, and parts of southern Rajasthan. Many improved varieties resistant to rust and high-yielding are available.

B) Durum/Bansi Wheat (*Triticum durum*)

Well adapted to hot and dry conditions in Madhya Pradesh, Gujarat, Maharashtra, Karnataka, and parts of Rajasthan. Known for high protein and golden-colored grains, it is widely used for making suji/rava, pasta, macaroni, and noodles due to its strong gluten.

C) Emmer/Khapli Wheat (*Triticum dicoccum*)

Recognized for long, narrow grains with high protein (11.8–15.3%), carbohydrates (78.7–83.2%), and dietary fiber (>16%). Popular for traditional foods such as rava, kheer, and breakfast items. With its low glycemic index, it is particularly beneficial for diabetic patients.

Standard Practices for Quality Seed Production

New wheat varieties are first released as breeder seeds by ICAR institutes or agricultural universities. These are then multiplied into foundation and certified seeds by organizations such as the National Seed Corporation and Mahabeej. It generally takes three to four years for seeds of a new variety to reach farmers. Once available, farmers can continue seed production on their fields or partner with seed companies for certified seed production Being self-pollinated, wheat allows farmers to reuse their own seed for two to three years, provided proper precautions and storage methods are followed.

Quality Standards for Wheat Export

- Moisture content: below 12.0%
- Admixture: below 0.70%

- Protein content: above 12.0%
- Broken/over-dried grains: below 4.0%
- Damaged grains: below 2.0%
- Grain damage: below 1.0%
- Wet gluten: above 25.0%
- Falling number: above 300 seconds
- Hectoliter weight: above 78.0 kg/hl

(Source: Haryana State Co-operative Supply and Marketing Federation Ltd.)

Seed Production Guidelines

- **Variety selection**: Improved seeds can boost yield by 15–20% (**Table 1**).
- **Source of seed**: Always use foundation or certified seed from reliable agencies (ICAR, SAU, State Seed Corporations, or recognized seed companies). Keep seed labels/tags.
- **Seed treatment**: Treat seeds with Carbendazim (1.25 g/kg) or Tebuconazole (1.0 g/kg) to prevent seed-borne diseases.
- **Isolation distance**: Maintain 3 m (up to 150 m if Smut is prevalent).
- **Roguing**: Remove off-types, diseased plants, or those differing in leaf/stem traits to ensure genetic purity.
- **Irrigation**: Provide 4–5 irrigations in medium to heavy soils at key stages—CRI (18–21 DAS), boot stage (40–45 DAS), flowering/milking (60–65 DAS), and grain filling (80–85 DAS).
- **Weed control**:
    - Pre-emergence: Pendimethalin (1250 ml/acre).
    - 30–35 DAS: Isoproturon (500 g/acre) or 2,4-D (500 ml/acre).
- **Fertilizer management**:
    - Timely sown: 58:24:16 kg N:P:K/acre (DAP, Urea, MOP).
    - Late sown: 52 kg DAP, 26 kg MOP + urea split across irrigations.
- **Crop protection**:
    - Rust: Spray Propiconazole (0.1%) + Copper Oxychloride (0.2%).
    - Blight: Spray Copper Oxychloride (0.2%) + Mancozeb (0.2%).
    - Aphids: Spray Imidacloprid (40 ml/acre).
    - Stem borer: Spray Quinalphos (300 ml/acre).

- **Harvesting & threshing**: Prevent mixing of seeds; ensure machines are cleaned.
- **Seed processing**: Pre-cleaning, grading, and separation of light/broken seeds (10–12%).
- **Seed testing**: Ensure ≥85% germination and ≥98% physical purity before certification.
- **Storage**: Store in dry, ventilated areas with 10–12% moisture; use new bags and wooden pallets to prevent contamination or moisture absorption.

Conclusion

By adopting improved varieties suited to local conditions and following standard seed production practices, farmers can successfully produce quality wheat seed on their own fields. Properly stored, these seeds can be reused for two to three years, ensuring both sustainability and profitability.

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Table 1 Recommended wheat varieties for Peninsular Zone as per sowing conditions

Sowing Condition	Period of sowing	Species	Name of the variety	Year of release	Productivity (q/ha)	Days to maturity
Timely Sown Rainfed Condition	15 to 31 October	*Triticum aestivum* (Sarbati)	Netravati (NIAW 1415)	2010	19.0	105
			Vimal (AKAW 3722)	2014	42.0	107
			UAS 347	2015	18.0	96
			UAS 375	2018	21.4	103
		Triticum durum (Bansi)	MACS 4028	2018	20.3	103
			Panchvati (NIDW 15)	2022	15.0	105
Timely Sown Restricted Irrigation condition (Max 2 irrigations)	25 October to 5 November	*Triticum aestivum* (Sarbati)	Netravati (NIAW 1415)	2010	28.5	110
			Pusa Ujala (HI 1605)	2017	30.0	105
			Phule Satwik (NIAW 3170)	2020	33.7	107
			Phule Anupam	2022	32.5	107

			(NIAW 3624)			
			Phule Anurag (NIAW 4028)	2024	35.5	105
			HI 8802	2020	29.5	106
			HI 8805	2020	30.9	100
			MACS 4058	2020	29.0	105
			NIDW 1149	2021	26.0	103
Timely Sown Irrigation condition	5 to 15 November	*Triticum aestivum* (Sarbati)	UAS 304	2013	46.0	110
			MACS 6222	2014	50.0	110
			Phule Samadhan (NIAW 1994)	2016	46.1	115
			MACS 6478	2016	45.0	107
			DBW 168	2018	48.8	112
		Triticum durum (Bansi)	MACS 3949	2017	44.0	111
			DDW 48	2020	44.0	110
		Triticum dicoccum (Khapli)	MACS 2971	2009	50.2	107
			HW 1098	2013	45.5	110
Late Sown Irrigation condition	15 November to 15 December	*Triticum aestivum* (Sarbati)	MACS 6222	2014	50.0	110
			Pusa Amulya (HD 3090)	2014	42.1	101
			Phule Samadhan (NIAW 1994)	2016	44.3	110
			PDKV Sardar	2016	39.2	108
			Pusa Wani (HI 1633)	2021	41.7	100
			Phule Shashwat (NIAW 4114)	2025	45.6	104

Volume: 05 Issue No: 10

SCOPE FOR ROBOTICS IN AQUACULTURE

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Introduction

By tackling different issues and boosting the effectiveness, sustainability, and productivity of aquatic food production, robotics has the potential to revolutionize the aquaculture industry. Here is an overview of aquaculture robots' potential. Labor often needs more supply in aquaculture, particularly in distant or challenging areas. To reduce the need for human work and increase operational effectiveness, robotic systems may automate duties like feeding, water quality monitoring, and cleaning. Robots may be fitted with sensors and cameras to gather data in real-time on environmental conditions, fish health, and water quality. Producers can use this information to manage their aquaculture operations effectively and make educated choices regarding feeding, disease control, and other factors.

The development and health of aquatic creatures depend on precise and regular feeding. Robotic feeders can distribute feed in the right amounts and at the correct times, preventing waste and overfeeding while encouraging healthy development. Submersible robots and autonomous underwater vehicles (AUVs) may inspect underwater structures, cages, and nets.

They may also monitor fish behavior, water temperature, dissolved oxygen levels, and other factors to guarantee the best circumstances for development.

However, as technology develops and more success stories are documented, the potential advantages of adopting robots in aquaculture are expected to exceed the difficulties, resulting in more effective and sustainable aquatic food production systems. Drones, autonomous surface vehicles (ASVs), remotely operated vehicles (ROVs), and autonomous underwater vehicles (AUVs) are all examples of cutting-edge technology that may dramatically improve water quality management in aquaculture. Here are some examples of how each of these technologies might aid with automation in this situation:

ROVs (Remote Operated Vehicles): ROVs are submerged robots humans operate on land. They have cameras, sensors, and sometimes manipulator arms. ROVs may be utilized in aquaculture for a variety of activities, including:

- ROVs can gather information on temperature, salinity, dissolved oxygen, pH, and other factors, giving them real-time insights into the condition of the aquatic environment. ROVs may examine net cages, machinery, and infrastructure to check for damage, fouling, or disease outbreaks.
- ROVs can clean nets and other submerged objects, reducing biofouling and preserving water quality.

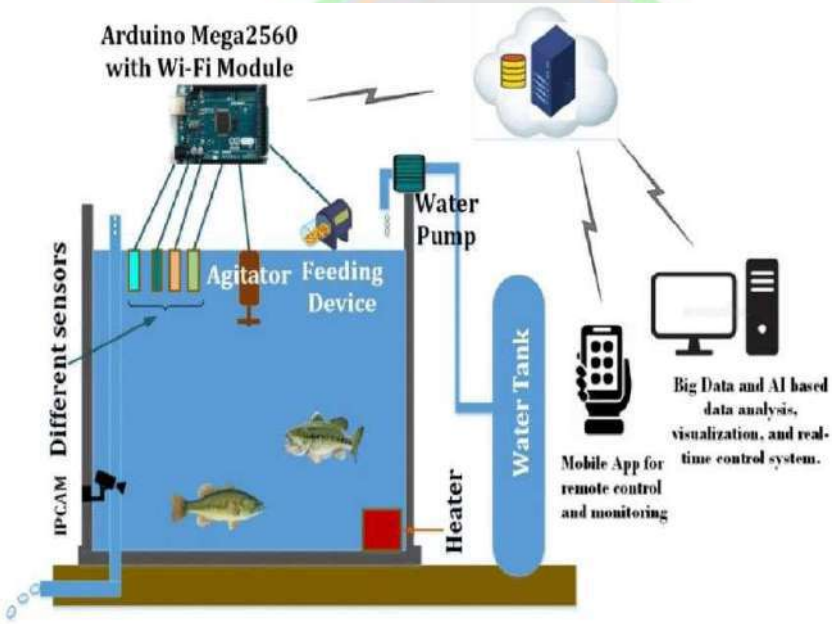
Autonomous Underwater Vehicles (AUVs): AUVs are underwater robots that can function without human assistance. They can employ adaptive algorithms or predetermined pathways to explore and collect data. Aquaculture uses for AUVs include:

- AUVs can scan broad regions and provide high-resolution data on water quality factors, assisting farmers in making wise choices.
- They can provide thorough maps of the underwater environment to help manage aquaculture installations.
- AUVs can track how the water quality varies over time and reveal long-term patterns.

Drones: Drone with cameras and sensors may provide essential data for managing water quality. Drones may hover above aquaculture plants and aquatic bodies, taking pictures and videos that can be used to detect problems like algal blooms, sedimentation, or pollution.

Drones may deploy or drop sensors into the water to gather samples to evaluate the water's quality. Drone thermal cameras can detect changes in water temperature, assisting in monitoring environmental factors that influence aquatic species.

ASVs (Autonomous Surface Vehicles): ASVs are autonomous surface-based robots that can travel across bodies of water. ASVs may be used in aquaculture for ASVs with sensors for measuring water quality may collect information on surface variables, including temperature, pH, and dissolved gases. They may monitor aquaculture sites, looking for irregularities and informing operators in real time. ASVs can gather water samples at predetermined locations, giving information on different water quality factors. These technologies' combination with data analytics and remote communication systems enables real-time monitoring, well-informed problem-solving, and the early identification of issues. These cutting-edge systems automate



water quality management, improving aquaculture operations' sustainability, efficacy, and production while reducing their adverse environmental effects.

Automation for water quality management in aquaculture.

By enabling real-time monitoring, data collecting, and prompt action to maintain ideal circumstances for the health and development of aquatic organisms, automation plays a significant role in water quality management in aquaculture. Here is how automation may be used in aquaculture to maintain water quality:

1. **Sensor Integration:** Automated systems are capable of integrating a wide range of sensors

to track vital water quality indicators including temperature, dissolved oxygen, pH, ammonia, nitrate, nitrite, salinity, and turbidity. These sensors provide data to a centralized control system continually.

2. **Real-time Monitoring:** Automation makes it possible to monitor water quality parameters continuously and in real-time. Instantaneous detection of any deviations from the ideal range enables prompt reaction and remedial action.
3. **Data Analysis and Trend Prediction:** Over time, the gathered data may be analyzed to spot trends and patterns. Based on previous data, machine learning algorithms may be used to identify prospective problems with water quality and enable preventative steps.
4. **Alert Systems:** Automated systems may be set to notify aquaculture managers or operators of alerts or notifications when certain water quality metrics go over specified limits. This guarantees rapid adoption of remedial measures.
5. **Automated Water Exchange:** When water quality drops below a given threshold, automated devices may start water exchange procedures. By reducing pollution and preserving crucial characteristics, this contributes to sustaining favourable circumstances.
6. **Aeration Control:** For fish health, dissolved oxygen levels are essential. In order to avoid oxygen depletion, automation may manage aeration systems, regulating oxygen supply based on real-time oxygen readings.
7. **pH Regulation:** Automation may regulate pH levels by adding acids or bases to the water using chemical dosing devices, keeping the pH within the ideal range for the species being grown.
8. **Feed Management Integration:** Automation may work with feeding systems to modify feeding schedules in response to changes in water quality. Feeding may be temporarily lowered to stop excessive waste generation if the quality of the water declines.
9. **Data Logging and Reporting:** Automated systems have the capacity to preserve historical data, giving aquaculture managers the ability to examine patterns, gauge the success of treatments, and make well-informed choices for long-term water quality management.
10. **Remote Control and Monitoring:** Lots of aquaculture installations are situated offshore or in far-flung locations. Automation eliminates the requirement for continual physical presence by enabling remote control and monitoring of water quality indicators.
11. **Decreased Human mistake:** Automated methods reduce the possibility of human mistakes

while monitoring and maintaining water quality, resulting in more reliable and accurate findings.

12. **Cost Savings:** Although establishing automated systems requires an initial investment, they may result in cost savings over time by lowering labour expenses, minimising losses brought on by poor water quality, and maximising resource utilisation.

Overall, automation for aquaculture water quality management increases productivity, boosts fish health, lessens environmental impact, and helps ensure the long-term viability of aquaculture operations. To guarantee that automated systems operate dependably and that human intervention is possible, when necessary, it is crucial to have enough training and backup procedures in place.

Automation in health management

Automation can significantly improve health management in aquaculture by providing continuous monitoring, early disease detection, and precise interventions.

- **Fish Behavior Monitoring:** Automated cameras and sensors can track fish behavior patterns, such as swimming activity, feeding behavior, and social interactions. Changes in behavior could indicate stress or health issues
- **Image Analysis and Pattern Recognition:** Machine learning algorithms can analyze images and videos to identify abnormal fish behavior or physical symptoms, such as lesions, discoloration, or fin damage.
- **Health Parameter Monitoring:** Automated systems can continuously monitor vital health parameters, including heart rate, respiration rate, and metabolic activity. Any deviations from normal values can trigger alerts for further investigation.
- **Water Quality Integration:** Since water quality has a direct impact on fish health, integrating water quality sensors with health monitoring systems allows for a comprehensive understanding of the environment-fish health relationship.
- **Early Disease Detection:** Automation can identify early signs of diseases by analyzing changes in fish behavior, vital signs, and other health indicators. Early detection allows for timely treatment, reducing the spread and impact of diseases.
- **Automated Sampling and Analysis:** Robotic systems can collect samples of fish mucus, blood, or other bodily fluids for analysis. Automated diagnostic tools can then identify pathogens, parasites, or physiological changes indicative of diseases.

- **Quarantine and Separation:** Automated systems can sort and separate unhealthy or infected fish from the healthy population. This prevents the spread of diseases while providing isolated conditions for treatment.
- **Medication Dispensing:** Robotic systems can precisely dispense medications, vaccines, or treatments to specific individuals or groups of fish. This targeted approach minimizes stress and reduces the use of chemicals.
- **Remote Health Monitoring:** In remote or offshore aquaculture facilities, automation allows for remote health monitoring. Aquaculture managers can receive real-time health updates without physically being present at the site.
- Data Integration and Decision Support: Automated health monitoring systems can integrate data from various sources, including water quality, environmental conditions, and fish health. Analytical tools can provide insights and suggestions for optimal management decisions.
- **Data Logging and Trend Analysis:** Historical health data can be logged and analyzed over time to identify recurring health issues, evaluate the effectiveness of treatments, and adjust management strategies.
- **Reduced Stress:** Automation reduces the need for frequent human interventions, minimizing stress on the fish and allowing them to exhibit more natural behaviors.
- **Traceability and Documentation:** Automated health management systems can maintain accurate records of treatments, interventions, and health status. This information is valuable for compliance, traceability, and auditing purposes.
- **Resource Optimization:** By identifying and addressing health issues early, automation can help reduce mortality rates, increase growth rates, and optimize resource utilization, leading to higher productivity.

Aquaculture health management can be revolutionized by automation, but it's important to take into account variables like system dependability, data quality, and the requirement for human experience in analyzing complicated health data. To guarantee efficient health management in aquaculture operations, an automation approach should include both technical solutions and qualified human control.

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ANTIDEPRESSANT AS AN EMERGING CONTAMINANT IN AOUATIC ECOSYSTEMS

Article ID: AG-VO5-I10-96

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Abstract

The widespread use of antidepressants, combined with the limited efficiency of wastewater treatment plants, has led to their persistence in aquatic environments. These pharmaceuticals enter water systems through human excretion, hospital effluents, and industrial discharges, where they are only partially removed. As a result, compounds such as fluoxetine, sertraline, and venlafaxine have been detected in sewage, surface waters, groundwater, and even drinking water. Antidepressants are biologically active molecules targeting neurotransmitter systems that are conserved across species. Even at low environmental concentrations, they disrupt fish behaviour, reproduction, hormone regulation, and growth, with early developmental stages particularly vulnerable. Multigenerational studies further reveal long-term effects, including altered stress responses and gene regulation. The potential for bioaccumulation raises concern for humans via the food chain, where chronic exposure may pose subtle health risks. Addressing this issue requires advanced treatment technologies, improved monitoring, and more sustainable pharmaceutical practices to protect ecosystems and human health.

Key words: Antidepressants, aquatic ecosystems, bioaccumulation, fish behaviour, pharmaceutical pollution

Introduction

Rapid population growth and technological progress have led to the production of many chemical compounds. Due to poor management and the limited efficiency of wastewater treatment plants, large amounts of these compounds end up in the environment. Some

contaminants, such as human pharmaceuticals like the antidepressant, are found in low concentrations in the environment. Antidepressant medications have become closely linked with improved mental well-being, easing severe anxiety, and influencing mood, energy, and behavior. They remain a cornerstone in the treatment of depression and generalized anxiety disorder. This is a serious concern because animals living in contaminated environments may be exposed to these chemicals throughout their entire lives and across generations. In some cases, harmful effects only appear after exposure over several generations.

Pharmaceuticals are biologically active compounds with different chemical structures, modes of action, and therapeutic uses. They are designed to act on specific targets in the body. After use, pharmaceuticals may be excreted in urine or faeces either as the unchanged drug or as metabolites, which may still be active. As they are designed to remain stable until they reach their target site, most of the pharmaceuticals resist breakdown. As a result, they can persist in the environment and contaminate aquatic systems. Our toilets carry these neuroactive ingredients that affect nervous systems into our wastewater. Despite best attempts to treat them, not all the components of antidepressants can be removed from our sewage. Pharmaceuticals have been detected in sewage, surface waters, groundwater, and even occasionally in drinking water.

Aquatic organisms may be exposed to these substances through surface water, drinking water, or other pathways. Recent studies show that antidepressants can disrupt important physiological functions in aquatic species. They affect development, reproduction, circadian rhythms, and hormone levels. These findings raise concerns about the presence of such biologically active substances in aquatic environments.

Types of Antidepressants

The main purpose of antidepressant therapy is to improve mood and behaviour by changing the activity of brain chemicals called neurotransmitters. These medicines work by affecting how neurotransmitters are released, used, or reabsorbed in the brain.

There are several types of antidepressants:

- **Selective serotonin reuptake inhibitors (SSRIs):** Examples include fluoxetine, sertraline, and citalopram. They block the reuptake of serotonin in nerve cells, which increases the amount of serotonin in the brain.
- **Serotonin norepinephrine reuptake inhibitors (SNRIs):** An example is venlafaxine.

These block the reuptake of both serotonin and norepinephrine, making more of these neurotransmitters available in the brain.

- **Tricyclic antidepressants (TCAs):** Examples include clomipramine, amitriptyline, and nortriptyline. They block the reuptake of serotonin and norepinephrine, but they can also affect other receptors in the body, leading to more side effects.
- **Monoamine oxidase inhibitors (MAOIs):** Examples include selegiline, isocarboxazid, and phenelzine. They work by blocking the enzyme that breaks down serotonin, norepinephrine, and dopamine, so these chemicals stay active longer.
- **Norepinephrine-dopamine reuptake inhibitors (NDRIs):** An example is bupropion. This type blocks the reuptake of dopamine and norepinephrine, increasing their levels in the brain.

Occurrence of antidepressants in the aquatic environment

Rapid industrial growth, technological advances, and population increase have led to the release of large volumes of wastewater. Treating this wastewater is crucial to reduce the impact of domestic, industrial, and hospital discharges. However, untreated or poorly treated wastewater contributes to water pollution, loss of aquatic biodiversity, and risks to human health. The use of antidepressants has increased worldwide, though the levels of consumption vary from country to country. Once consumed, these drugs enter the environment through human excretion, disposal of unused medicines, hospital effluents, and wastewater from pharmaceutical industries. Most wastewater treatment plants (WWTPs) are not designed to fully remove pharmaceuticals, allowing antidepressants and their metabolites to reach the water bodies.

Studies have detected various antidepressants, especially SSRIs and SNRIs, in influents, effluents, and surface waters. Commonly found compounds include fluoxetine, sertraline, venlafaxine, and their active metabolites. In some cases, the concentration of antidepressants is even higher in treated effluents than in untreated influents, because breakdown products can be reconverted to the original compounds during treatment. The removal efficiency of WWTPs depends on factors such as sludge age, temperature, and retention time. Traditional treatment methods, like activated sludge, are not very effective at removing these persistent drugs. Advanced technologies such as ozonation, activated carbon, advanced oxidation, and reverse osmosis show better results but are not widely applied.

The continuous release of antidepressants into aquatic systems exposes fish and other organisms to these substances, increasing the risk of bioaccumulation in tissues. Since surface and groundwater are often used for drinking water, this also poses potential risks to human health. To address this problem, regular monitoring of antidepressant levels in water is needed. Improved analytical methods that can detect very low concentrations of these compounds should also be developed, ensuring better assessment and control of these emerging contaminants.

Effects of antidepressants on aquatic organisms

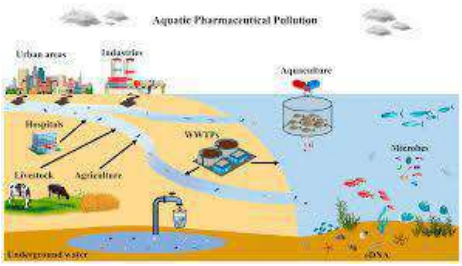
Serotonin is a key regulator across species. In vertebrates, it functions as a neurotransmitter influencing mood, behaviour, learning, and development. In invertebrates, it plays a central role in survival, growth, and movement. Because serotonin systems are highly conserved across organisms, antidepressants that target serotonin transporters and receptors can affect a wide range of species, even at very low environmental concentrations.

Although humans and fish differ greatly in form, their physiological and neural foundations share striking similarities. This makes fish particularly vulnerable to the effects of antidepressants, with responses often depending on the life stage of the animal. Early developmental stages, such as embryos and larvae, are especially sensitive to chemical exposure. Disruptions during these stages can produce long-term consequences for growth, fitness, and survival. Fish embryos are widely used in toxicological studies as models for vertebrate responses, offering an ethical and informative approach to understanding chemical impacts.

Environmental levels of antidepressants have been shown to alter fish behaviour, which is critical for survival. Subtle changes in swimming or foraging can upset the delicate balance between energy intake and expenditure, reducing the ability of fish to secure food, escape predators, or reproduce successfully. Crayfish exposed to SSRIs exhibited increased boldness and spent more time orienting to food resources than nonexposed crayfish.

Beyond behaviour, antidepressants disrupt essential physiological systems. Drugs that act on serotonin can reduce the quality and quantity of eggs and sperm, alter reproductive hormones, and impair tissue development. Some compounds leave long-lasting developmental imprints: for example, fluoxetine (Prozac) alters cortisol production, a stress hormone crucial for coping with environmental challenges, while other antidepressants have been linked to stunted growth, lowering survival chances in the wild.

Different classes of antidepressants exert distinct effects. Selective serotonin reuptake inhibitors (SSRIs) influence reproduction, behaviour, antioxidant activity, gene expression, and development. Serotonin-norepinephrine reuptake inhibitors (SNRIs) affect behaviour, reproduction, circadian rhythms, and survival. Tricyclic antidepressants (TCAs) are associated with developmental and structural abnormalities, particularly during early life stages.





Multigenerational studies

Animals in polluted environments are exposed to contaminants throughout their lives and across generations. Prenatal and early-life exposures may cause long-term changes by altering gene regulation, and these effects can be passed to offspring. Studies with zebrafish show that antidepressants can affect future generations. For example, exposure to fluoxetine during early development reduced stress hormone (cortisol) levels in the parent fish and in their offspring, but only through maternal transmission. Fluoxetine exposure also altered gene regulation in female eggs, especially in genes related to stress response and epigenetic control. Another study found that fluoxetine exposure made later generations more sensitive to venlafaxine, leading to reduced cortisol production in females but not in males. This suggests a female-specific sensitivity to antidepressants across generations.

Effects on humans through the food chain:

- **Bioaccumulation:** Small organisms absorb antidepressants, which then move up the food chain to larger fish and eventually to humans who eat them.
- **Chronic exposure:** Even at very low concentrations, long-term ingestion through food or drinking water could lead to subtle health risks, since antidepressants are biologically active compounds.
- **Potential health concerns:** These may include changes in hormone balance, disruption of the nervous system, and effects on mood or behaviour if exposure is continuous. The

risk is considered low at present, but not fully understood, since most wastewater plants cannot completely remove pharmaceuticals.

- **Antibiotic resistance link:** Though mainly associated with antibiotics, antidepressants have also been shown in studies to influence microbial communities, possibly contributing indirectly to resistance issues that affect human health.

Using Antidepressants with Caution

Although it remains uncertain whether antidepressants directly reduce fish survival, evidence shows that even at concentrations currently found in the environment, these drugs can alter how fish function and perform. At higher levels, their effects only intensify. This raises wider concerns. In recent years, medical experts have cautioned that antidepressants, despite their clear therapeutic benefits, may be over-prescribed. Many of these medications also carry a risk of dependence, making their widespread use even more troubling. While antidepressants are often treated as the first line of defence against depression and related disorders, some psychiatrists and pharmaceutical researchers argue that therapy and lifestyle interventions may be sufficient for managing many mild to moderate cases. If the global reliance on antidepressants continues to grow, environmental concentrations could approach critical thresholds posing risks not only to fish, but also to other wildlife and potentially humans. Such consequences would come at a cost to ecosystems, a price we cannot afford to pay.

Conclusion

The increasing use of antidepressants worldwide, coupled with their incomplete removal in wastewater treatment plants, has resulted in their persistence in aquatic environments. Even at low concentrations, these biologically active compounds can disrupt critical physiological and behavioural processes in aquatic organisms, particularly fish, with consequences for reproduction, development, stress regulation, and survival. Early-life exposures are especially concerning due to long-lasting and multigenerational effects, which may alter gene regulation and stress responses across generations. The potential for bioaccumulation and transfer through the food chain raises concerns for human health, especially under conditions of chronic exposure. While antidepressants remain essential in the treatment of depression and anxiety, over-prescription and dependence highlight the need for more cautious and balanced use. Addressing this issue requires improved wastewater treatment technologies, regular monitoring, and the integration of non-pharmaceutical interventions in healthcare. Safeguarding ecosystems

and human health ultimately depend on a more sustainable approach to both pharmaceutical usage and environmental management.

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SMART HARVESTING SOLUTIONS: ADVANCING COTTON FARMING PRACTICES

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Abstract

The harvesting is one of the most labor-intensive operations in cotton production. The introduction of cotton harvesters has significantly improved efficiency, reduced labor dependency, and enhanced the overall productivity of cotton farming. A cotton harvester is a mechanized device designed to pick or strip cotton fibers from the bolls while minimizing damage to the plant and lint. There are mainly two types of cotton harvesters: **spindle pickers** and **stripper harvesters**, each suited to specific field and crop conditions. The use of modern harvesters not only accelerates the harvesting process but also ensures uniform collection, reduces field losses, and enables timely harvesting, which is crucial for maintaining fiber quality. This project discusses the design, working principle, components, advantages, and limitations of cotton harvesters, emphasizing their role in agricultural mechanization and sustainable cotton production.

Introduction

The cotton harvester is a machine designed for harvesting cotton bolls. There are two main types of mechanical cotton harvesters: strippers and pickers. Strippers remove entire plants including open and unopened bolls along with leaves and stems, which are later cleaned at the gin. Pickers, often called spindle-type harvesters, remove only the cotton from open bolls, leaving the rest of the plant intact. The key technology in spindle pickers involves rapidly rotating spindles that wrap cotton fibers around them and a device called a doffer that removes the cotton from the spindles to collect it in a basket. Although the first patent for a cotton

harvester was issued in 1850, widespread development and acceptance only occurred in the 1940s, with major advances such as the introduction of a moist spindle that improved cotton picking efficiency. Modern cotton harvesters have revolutionized cotton farming by significantly reducing manual labor, improving harvesting speed, and increasing yield quality, which has modernized the cotton industry substantially

COTTON HARVESTING SYSTEMS

A cotton harvesting system refers to the methods and machinery used to remove cotton from the plants efficiently and transport it for further processing. The two primary mechanical methods are spindle pickers and stripper harvesters, both of have largely replaced manual hand-picking in major cotton-producing .

TRADITIONAL METHODS

Traditional methods of cotton harvesting primarily involve handpicking, where workers manually pluck the cotton bolls from the plants. This method requires skill and care to select only the mature cotton bolls while leaving unripe ones to develop further. It is labor-intensive but offers advantages such as higher quality control, reduced contamination with leaves and other plant materials, and the ability to perform multiple rounds of picking as bolls mature at different times. Handpicking is also more suitable for small or irregularly shaped fields and remains widely used in countries like India.

The process of manual cotton harvesting Involves identifying fully opened mature bolls, carefully removing the cotton from the boll without damaging the fibers, collecting the cotton in bags or baskets, and repeating this over several weeks as more bolls ripen. While it provides employment and quality benefits, it is time-consuming and limited by labor availability and weather conditions.



MECHANICAL METHODS

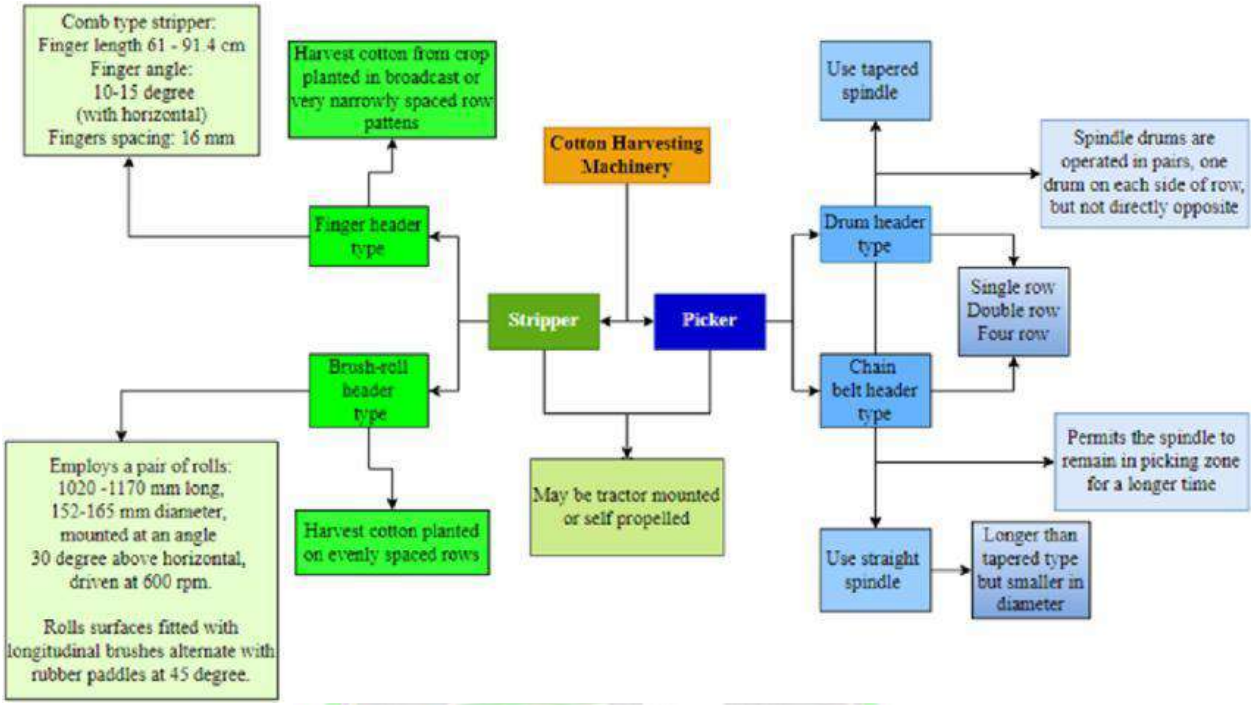
Mechanical methods of cotton harvesting primarily involve two types of machines: cotton pickers and cotton strippers.

Cotton pickers use rotating spindles to selectively pluck the cotton fibers from the open bolls while leaving the rest of the plant intact, including unopened bolls and the bur. This method is typically used for high-quality cotton harvesting and is common in regions where the plants are larger and open bolls are abundant. Spindle-type cotton pickers rotate rapidly, wrapping cotton fibers around the spindle for collection, then the cotton is removed by a doffer onto a basket on the machine. Modern cotton pickers are usually self-propelled and harvest multiple rows simultaneously .

Cotton strippers, on the other hand, remove the entire boll—both open and unopened—along with leaves, stems, and burs. This method is non-selective and is suited for smaller plants or cotton varieties with shorter fibers. The harvested material then goes through cleaning processes to separate cotton from the plant matter. Strippers are generally used in ultra-narrow row cotton cultivation or where higher impurity tolerance is acceptable or expected. Stripper harvesters operate by either two inclined rotating rollers or a roller and a stripping bar to remove the plant material .



FLOW CHART



SPECIFICATION

- Cotton harvesters come in various types and models with differing specifications depending on design, capacity, and technology. A few representative specifications of modern cotton harvesters include:
- Engine power: Around 555 HP for large models like the John Deere CP770.
- Harvesting speed: Up to approximately 7.4 km/h (4.6 mph).
- Operational width: Usually from 2 rows up to 6 rows depending on the model.
- Module building: Features for packing cotton into round or rectangular modules with wrap systems for protection.
- Harvesting mechanisms: Include pickers and strippers; pickers remove cotton from opened bolls, while strippers remove cotton along with burrs/sticks from the plant. Collection capacity: Often equipped with large baskets (e.g., 13 Q. Mtr) or tanks up to 20 kg capacity for cotton gathering.
- Frame dimensions: Approximately 9 to 10 meters long, about 3.8 to 4.3 meters wide and high in operating condition.

Conclusion

The conclusion of cotton harvester usage highlights that the adoption of cotton harvesters has revolutionized cotton farming by significantly increasing efficiency and productivity. These machines deliver faster cotton picking compared to manual labor, reduce labor costs, and maintain consistent quality standards of the cotton fibers. Modern cotton harvesters are also equipped with advanced technologies such as sensors and data collection systems that enhance precision and support sustainable farming practices by minimizing environmental impact. Despite challenges, mechanization with cotton harvesters is essential for meeting the rising global demand for cotton and ensuring profitability for farmers as well as improved overall cotton quality

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PRECISION WEED MANAGEMENT USING ARTIFICIAL INTELLIGENCE

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Introduction

Weed management plays a crucial role in ensuring agricultural productivity and food security. Weeds compete with crops for essential resources such as water, nutrients, sunlight, and space, leading to significant yield losses and reduced crop quality. According to global estimates, weeds alone can cause up to 30–40% loss in agricultural production if not effectively managed. Traditional weed control methods, including manual removal and uniform herbicide application, are not only labor-intensive and time-consuming but also pose serious environmental and health hazards due to the overuse of chemicals. Moreover, these conventional practices often lack precision, resulting in non-target crop damage, herbicide resistance, and soil contamination.

With the rapid advancement of digital technologies, Artificial Intelligence (AI) has emerged as a transformative tool in modern precision agriculture. AI enables site-specific, data-driven decision-making by integrating sensors, imaging systems, and machine learning algorithms to monitor and manage crops more efficiently. In the context of weed management, AI provides the capability to automatically detect, classify, and localize weeds among crops using high-resolution images captured by drones, autonomous robots, or ground-based cameras.

AI-ASSISTED WEED MANAGEMENT:

What is it

AI-assisted weed management refers to using artificial intelligence (AI) technologies — especially computer vision, machine learning, deep learning — combined with robotics / sensors / unmanned aerial vehicles (UAVs) / Internet of Things (IoT) etc., to:

- **Detect** weeds (versus crops or soil) in field images
- **Classify** weed species or growth stages
- **Localize** where weeds are (spatial location, mapping)
- **Decide** when and where to apply interventions (e.g. spot spraying, mechanical weeding, laser, thermal, or robotic removal)
- **Operate** robotic/automated platforms to carry out the intervention with minimal human labor

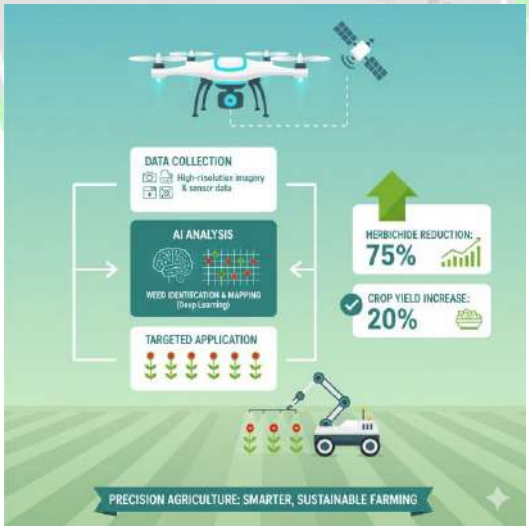


HOW IT WORKS :

1. **Data Acquisition**
    - Ground cameras, drone/UAV imaging, multispectral / hyperspectral sensors, RGB/thermal imaging
    - Sometimes combined with other sensors (soil moisture, environmental)
2. **Preprocessing & Dataset Preparation**
    - Annotated images (weed vs crop vs soil), possibly weed species, growth stages
    - Dealing with lighting, occlusion, shadows, variations in background
3. **Modeling / AI Algorithms**
    - Deep learning object detection (e.g., YOLO, RetinaNet, DETR) for locating weeds
    - Semantic/instance segmentation (e.g. U-Net, SegNet) to distinguish weed area precisely

- Classification models (to recognize weed species or stage)
- Transfer learning, data augmentation to help when data are limited

4. **Decision Logic / Control**
    - Deciding spot vs blanket treatment
    - Mapping weed density and deciding intensity of intervention
    - Integration with robotics, sprayers, arms, or mechanical weeders
5. **Deployment Platform**
    - Robotic spot-sprayers
    - Autonomous weeding robots
    - UAVs/drones for imaging or even spraying
    - Edge devices for processing (to enable real-time or near real-time)
6. **Feedback & Monitoring**
    - Monitoring success (weed kill rate, crop damage)
    - Measuring environmental impact (herbicide runoff, etc.)
    - Adjusting models over time



EXAMPLES/CASE STUDIES:

- **Robotic spot-spraying on sugarcane farms**: Trials over ~25 hectares showed that a robot with computer vision & deep learning achieved almost the same weed control (~97%) compared to broadcast spraying, but with **~35% less herbicide** usage; in low weed density strips, reduction up to ~65%. Also, herbicide runoff in water reduced significantly.

- **Weed Net foundation model**: A large-scale AI model trained to recognize ~1,593 weed species globally; local fine-tuning for specific regions (e.g. Iowa) yielded high accuracy (~97.4%) for local weed sets. Good generalization across species and growth stages.
- **Targeted weed management of Palmer amaranth using robotics & YOLOv7**: Developed full stack with a gantry-based sprayer; achieved ~60% precision and ~62% recall in real-time detection during different growth stages. Shows viability but also room for improvement.

ADVANTAGES:

- **Reduced chemical / herbicide usage**, which means cost savings and reduced environmental damage.
- **Increased precision**: Only the weed-infested parts are treated, minimizing crop damage.
- **Labor savings**: Less manual weeding or broad spraying.
- **Potential improvements in yields** because weeds compete less for nutrients/water/light.
- **Better environmental outcomes**: Less runoff, less herbicide residue, slower development of herbicide resistance.
- **Scalability**: Drones or robots can cover large areas, or difficult/remote terrain.

CHALLENGES & LIMITATIONS:

- **Dataset limitations**: Insufficient annotated images covering all species, growth stages, lighting / environmental variation.
- **Real-world variability**: Shadows, occlusion, similar appearance between weeds and crops, overlapping plants.
- **Resource constraints**: Edge computing vs cloud computing tradeoffs; power, hardware costs.
- **Implementation cost**: Robots, sensors, UAVs, maintenance can be expensive — especially for small farmers.
- **Latency and speed**: For real-time detection and treatment, inference must be fast. Some models are heavy.
- **Farmer acceptance and usability**: Digital literacy, cost, trust in technology.
- **Regulatory and safety issues**: Use of chemicals, drones, lasers etc.
- **Generalization**: Models trained in one region or on specific weed species may not work well in another without retraining or adaptation.

FUTURE DIRECTION:

- **More robust datasets**: Cover more weed species, growth stages, environmental conditions; open datasets.
- **Lightweight / efficient models** for edge deployment (low power devices).
- **Multi-sensor fusion**: RGB + multispectral + thermal etc. to better distinguish weeds.
- **Human-AI interaction**: Systems that help farmers, rather than replace them; user interfaces, explainable AI.
- **Autonomous robotic platforms**: Further integration and optimization in real conditions.
- **Precision / adaptive strategies**: Variable rate spraying, mapping weed density, predictive models to anticipate weed outbreaks.
- **Cost reduction**: Making technology accessible for small/medium farmers
- **Sustainability metrics**: Measuring long-term environmental, economic, social impacts.



Conclusion

The integration of **Artificial Intelligence (AI)** into precision weed management marks a revolutionary advancement in sustainable agriculture. By combining **computer vision, deep learning, robotics, and sensor technologies**, AI systems are capable of accurately identifying, classifying, and controlling weeds with remarkable precision. Unlike conventional blanket herbicide spraying or manual weeding, AI-driven approaches enable **site-specific, data-guided interventions**, significantly reducing chemical usage, labor costs, and environmental pollution.

Certainly! Here are some notable references on precision weed management using Artificial Intelligence (AI), complete with direct links to the respective studies and articles:

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NATURE'S PHARMACY: THE ROLE OF FISH IN TRADITIONAL INDIAN MEDICINE

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Abstract

Fish have long served dual roles in India—as a key food source and a part of traditional healing. This study explores the ethnomedicinal uses of fishes across India, linking cultural practices with scientific insights. Various preparation methods such as whole fish consumption, fermentation, drying, and topical application are described. Species like *Channa striatus*, *Clarias batrachus*, and *Amblypharyngodon mola* are commonly used for ailments through parts like flesh, bile, or swim bladder. The pharmacological basis of these uses lies in bioactive peptides, omega-3 fatty acids, and micronutrients that aid healing and immunity. Yet, issues like contamination and overharvesting stress the need for safety validation. Integrating traditional knowledge with modern research can promote sustainable and evidence-based use of medicinal fishes, bridging India's ancient wisdom with contemporary health science.

Keywords:

Ethnomedicine; Medicinal fishes; Traditional healing; Indigenous knowledge; Ethnoichthyology; Bioactive compounds; Sustainable use; Fish-based remedies; Folk medicine; Blue medicine; India

Introduction

For hundreds of years, people living along the coast and rivers in India have used fish not only for food but also for medicine. This practice, sometimes called **ethnoichthyology** or **fish-based zootherapy**, is part of the broader tradition of ethnomedicine worldwide (Nazar *et al.*,

2024). In India, over 200 fish species are reported in the ethnomedicinal literature for the treatment of conditions such as asthma, arthritis, skin disease, digestive ailments, and more (Nazar *et al.*, 2024). In this article, I highlighted what is known, proposed candidate species likely used in India, discussed mechanisms and risks, and suggested directions for future research.

Traditions Along the India : What We Can Infer

Direct academic documentation of fish-based medicinal practices in Tamil Nadu, Kerala, Andhra Pradesh, Karnataka, or Puducherry is limited. However, combining general Indian reports, media accounts, and knowledge of fish fauna from Indian waters allows us to infer plausible practices. Some of these remain local oral traditions, temple practices, or ritual healings.

One widely publicized practice is the **live fish asthma cure**, where a small live fish (often a sardine or murrel) with an herbal paste is swallowed by a patient with bronchial asthma. The fish is believed to deliver the medicine internally. Though much of the reporting is journalistic, it highlights how fish are symbolically thought to carry medicinal effects via life.

In coastal Tamil Nadu and Andhra, small pelagic fishes (anchovies, sardines, and mackerel) and freshwater fish from backwaters or estuaries are readily available. In local folk knowledge, older healers sometimes prescribe fish broth (especially of oily fishes) for generalized weakness, postpartum recovery, cough, and rheumatic pain. These might not have been formally recorded yet.

Because many medicinal uses in India involve **organ parts** (e.g., swim bladder, liver, brain), one may hypothesize that southern coastal fish with well-developed swim bladders (e.g., some clupeids, carps) or lipid-rich species (e.g., mackerel, sardines) could be used in local traditions.

Parts Used & Preparation Methods in Medicinal Fish Species of India

1. Whole Fish Consumption

In many indigenous communities, the entire fish, including its head, bones, and flesh, is consumed. This holistic approach ensures the intake of all nutrients and medicinal properties inherent in the fish. For instance, small indigenous freshwater fish species are traditionally prepared and consumed as whole fish in Northeast India.

2. Fermented Fish Products

Fermentation is a common preservation method that also enhances the medicinal properties of fish. In Manipur, the small Indian flying barb (*Puntius sophore*) is sun-dried and ground into a powder, which is then mixed with aroid petioles and fermented in an earthen pot to produce *Hentak*, a fermented fish paste consumed for its health benefits.

Similarly, in Manipur, *Ngari* is a fermented fish product made from sun-dried pool barbs, packed tightly in an earthen pot with a small amount of vegetable oil and sealed for fermentation. This condiment is rich in protein and essential nutrients.

3. Drying and Smoking

Drying and smoking are traditional methods used to preserve fish and enhance its medicinal properties. In Assam, fish is washed, rubbed with salt, and dried in the sun for several days to produce products like *Karati*, *Bordia*, and *Lashim*. These preserved fish products are used in various medicinal preparations.

4. Medicinal Preparations

The preparation methods for medicinal use vary depending on the ailment being treated. Common methods include:

- Crushing or Powdering: Fish parts are crushed or powdered and consumed directly or mixed with other ingredients.

Boiling: Fish is boiled, and the resulting broth is consumed for its healing properties.

- Application: Certain fish parts are applied topically for wound healing or skin ailments.

These methods are employed based on the specific therapeutic needs and the fish species used.

5. Cultural Significance

The preparation and consumption of medicinal fish are not only health practices but also hold cultural significance. For example, in Odisha, *Maachha Bihana*, a dish made from fish roe, is prepared by mixing the roe with a paste of black gram dal and spices, forming small balls that are fried and made into a curry. This dish is traditionally prepared during the monsoon season and is believed to have health benefits.

Modes of Use, Preparation and Ritual

In India, fish-based remedies are administered via several modes:

- **Oral ingestion**: fish flesh and organ extracts (e.g., swim bladder, liver, and brain) are boiled, dried, powdered, or made into broths and consumed for general strength, anemia, postpartum recovery, coughs, and joint pain.
- **Contact or topical application**: fish paste or extracts are applied externally for skin conditions, boils, and inflammation.
- **Live fish ritual**: a live fish, often coated with herbal paste, is swallowed or allowed to swim internally (rare but dramatic). The best-known is the asthma-cure fish. While not widely documented in academic sources, media accounts highlight its persistence in folk belief.
- **Ichthyotherapy/fish pedicure**: fish cause mechanical exfoliation of dead skin. While mainly commercial now, analogous local practices may exist in folk skin care.
- **Composite remedies**: often fish parts are combined with herbal medicines or spices, increasing the 'medicine' value via synergy.

Potential Mechanisms and Pharmacological Basis

- **Nutritional support**: Fishes are high in quality protein, essential fatty acids (especially omega-3s), vitamins (A, D, and B12), and minerals (zinc and selenium). For general weakness, convalescence, and anemia, such nutrition could support healing (Iqbal *et al.*, 2023).
- **Bioactive molecules**: Fishes contain peptides, enzymes, antioxidants, lipids, and small molecules. Some reviews emphasize fish-derived peptides with antimicrobial, anti-inflammatory, or anticancer potential (Sonar *et al.*, 2025; Nazar *et al.*, 2024). In Asia, compounds from fish have been explored in pharmaceutical research (Nazar *et al.*, 2024).
- **Mechanical / exfoliation effects**: In skin therapy, fish nibble dead skin, stimulating renewal and improving skin health (ichthyotherapy literature).
- **Ritual / placebo / psychosocial effect:** Some benefits may come from belief, the act of care, or other indirect effects.

Table 1 – List of Fishes and their medicinal uses (Sonar *et al.*, 2025)

No.	Scientific Name	Family	Part Used	Disease / Ailment Treated
1.	*Amblypharyngodon mola*	Cyprinidae	Head / Flesh / Whole fish	Improves eyesight; increases blood cells; relieves

				stomach pain, pox, asthma, premenstrual pain
2.	*Anguilla bengalensis*	Anguillidae	Fats / Head	Rheumatoid arthritis; piles
3.	*Labeo pangusia*	Cyprinidae	Whole fish	Health tonic; energy booster
4.	*Puntius* sp.	Cyprinidae	Head / Whole fish	Improves memory; blood purifier
5.	*Anabas testudineus*	Anabantidae	Whole fish	Jaundice, cold, fever, menstrual cramps
6.	*Badis badis*	Badidae	Flesh, Head	Post-partum respiratory issues
7.	*Channa gachua*	Channidae	Head / Whole fish	Arthritis, joint pain, low lactation, abdominal pain
8.	*Channa marulius*	Channidae	Flesh, Head	Improves haemoglobin
9.	*Channa punctata*	Channidae	Flesh, Head, Eyes, Whole fish	Cold, fever, kidney stone, corn removal, tuberculosis, sex stimulant
10.	*Channa stewartii*	Channidae	Whole body	Pain, diabetes, hypertension
11.	*Channa striatus*	Channidae	Head, Caudal fin	Cold, fever, wound, blood purifier, typhoid, gastritis
12.	*Trichogaster fasciata*	Osphronemidae	Head, Flesh	Jaundice, cold, fever
13.	*Labeo rohita*	Cyprinidae	Head, Flesh, Stomach, Gut, Gall bladder	Brain development, digestion, gastric ulcer, adenocarcinoma
14.	*Clarias magur*	Clariidae	Flesh	Anaemia, haemoglobin improvement
15.	*Heteropneustes fossilis*	Heteropneustidae	Flesh / Whole body	Anaemia, wound healing, pain relief
16.	*Wallago attu*	Siluridae	Skin, Head, Air bladder	Scars, liver tonic, asthma
17.	*Labeo gonius*	Cyprinidae	Whole fish, Flesh, Head	Allergic reactions

18.	*Nandus nandus*	Nandidae	Flesh, Head	Cold, fever
19.	*Botia dario*	Botiidae	Flesh, Head	Cold, fever, anaemia
20.	*Lepidocephalichthys guntea*	Cobitidae	Whole fish	Ulcers
21.	*Rasbora* sp.	Cyprinidae	Flesh, Head	Eyesight and brain development
22.	*Chitala chitala*	Notopteridae	Scales	Removes dandruff in children
23.	*Notopterus notopterus*	Notopteridae	Whole fish	Abdominal and delivery pain
24.	*Anguilla* sp.	Anguillidae	Blood / Body mucus	Weakness, burns
25.	*Trichogaster lalius*	Osphronemidae	Whole fish	Typhoid
26.	*Clarias batrachus*	Clariidae	Whole fish	Smallpox, weakness, body ache, wound healing, energy booster
27.	*Danio rerio*	Cyprinidae	Whole fish	Anaemia
28.	*Puntius sarana*	Cyprinidae	Flesh	Improves eyesight
29.	*Puntius sophore*	Cyprinidae	Alimentary canal, bile	Pain relief
30.	*Mystus carcio*	Bagridae	Flesh	Strength after illness
31.	*Mystus tengara*	Bagridae	Flesh	Regain strength

Risks, Safety Concerns, and Ethical Issues

Any medicinal practice involving fish must also consider potential hazards:

Pathogens and infections: Live fish or raw fish parts may harbor bacteria, parasites, or fungi. Oral or internal use or skin exposure opens the risk of zoonotic infections. Fish pedicures have been flagged for infection risks in poor hygiene settings.

Bioaccumulated toxins: Fishes, especially predatory or large species, may accumulate heavy metals (mercury, lead) or persistent organic pollutants. Organs (liver, swim bladder) may concentrate these, elevating risk.

Dose variability and toxicity: Folk remedies often lack standardization of dosage, purity, or preparation, raising the risk of overdose, contamination, and side effects.

Conservation and overharvest: Demand for specific medicinal fish species may push overfishing or habitat disruption, especially in ecologically sensitive coastal zones.

Animal welfare/ethical concerns: Live-fish rituals or fish pedicures raise questions of cruelty, stress to animals, and ethical treatment, particularly when fish are used in a harmful or exploitative way.

Therefore, integrating traditional knowledge with modern safety assessments is essential.

Conclusion

Fish hold a unique place in Indian tradition as both food and medicine, symbolizing the bond between culture, health and aquatic biodiversity. Ethnomedicinal practices involving fish reflect deep ancestral knowledge of nutrition and healing, supported today by emerging scientific evidence. Nevertheless, these traditions face threats from overexploitation, pollution and loss of indigenous wisdom. To preserve and validate this heritage, collaborative research among ethnobiologists, pharmacologists and fisheries experts is vital. Promoting sustainable use and scientific evaluation can transform these age-old practices into safe, eco-friendly healthcare solutions. Harnessing the healing wisdom of fishes thus offers India a pathway toward sustainable "blue medicine" for both people and the planet.

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FUNCTIONAL FEED: THE NEW FUEL FOR HEALTHY SHRIMP FARMING

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Abstract

Shrimp industry is one of the developing branches of world aquaculture, and its production has great importance in safety of food, development of the rural areas, and international trade. Nevertheless, it is subjected to unsustainability due to the high costs of feed and diseases and environmental forces. Feeds that are functional and have probiotics and prebiotics and enzymes and plant extracts and immunostimulants are imposed not only with the level of nutritional requirement of shrimp, the functional feeds also help in boosting the immunity and survival and decrease the incidence of antibiotics. Semi-intensive systems enjoy the productivity of naturally present pond life such as algae, planktons and microbes, which supplement feeds and provide better nutritional balance. Based on life cycle analyses, plant-based protein sources produce reduced carbon emissions, compared to fishmeal, and plant-based alternatives, such as soybean meal, insect meal, algae, and single-cell proteins are vital toward sustainable shrimp culturing. These technologies are an indicator of what the future of shrimp production will look like, where it is profitable, robust, and environmentally friendly.

Introduction

The culture of shrimp forms a successful industry in all aquaculture with a nutritional need, rural sector and trade world-wide. The shrimp industry is export-driven and helps national economies to prosper and fulfill the increasing need in seafood (Olmos Soto et al., 2015). Nevertheless, there are issues connected to the high cost of feeds, disease outbreaks, and

environmental pressure including water pollution and overfishing of fishmeal, and carbon emissions (Al Eissa et al., 2022).

To survive these challenges, farmers are turning towards functional and sustainable feeds that help impart vital nutrients on shrimps, improving their health, developing immunity, and minimizing the chances of diseases. This can also eliminate fishmeal and replace it with environment friendly and low-cost raw materials in the sustainable feed formulation. Collectively, these strategies can help to make shrimp farming more sustainable as well as environmentally friendly and financially rewarding (Olmos Soto et al., 2015; Al Eissa et al., 2022)

Functional Feeds – A Health Booster for Shrimp

The term functional feeds has been noticed in aquaculture as a remedy in enhancing health and productivity of the farmed shrimp. Compared to traditional feeds, in which the emphasis is primarily on supplying the basic, component nutrients-proteins, fats, carbohydrates-functional feeds have been formulated specifically to do more than simply supply nutrients. They are designed to improve shrimp health, boost immunity, and help shrimp cope with stress and disease outbreaks. The authors suggest that, in spite of this, the family unit is a helpful resource that is neglected Olmos Soto et al., (2015). Functional feeds usually contain a variety of bioactive components. The most widespread include:

• **Probiotics**: beneficial Microorganisms having beneficial health effects on the gut and digestion.

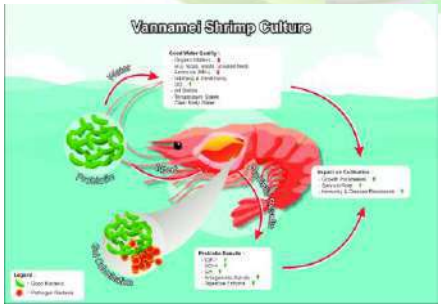


Figure 1. Role of probiotics in vannamei shrimp aquaculture (Amiin et al., 2023).

• **Prebiotics**: non-digestible foods with stimulatory effects on healthy gastrointestinal organisms.

• **Enzymes**: Enzymes assist in the digestion of complex ingredients of foods, enhancing nutrient availability.

• **Plant extracts**: deliver natural compounds, which have antimicrobial, antioxidant or growth-promoting properties.

• **Immunostimulants**: shrimp which have substances in them that help the immunity of shrimp and thus making them very strong against pathogens.

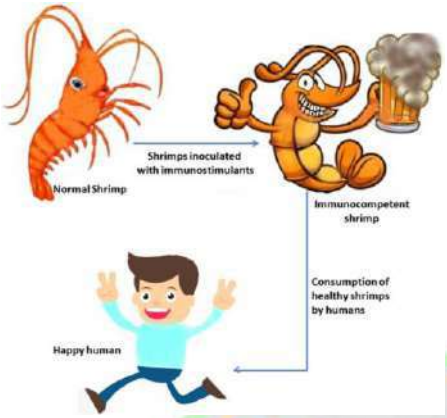


Figure 2. Effects of immunostimulants on shrimp aquaculture and its environment. Source: Kumar et al. (2022).

Nutrition and Feeding Strategies in Shrimp & Prawn Culture

Nutrition and feeding practices are central to productivity in shrimp and prawn farming. Shrimp are no different since they have to be allowed to grow, survive, and reproduce properly over a balanced diet much like any other animal. During the nutritional status Peer/Development stages, it is known that they need:

• **Proteins** - the most important nutrient, which is used as the muscle development blocks.

• **Lipids (fats)** - concentrated energy source (contains essential fatty acids) that facilitates cell functions and stress tolerance.

• **Carbohydrates** -These are the supply of energy but again, shrimp depict them less efficiently than proteins and fats.

• **Vitamins/Minerals**- In tiny amounts valuable, but crucial to metabolism, immunity, shell formation and general well-being.

Overall, nutritious food and responsive feeding practices mean improved growth, less wastage, and managerial accuracy to the farmers. Sustainable and profitable shrimp and prawn aquaculture is consequently based on proper nutrition. (D Abrampo, New, 2000)

The Role of Natural Productivity in Semi-Intensive Farming

In semi-intensive shrimp culture systems, nutriment must not only lie within the formulated feeds, yet it must also lie within the products of the natural productivity of the pond ecosystem. This natural food consists of algae, plankton, bacteria, detritus, other microorganisms and grow in the water column and in the pond bottom. These are organisms which provide an unending food supply that can supplement the shrimp diet better than the commercial feeds exclusively. (Gamboa-Delgado, 2014)

Introducing the natural productivity into the formulated feed has a number of benefits:

- **Cost saving** - less to be spent on bought feeds.
- **Nutritive balance** - in natural organisms, there are forms of micronutrients and other bioactive compounds that commonly lack artificial diets.
- **Better pond health-** by promoting the growth of microbes, better water quality and nutrient recycling is enhanced.

Using mixtures of natural productivity and formulated feeds, farmers can produce a more sustainable and efficient production system. This method does not only reduce feeding expenses but also makes the process of farming healthier, thus being compliant with the ideas of the eco-friendly fish farming. (Gamboa-Delgado, 2014)

Reducing Environmental Impacts of Shrimp Feeds

The feed that shrimp farming utilizes is one of the major factors affecting the final effect of the production on the environment. It would impact the resource consumption, waste production and green emissions since feed contributes to such factors as no one item in the shrimp aquaculture is more influential in this area than feed. According to Al Eissa et al., (2022), there is a significant improvement in follow-up care after the first 5-year period.

As recent research employing Life Cycle Assessment (LCA) has indicated, high-fishmeal, high-fish-oil feeds generate a large contribution of carbon emissions, energy use, and strain to marine environments. On the contrary, feed formulas that contain plant-based proteins like soybean meal or some other alternative feed achieve fewer carbon footprint and environmental burden.

Thus, the creation of sustainable feed formulas and selection of farming regimes are crucial measures in order to minimize the ecological effects of shrimp farm. The article reported (Al Eissa et al., 2022).

Conclusion

The world of shrimp farming is evolving, and functional feeds are an important part of enhancing immunity, dietary growth, and survival and combating disease losses. In semi-intensive system, integrated natural pond productivity ensures that the costs are minimized and performance improved by combining 100 percent balanced feeds. Sustainability is also key - instead of fishmeal, sustainable fishmeal alternatives are used e.g. plant-based, eco-friendly, and novel protein sources and include soybean, insects, algae, and single-cell proteins that reduce environmental impact. Comprehensively, functional and sustainable feeds introduce a direct route to lucrative, accountable, and green shrimp farming**.**

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THE BAOBAB TREE – A HIDDEN MYSTERY IN ITS TRUNK

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Introduction

The Adansonia is also called **"Baobab tree"** has various common names such as the **tree of life, upside-down tree, bottle tree, monkey bread tree, lemonade tree** due to its large water storing bloated trunk, unique appearance and the taste of the fruit. It also provides shelter, food and water to the people in the arid and semi-arid regions. Baobab or shortly called Boab is a deciduous tree indigenous to Africa, Australia, and the Middle East. Its distinctiveness doesn't stop at its appearance; it also includes the fruit it produces. The fruit is frequently considered a superfood because of its extraordinary nutritional value.



Features of Baobab tree

- Deciduous tree with gigantic growth and massive trunk.
- Branches clustered at the top and it looks like roots touching the sky (upside-down tree)

- Drought and Fire resistance
- Longest lifespan
- Produce large, white flowers that bloom at dusk and only last for a single night.

Species of Boabab tree

There are only 9 Types of Adansonia, all of which are native to Africa or Madagascar.

- *Adansonia Gregorii* – Australian Baobab (reach up to 20 meters in height and a bulbous base that can reach up to 5 meters in diameter)
- *Adansonia Digitata* – African Baobab ("upside-down tree." The tree's fruit and leaves have long been used in traditional African medicine)
- *Adansonia Grandidieri* – Grandidier's Baobab (enormous trunk and distinctive bottle-shaped structure and can grow up to 30 meters tall and live up to 800 years)
- *Adansonia Madagascariensis* – Madagascar Baobab (thick trunk and sparse branches)
- *Adansonia Perrieri* – Perrier's Baobab (grow up to 25 meters in height and is recognized for its thick, bottle-shaped trunk and sparse, finger-like branches; endemic to **Madagascar**)
- *Adansonia Rubrostipa* – Fony Baobab (20 meters tall and has a distinctive bottle-shaped trunk; endemic to **Madagascar**)
- *Adansonia Suarezensis* – Suarez Baobab (a large and distinctive tree with a swollen trunk and sparse branches; endemic to **Madagascar)**
- *Adansonia Za* – Za Baobab (reach up to 10 meters in height and store large amounts of water during the dry season; endemic to **Madagascar**)
- *Adansonia Kilima* – Kilima Baobab (large trunk and distinctive barrel-shaped crown. The tree is often found in savanna areas and can reach heights of up to 20 meters, mainland **Africa and Arabian Peninsula**)

Native locations of Boab tree

The mainland of Boab tree is Africa and the species African baobab (*Adansonia digitata*) is the most widespread across the dry, hot savannas of sub-Saharan Africa and parts of the southern Arabian Peninsula.

- **Africa:**

  Two species such as the African baobab (*Adansonia digitata)* and the montane African baobab *(Adansonia kilima),* are native to mainland Africa and the highlands of eastern

and southern Africa.

- **Madagascar:**

  Six of the nine baobab species are native to this island nation, with Adansonia grandidieri being one of the most famous species.

- **Australia:**

  One species, the boab tree (*Adansonia gregorii*), is native to the Kimberley region of northwest Australia.

- **Arabian Peninsula:**

  The African baobab (*Adansonia digitata*) also ranges into the southern parts of the Arabian Peninsula.

Boab tree introduced in India

Although this tree is present in India, it was introduced here centuries ago by Arab traders and are not native to the country.



An icon of the African continent - "Centuries old"

The Baobab tree can store up to 32,000 gallons water in its trunk, and they are water reservoirs in dry hot arid regions. The oldest tree is found in Tanzania which is 6000 years old. One of the rare beauties of nature, is the flower of the Baobab tree, a whim of nature that blooms once every 50 years. The Baobab takes at least eight years for the flower to bloom, it blooms at sunset, especially on the full moon and it wilts over 24 hours. This tree can live without rain for a period of ten years, and in dry periods it contains a large amount of water.

WATER STORAGE TANK/TRUNK



BAOBAB FRUITS





A little care for Boab tree

- **Soil and sunlight:** Baobabs prefer well-draining soil and plenty of sunlight. The soil with too much nitrogen can cause excessive leaf growth at the expense of trunk and root growth.

- **Watering:** Baobabs can go for long periods without water, as they have adapted to survive in dry conditions. However, they do need to be watered occasionally, especially when young.

MASSIVE AND BLOATED TRUNK (Bottle tree)



SPINDLY BRANCHES AND UNIQUE APPEARANCE LIKE ROOT REACHING THE SKY (Upside down tree)



- **Pruning:** Baobabs can be pruned to control their size and shape. The best time to prune is late winter or early spring before new growth starts. Remove any branches that are unhealthy, crossing, or rubbing against one another as well as any that are dead.
- **Fertilizing:** Baobabs do not require much fertilizer, but a slow-release fertilizer can be applied in the spring.
- **Climate:** Baobabs grow best in warm, tropical climates. In areas with colder winters, they can be grown in containers and brought indoors during the winter months.

Overall, Adansonia is a hardy and low-maintenance tree that can add a unique touch to any landscape.

Propagation techniques of Boab tree

By seeds

Baobabs can be propagated from seeds or cuttings. Seeds take a long time to germinate, so it is best to start them in the spring or summer. Cuttings should be taken in the summer, and the ends should be allowed to dry out for a few days before planting.

- Fresh seeds from a mature Adansonia tree is collected.
- Soak the seeds in water for 24-48 hours to soften the hard outer layer of the seed coat.
- Remove the seeds from the water and let them dry for a few days.
- Fill a pot with well-draining soil and plant the seeds about 1 inch deep.
- Water the pot and place it in a warm and bright location. Keep the soil moist but not waterlogged.
- Germination may take up to a month, and the seedlings will take several years to reach maturity.

By cuttings

- Take a cutting from a mature Adansonia tree that is at least 6 inches long and has a few leaves attached.
- Dip the cut end of the cutting in the rooting hormone.
- Plant the cutting in well-draining soil.
- Water the soil and cover the pot with a plastic bag to create a humid environment.
- Place the pot in a warm and bright location but out of direct sunlight.
- Check the cutting regularly and mist it with water if the soil begins to dry out.
- Once the cutting has rooted and begun to grow new leaves, it can be transplanted into a larger pot or directly into the ground.

Conclusion

Despite its unique appearance, large volume of water storing ability and potential health benefits, making them worth the effort of propagating. It also produces edible fruits and is highly valued for its medicinal properties in traditional medicine but needs scientific evidence and more extensive research on its medicinal properties. The trees are threatened due to habitual loss, deforestation, overexploitation and climate change, which has led to a decline in its population. To save and conserve the species, various efforts are being taken, and it is the need of the hour to realise the importance of growing this tree to mitigate climate change, water crisis and desertification.

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CARBON SMART FARMING: THE FUTURE OF AGRICULTURE

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Introduction

Agriculture has always been at the heart of human survival, but today it faces one of its greatest challenges **climate change**. Rising temperatures, erratic rainfall, and declining soil fertility are putting pressure on farmers everywhere. While agriculture is frequently seen as a source of greenhouse gas emissions, the very soil we cultivate could also become part of the solution. **Carbon smart farming** offers this opportunity. By implementing practices that capture and store carbon like biochar application, cover cropping, no-till cultivation, and the use of beneficial microbes farmers can turn their fields into effective allies in the fight against climate change. Even more exciting, new digital tools like AI, remote sensing, and MRV systems are making it possible to measure these carbon gains with precision, opening the door to **carbon credits** and new income opportunities. In this way, carbon smart farming represents more than just a sustainability effort it is the future of agriculture, where caring for the soil also means caring for the planet and securing farmers' livelihoods.



2.What Is Carbon Farming?

Carbon farming is a way of growing crops that not only produces food but also helps the soil **capture and store carbon** from the atmosphere.

it turns farmland into a natural sponge that traps carbon dioxide (CO_2), one of the main greenhouse gases causing climate change. Instead of letting this carbon escape into the air, it gets locked safely in the soil improving soil health and fighting global warming at the same time.

2.1 Sources of Carbon Emissions in Agriculture

Soil Degradation and Tillage Practices: Frequent tillage breaks soil structure and exposes organic matter to oxidation, releasing CO_2 into the atmosphere. Soil erosion and loss of organic carbon reduce the soil's ability to store carbon, turning it from a carbon sink into a carbon source.

Fertilizer Use and Methane Emissions from Livestock: Overuse of nitrogen fertilizers leads to the emission of nitrous oxide (N_2O), a potent greenhouse gas. Livestock, especially ruminants, emit methane (CH_4) through digestion (enteric fermentation) and manure decomposition under anaerobic conditions.

Energy Use in Farm Operations: The burning of fossil fuels for machinery, irrigation pumps, and transport produces carbon dioxide (CO_2). Dependence on non-renewable energy sources increases the overall carbon footprint of agricultural systems**.**

2.2 Practices in Carbon Farming

a) Biochar Application: It is a stable, carbon-rich material produced by heating agricultural residues (such as crop stubble, husks, or wood waste) in the absence of oxygen a process called pyrolysis. When applied to the soil, biochar acts as a long-term carbon sink, locking up carbon that would otherwise return to the atmosphere as CO_2.

Carbon Sequestration: Biochar can retain carbon in the soil for hundreds to thousands of years, reducing atmospheric CO_2 levels.

Soil Health: It enhances soil structure, nutrient retention, and water-holding capacity, especially in degraded or sandy soils.

Fertilizer Efficiency: Biochar improves the cation exchange capacity (CEC) of soils, helping retain essential nutrients like nitrogen and phosphorus.

Climate Benefit: By converting waste biomass into stable carbon, it prevents emissions from open burning and decomposition.

b) Cover Cropping: It involves planting specific crops, such as legumes, grasses, or clovers, during off-seasons when main crops are not growing. These plants protect the soil surface and continuously feed organic matter into the soil system.

Carbon Storage: The root systems of cover crops deposit organic carbon deep into the soil, enhancing soil carbon stocks.

Nitrogen Fixation: Leguminous cover crops naturally fix atmospheric nitrogen, reducing the need for chemical fertilizers and lowering N_2O emissions.

Erosion Control: Cover crops shield the soil from wind and water erosion, preventing carbon and nutrient losses.

Soil Microbial Activity: They support beneficial microbial communities that help stabilize soil carbon.

c) No-Till Cultivation: No-till (or zero-tillage) farming minimizes soil disturbance by avoiding plowing and instead planting seeds directly into the residue of previous crops. This helps preserve soil structure and retain organic carbon.

Carbon Retention: By leaving residues on the soil surface, no-till systems slow down decomposition and reduce CO_2 emissions.

Soil Structure Improvement: It enhances soil aggregation, porosity, and moisture retention, all of which contribute to long-term carbon sequestration.

Biodiversity Benefits: Reduced disturbance supports beneficial soil organisms like earthworms and fungi that build stable carbon compounds.

Energy Savings: Less machinery use also means lower fuel consumption and reduced fossil fuel emissions.

d) Microbial Biostimulants: Microbial biostimulants are formulations containing beneficial microorganisms such as rhizobacteria, mycorrhizal fungi, and actinomycetes, which promote soil health and plant growth.

Carbon Stabilization: These microbes help convert plant residues into stable soil organic matter, increasing carbon storage.

Enhanced Nutrient Uptake: They improve nutrient solubilization and absorption, reducing dependence on chemical fertilizers.

Root Growth Promotion: Stronger root systems contribute more root biomass, a significant source of soil carbon input.

Resilience and Productivity: Microbial activity enhances soil biological functions, improving plant resistance to stress while promoting carbon sequestration**.**

3.The MRV Revolution: Tracking Soil Carbon in Real Time

One of the biggest challenges in carbon farming is proving **how much carbon is actually stored in the soil**. Until recently, farmers had to depend on expensive lab tests and time-consuming field surveys. Now, a new wave of technology known as **MRV (Measurement, Reporting, and Verification)**



MRV works by combining several advanced tools to track soil carbon in real time. High resolution satellite imagery **monitors** land use, showing whether fields are under cover crops, tilled, or left bare each of which influences carbon storage. Artificial intelligence then **analyzes patterns** in soil color, vegetation health, and moisture, learning from past data to estimate carbon levels with remarkable accuracy. On the ground, remote sensors **measure** soil moisture, temperature, and organic matter, adding fine details to the bigger picture. Together, these technologies give farmers credible proof of their carbon gains, which can be used to access carbon credit markets, earn new income, and make smarter choices about practices like irrigation, fertilizer use, and cover cropping. Most importantly, MRV builds trust and transparency, turning carbon farming from a buzzword into a measurable and financially rewarding reality.

4.Economic Promise: Turning Regeneration into Revenue

The real power of carbon farming lies in its ability to transform good soil practices into a new source of income for farmers. With MRV providing reliable data, carbon markets are no longer out of reach even for small and medium growers. Farmers who adopt practices like cover cropping, biochar use, or no-till farming can now prove how much carbon their soil is storing and sell these verified savings as **carbon credits**. Each credit represents a measurable environmental benefit that companies and governments are willing to pay for as part of their climate commitments.

This approach delivers benefits on multiple levels farmers **generate additional income** while enhancing soil fertility, saving water, and cutting input expenses. By turning soil care into a profitable practice, MRV not only opens new revenue pathways for farmers but also drives agriculture toward greater sustainability and resilience.

5.Technological Backbone

At the heart of carbon-smart farming is a powerful blend of **artificial intelligence (AI) and remote sensing technologies.** AI algorithms can process enormous amounts of data, spotting patterns in soil color, crop growth, and moisture levels that are invisible to the human eye. When paired with Space and Aerial imaging technologies such as satellites and drones, these systems provide farmers with detailed maps of soil health showing where carbon is being stored, how much water the soil holds, and which areas need fertility improvements.





The result is real-time, field-specific insights delivered with speed and accuracy, helping farmers manage their land more precisely than ever before. This technological backbone is what makes modern carbon farming measurable, reliable, and scalable.

6.Case Studies & Real-World Impact

Across the world, farmers are already proving that carbon-smart practices work when supported by modern MRV systems. In India, projects using **biochar made from crop residues** have shown how waste can be turned into a long-term carbon store while also improving soil fertility and water retention. Some farmer groups are combining this with **microbial inputs**, which boost root growth and help lock carbon deeper in the soil. Globally, pilot programs in Africa, Australia, and South America are using **AI-driven MRV model** to verify carbon gains and connect farmers directly to carbon credit markets. Such models highlight how climate smart farming is no longer just a theory but a practical pathway toward healthier soils, stronger harvests, and new economic possibilities for farmers.

7.Challenges in Carbon-Smart Farming

- **Upfront Cost**: Investing in biochar, no-till equipment, sensors, or digital tools can be expensive for small and medium farmers.
- **Tech Literacy**: Many farmers are unfamiliar with advanced platforms like AI-based apps, satellite monitoring, or digital MRV systems, making training essential.
- **Data Reliability**: Carbon measurements must be accurate, transparent, and trusted by buyers; errors can weaken the credibility of carbon credits.
- **Policy & Regulations**: Strong government frameworks are needed to standardize carbon markets, ensure fair payments, and safeguard farmer interests.
- **Accessibility Gap**: Smallholders, who make up the majority in countries like India, may struggle to access these opportunities without subsidies or cooperative models.

Conclusion

2025 is a turning point for carbon-smart farming with the help of AI, satellite monitoring, and MRV systems, farmers can **measure and earn from the carbon** stored in their soils. Carbon markets make soil restoration not just eco-friendly but **profitable**, turning climate-smart practices into real income. This year, sustainable agriculture moves from aspiration to action offering healthier soils, stronger harvests, and new economic opportunities for farmers everywhere.

"Carbon smart practices are not just about storing carbon; they're about restoring life to the land."

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EPIGENETIC EFFECTS OF NUTRITION ON GENE EXPRESSION

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1. Introduction

Epigenetics is a fascinating area of genetics. It looks at how external factors and environmental conditions can affect gene expression without altering the DNA sequence. The prefix "epi-" means "above" or "on top of," highlighting that these changes occur alongside the genetic code. Researchers recognize these changes as important in various biological processes, such as embryonic development, cell differentiation, aging, and susceptibility to diseases. Many dietary components can improve human health by changing how genes associated with diseases like cancer and cardiovascular conditions are expressed. Nutritional epigenetics explores how nutrition impacts gene expression and chromatin accessibility. This field studies how dietary components affect epigenetic events, including DNA methylation and modifications to histones. When these epigenetic mechanisms are disrupted, it may lead to various human diseases, including cancer, neurodegenerative disorders, and metabolic conditions. Nutrients can reverse or modify these epigenetic events, influencing the expression of key genes involved in processes like embryonic development, aging, and cancer. For instance, bile acids, essential for digesting and absorbing fats, have recently been shown to act as signaling molecules that affect gene regulation. Understanding epigenetics is vital for personalized medicine. It reveals how

environmental factors and lifestyle choices shape health outcomes. Researchers aim to uncover the intricate relationship between genetics and the environment to identify new targets and strategies for preventing and treating diseases.

2. Basic mechanisms of epigenetic regulation

At the core of epigenetics are chemical changes to DNA (without changing nucleotide sequences) and its associated proteins, particularly histones. These changes help package DNA into chromatin. They can modify how accessible genes are to the cellular machinery that drives gene expression, determining whether a gene is active or inactive. Several mechanisms regulate epigenetics such as:

2.1 DNA Methylation: Adding methyl groups to specific cytosine nucleotides in DNA can block gene expression by preventing transcription factors from binding or recruiting proteins that silence gene activity. Diet, environmental exposure, and lifestyle choices can affect patterns of DNA methylation.

2.2 Histone Modifications: Histone proteins can undergo various chemical changes, such as acetylation, methylation, phosphorylation, and ubiquitination. These changes can alter chromatin structure and regulate gene expression. Histone modifications can be dynamic and reversible, allowing quick responses to environmental signals.

2.3 Non-coding RNAs: Non-coding RNAs, including microRNAs and long non-coding RNAs, play crucial roles in epigenetic regulation. They can bind to specific mRNA molecules to promote their degradation or inhibit their translation. Non-coding RNAs can influence gene expression in response to developmental cues, environmental stress, and disease states.

3. Foods that influence epigenetics

Certain foods can positively or negatively affect epigenetics. Some foods can promote beneficial epigenetic processes (Figure 1):

3.1 Folate-Rich Foods: Folate (vitamin B9) is essential for DNA methylation, providing the necessary methyl groups. Foods high in folate includes leafy greens like spinach and kale, legumes such as beans and lentils, and avocados.

3.2 Cruciferous Vegetables: Broccoli, cauliflower, and Brussels sprouts contain compounds like sulforaphane that can influence histone modifications and gene expression.

3.3 Soy: Soy contains the isoflavone genistein, which may reduce DNA methylation in certain genes.

3.4 Omega-3 Fatty Acids: Found in fatty fishlike salmon and mackerel, flaxseeds, and walnuts, omega-3s can affect gene expression related to inflammation and heart health.

3.5 Green Tea: Epigallocatechin gallate (EGCG) in green tea may modify DNA methylation patterns and influence genes associated with cancer.

3.6 Turmeric: Curcumin, the active compound in turmeric, has epigenetic effects that may impact inflammation and cancer pathways.



Figure 1: foods that positively impacts epigenesis

While many foods can support positive epigenetic effects, some may negatively affect gene expression:

3.7 Highly Processed Foods: Diets rich in processed foods containing added sugars, unhealthy fats, and artificial additives may lead to epigenetic changes associated with inflammation and chronic diseases.

3.8 Trans Fats: Trans fats found in fried foods, baked goods, and margarine can alter gene expression and increase the risk of heart disease.

3.9 Excessive Alcohol Consumption: Regular heavy drinking can change DNA methylation, affecting liver function genes.

3.10 High Sugar Intake: Consuming too much sugar might influence DNA methylation patterns and contribute to metabolic disorders.

3.11 Red Meat and Cancer Risk: Some studies suggest that eating red meat may alter DNA methylation and raise cancer risk.

A balanced diet rich in various nutrients supports overall health and may positively influence epigenetic processes.

4. Effect of food on epigenetic mechanisms

Food choices can significantly affect epigenetics, defined as changes in gene expression

caused by mechanisms that do not involve changes in the DNA sequence. The relationship between diet and gene expression demonstrates how what we eat influences gene activity and health outcomes (Figure 2). Dietary choices can change gene expression through various pathways:

4.1 Effect of Nutrient Availability on DNA Methylation: Food choices significantly impact DNA methylation, a key epigenetic mechanism that regulates gene expression. Nutrients in our diet directly affect these modifications. For example, compounds like folate, vitamin B12, and choline are vital for DNA methylation. Insufficient intake of these nutrients may lead to altered methylation patterns, affecting gene expression and increasing the risk of diseases like cancer and heart disorders. Additionally, certain dietary components can modulate specific microRNAs involved in processes such as lipid metabolism, inflammation, and cancer progression. Omega-3 fatty acids and phytochemicals have been shown to influence the expression of microRNAs linked to these processes.

4.2 Phytochemicals: Many plant-based foods contain phytochemicals such as polyphenols and flavonoids. These compounds can influence epigenetic mechanisms, affecting DNA methylation, histone modifications, and non-coding RNA expression. This leads to changes in gene expression patterns associated with reduced inflammation, improved antioxidant defence, and better cellular repair. Polyphenols from fruits, vegetables, and plant foods can alter histone acetylation and methylation patterns, changing chromatin structure and gene expression profiles. These changes can affect processes like inflammation, oxidative stress, and cell death, which in turn impact disease risk and overall health.



Figure 2: Effect of Nutrient Availability on DNA Methylation

4.3 Epigenetic Clocks: Recent studies suggest that dietary patterns and nutrient intake may influence epigenetic aging, as shown by epigenetic clocks, which estimate biological age based

on DNA methylation patterns. A diet high in fruits, vegetables, and omega-3 fatty acids has been linked to slower epigenetic aging, while diets rich in processed foods and sugar may accelerate the aging process.

4.4 Foetus Developmental Programming: Food choices greatly impact epigenetic regulation, shaping gene expression patterns and individual health trajectories. For instance, maternal diets high in fruits, vegetables, and whole grains are linked to beneficial DNA methylation patterns in offspring. Conversely, high-refined carbohydrate and sugar diets may lead to negative epigenetic changes that affect health. Maternal nutrition during pregnancy and early life can have lasting effects on the child's epigenome, influencing their risk of chronic diseases later in life. Research shows that maternal diet, including specific nutrients and bioactive compounds, can induce epigenetic changes in the foetus, altering gene expression and metabolic programming, which might predispose children to obesity, diabetes, and heart disease. By focusing on a nutrient-rich diet and minimizing processed foods and unhealthy fats, individuals can support favorable epigenetic profiles that reduce disease risk and enhance overall well-being.

4.5 Gut Microbiota: Food choices can shape the gut microbiota's composition and function, impacting host epigenetic regulation. The gut microbiota, which diet influences, can affect epigenetic regulation through mechanisms such as metabolites that interact with host epigenetic pathways. For example, short-chain fatty acids produced by gut bacteria can regulate histone acetylation and DNA methylation in host cells, influencing immune function, inflammation, and metabolic health.

5. Major impact of food on gene expression

Food plays a significant role in gene expression through various epigenetic mechanisms. The connection between food and genes is explored in nutrigenomics, which studies how nutrients and bioactive compounds in food interact with genes to affect health and disease risk. This relationship can be described as follows:

5.1 Gene Expression: Nutrients and bioactive compounds in food can determine which genes are activated or suppressed in cells. This regulation is crucial for processes such as metabolism, inflammation, and cell signaling. Some foods contain components that directly affect gene expression, leading to changes in cellular functions and responses. Chronic inflammation, often caused by poor dietary choices, can alter gene expression patterns. Inflammatory signals can

activate transcription factors that trigger the expression of genes related to inflammation, oxidative stress, and other connected processes.

5.2 Genetic Variability: Genetic variations, like single nucleotide polymorphisms (SNPs), can influence individual responses to dietary components. For example, variations in genes involved in nutrient metabolism can affect how the body processes carbohydrates, fats, and proteins. Understanding a person's genetic profile can provide insights into their unique nutritional needs and dietary requirements.

5.3 Epigenetic Modifications: Epigenetic mechanisms regulate gene expression without changing the underlying DNA sequence and can be influenced by dietary factors. Nutrients and bioactive compounds in food can impact epigenetic processes like DNA methylation, histone modifications, and non-coding RNA expression, leading to changes in gene expression. These epigenetic changes can have lasting effects on cellular function, development, and disease risk.

5.4 Disease Risk: The interaction between food and genes can affect a person's risk of developing specific diseases. Genetic factors, along with diet, can either increase or decrease the likelihood of conditions such as obesity, type 2 diabetes, heart disease, and some cancers. Understanding how certain food components interact with genes can help in developing personalized approaches for disease prevention and treatment.

5.5 Personalized Nutrition: Advancements in nutrigenomics have led to personalized nutrition approaches tailored to an individual's genetic profile and dietary habits. By analyzing genetic information and factors like metabolic pathways, nutrient needs, and eating behaviours, we can create nutrition plans aimed at improving health and lowering the risk of diet-related diseases. These personalized nutrition plans may include recommendations for specific dietary changes, supplements, or lifestyle modifications based on a person's unique genetic traits.

6. Role of diet in reversing the adverse effects of genetic factors

Research shows that diet can counteract negative genetic effects. While genes play a significant role in our susceptibility to certain diseases, recent studies suggest that diet can influence gene expression and may help lessen the impact of some genetic variants. Here’s how food can mitigate these negative effects:

6.1 Nutrigenomics: Nutrigenomics investigates how nutrients and bioactive substances in food interact with genes to affect health outcomes. Some dietary components can alter gene expression by turning specific genes on or off, influencing disease risk. For instance,

polyphenols found in fruits, vegetables, and plant-based foods have anti-inflammatory and antioxidant properties that may counteract the harmful effects of genes associated with inflammation and oxidative stress.

6.2 Epigenetic Modifications: Dietary factors can impact epigenetic mechanisms like DNA methylation and histone modifications. Certain nutrients and bioactive compounds may encourage positive epigenetic changes that modify gene expression and lower disease risk. For instance, folate, vitamin B12, and choline are critical for DNA methylation. Consuming enough of these nutrients can support proper epigenetic regulation, potentially reversing the adverse effects of genetic variants associated with changes in DNA methylation.

6.3 Targeted Nutritional Interventions: Personalized nutrition can consider a person's genetic makeup and dietary choices, allowing for targeted interventions aimed at reducing the negative effects of specific genetic variants. By analysing genetic data and understanding how certain genes interact with diet, healthcare professionals can offer tailored dietary advice. For example, individuals with genetic variants related to impaired folate metabolism may benefit from including folate-rich foods or supplements in their diet to support proper epigenetic regulation and decrease disease risk.

6.4 Lifestyle Modifications: In addition to dietary changes, lifestyle factors such as regular exercise, effective stress management, and good sleep can also influence gene expression and minimize the negative effects of genes associated with disease risk. A holistic approach that combines dietary changes with lifestyle modifications can improve health and mitigate the impact of genetic predisposition to certain diseases.

While diet can greatly influence gene expression and disease risk, it's important to remember that genetics is just one factor. Lifestyle also plays a key role in overall health. By following a balanced diet with nutrient-rich foods, engaging in regular exercise, managing stress, and getting enough sleep, individuals can support healthy gene expression and reduce the effects of their genetic variants on health.

Conclusion

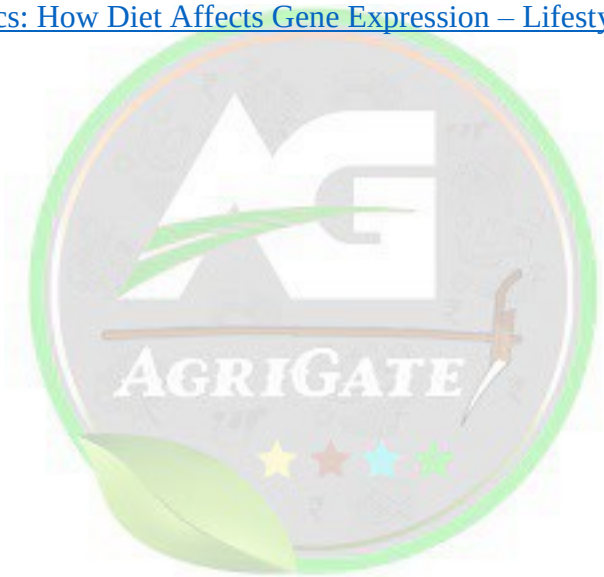
The link between food and gene expression is complex and involves both direct and indirect mechanisms. By understanding how different nutrients and dietary patterns impact gene expression, researchers and healthcare professionals can develop effective strategies for nutritional interventions and improve individual health outcomes. However, more research is

needed to clarify the complicated relationships between diet, epigenetics, and health. Our diet nourishes our bodies and affects our genes through epigenetic processes. Natural compounds have various biological activities that influence the final results in a biological system.

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Nutrition and Epigenetics: How Diet Affects Gene Expression – Lifestyle Medicine



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INSECT MEAL AS A SUSTAINABLE PROTEIN SOURCE: EMERGING TREND AND FUTURE PROSPECTS IN AQUAFEED

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Introduction

The demand for sustainable, high-quality protein sources for aquafeeds has increased as a result of aquaculture's global expansion. The main protein sources in commercial diets have historically been fishmeal and soybean meal. Significant sustainability issues, such as overfishing, land degradation, and competition with human food systems, are brought on by their use. Because fishmeal production requires a lot of resources and depends on wild fish stocks, it is susceptible both economically and environmentally as aquaculture expands quickly around the world (Macusi *et al.*, Hodar *et al.*). Concerns regarding the long-term viability of soybean farming in aquafeed are also raised by the fact that it contributes to deforestation, water use, and greenhouse gas emissions (Tschirner & Kloas).

Insect meal has become a viable substitute protein source in response to these issues. Insects like the black soldier fly (BSF) have a good nutritional profile, need little water and land, and may be raised on organic waste. According to a number of studies, fish growth performance and health can be maintained when using insect meal in aquafeeds in place of fishmeal, either completely or partially (Tran & Van Doan; Luthada-Raswiswi *et al.).*Therefore, adding insect protein to aquafeeds is a creative step toward a more robust and sustainable aquaculture sector.

Limitations of Traditional Protein Sources in Aquafeed

The extensive usage of **soybean meal (SBM)** and **fishmeal (FM)** in aquaculture has brought up serious issues with performance and sustainability. Because of its high-quality protein and necessary amino acids, fishmeal has long been regarded as the gold standard in aquafeeds, but it is now increasingly seen as environmentally unsustainable. Its heavy reliance

on capture fisheries puts strain on wild fish stocks, leads to overfishing, and reduces biodiversity. Furthermore, while the demand for aquaculture products keeps rising, fishmeal's price volatility and restricted worldwide availability have made it economically unstable (Zlaugotne *et al*.; Hodar *et al.).*

Likewise, soybean meal has drawbacks even though it's one of the most popular plant-based substitutes. Protease inhibitors and oligosaccharides, two of its anti-nutritional components, can hinder digestion and lower feed efficiency in a variety of aquatic species. Additionally, there are questions regarding the long-term environmental compatibility of soybean farming with sustainable aquaculture due to its high land and water use, deforestation, and greenhouse gas emissions (Gasco *et al.;* Chakraborty *et al*.).

Furthermore, there are species-specific performance restrictions for both fishmeal and soybean meal. When plant proteins are used in place of fishmeal or when the amount of soybeans surpasses tolerance criteria, certain carnivorous fish exhibit poor digestibility and palatability (Daniel; Hua *et al*.). Together, these problems show how urgently we need sustainable, nutrient-dense, and financially feasible substitutes for conventional protein sources.

Rise of Insect Meal as an Alternative in Aquafeeds

As the need for sustainable, high-quality proteins in aquaculture continues to expand, one of the most potential substitutes for conventional sources such as fishmeal and soybean meal is insect meal. Due to their capacity to recycle organic waste, grow on non-arable land, and provide a nutrient-dense, high-protein biomass appropriate for aquafeeds, insects like the black soldier fly (Hermetia illucens), mealworms (Tenebrio molitor), and houseflies (Musca domestica) are becoming more and more popular (Tschirner & Kloas; Vala *et al*.).

In the diets of species such as tilapia, catfish, salmonids, and shrimp, insect meals can be used in place of fishmeal in part or in full, according to recent studies, without having an adverse effect on growth, feed conversion, or survival rates. Indeed, several diets based on insects have been proven to improve gut health and immunological response in aquatic animals (Motte *et al.;* Hua).

In addition to their nutritional value, bug meals support climate-smart aquaculture by lowering dependency on overfished marine resources and soy production connected to deforestation. In terms of land, water, and greenhouse gas emissions, their life cycle

environmental impact is substantially less than that of fishmeal and soybean meal (Tran & Van Doan; Macusi *et al*.).

Adoption and investment in insect farming technology are also being accelerated by expanding market acceptability and legislative changes, such as the EU's approval of insect protein in aquafeeds. Insect meal is becoming more widely acknowledged as a key component of sustainable aquaculture going forward, not merely as a supplement, as feed prices rise and environmental pressure increases (Gasco *et al*.; Ameixa *et al*.).

Types of Insects Used in Aquafeed

1. Black Soldier Fly (*Hermetia illucens*)

The most extensively studied and economically feasible insect for aquafeed is the Black Soldier Fly (BSF). Its larvae are a potent instrument for waste valorization and the integration of the circular economy since they are high in protein (~40–45%) and lipids (~30%) and can be reared on a range of organic wastes. It has been demonstrated that BSF meal is extremely digestible and promotes superior growth performance in shrimp and fish. Its effectiveness as a partial or complete fishmeal substitute has been validated by numerous feeding trials, with no negative effects on growth, feed conversion ratio (FCR), or immunity (Devic; Sándor *et al*.).

2. Yellow Mealworm (*Tenebrio molitor*)

Larvae of yellow mealworms are likewise becoming more and more well-liked as an insect protein source. In addition to having healthy lipids and micronutrients, they are abundant in critical amino acids, especially lysine and methionine. Compared to diets based on fishmeal, yellow mealworm meal has supported growth rates that are equivalent to or even better in feeding trials including species such as rainbow trout, European sea bass, and shrimp. It is appealing for commercial scaling due to its low environmental impact and good raising efficiency in regulated settings (Thrastardottir *et al.;* Tran & Van Doan).

3. Housefly (*Musca domestica*)

The typical A valuable insect species utilized in aquafeed, especially in low-cost production settings, is the housefly. On waste substrates, its maggots can be raised effectively and harvested in a matter of days. According to studies, tilapia, catfish, and other freshwater species can safely switch out a sizable amount of fishmeal in their diets with housefly maggot meal. It also supports immunological function in cultured species and is a great source of bioavailable nutrients (Hameed *et al.;* Abasubong).

Sustainability and Environmental Benefits of Insect Meal

1. Lower Greenhouse Gas Emissions

When compared to conventional protein sources like fishmeal and soybean, insect meal has substantially reduced greenhouse gas (GHG) emissions, which is one of its most convincing environmental benefits. Raising insects, especially the Black Soldier Fly (*Hermetia illucens*), results in very low greenhouse gas emissions throughout their life cycle, especially when they are fed low-emission substrates like food and agricultural waste. In carbon footprint evaluations, dried insect meals routinely perform better than fishmeal, claim Tran & Van Doan. Aquafeed's sustainability profile is further improved by the use of insect protein, which is linked to lower emissions from the breakdown of organic waste (Auzins *et al*.).

2. Water and Land Use Efficiency

The land and water requirements of insects are significantly lower than those of marine fisheries or soybeans. Larvae of the Black Soldier Fly, for instance, may be grown vertically and don't need arable ground, which reduces land rivalry with food crops. Particularly when raised on moist sewage streams, their water needs are minimal. Soybean meal, which contributes to deforestation and water depletion in important producing countries, stands in stark contrast to this efficiency (Tschirner & Kloas).

3. Bioconversion of Organic Waste

Sustainable aquafeed systems depend on waste valorization and nutrient recycling, which are supported by insect farming. With remarkable conversion efficiency, species such as Hermetia illucens can turn manure, food waste, and agricultural byproducts into high-value biomass. This method creates nutrient-rich frass that can be used as organic fertilizer, diverts trash from landfills, and lowers methane emissions (Hasan & Lateef; Jagtap *et al*.).

4. Integration into Circular Economy Models

Aquafeeds made from insects are essential for completing nutrient cycles and enabling models of the circular bioeconomy. A circular circuit that optimizes resource usage and reduces ecological impact is established by feeding insects with pre-consumer food waste and employing them as a source of protein in aquaculture. According to studies, insect meal helps create environmentally friendly aquaponic systems that recycle inputs and outputs (such as frass) internally (Bordignon *et al*.; Tadesse).

Performance in Aquatic Species

1. Growth and Feed Conversion in Fish

In aquafeeds, insect meals have shown great promise as fishmeal substitutes, especially when it comes to growth and feed conversion efficiency. Insect-based diets can maintain similar or even better development rates and feed conversion ratios (FCR), according to studies conducted on a variety of species, including salmon, tilapia, catfish, and jade perch. For instance, in biofloc systems, jade perch (Scortum barcoo) exhibited excellent development and feed efficiency with no adverse effects when fishmeal was partially substituted with Hermetia illucens (Black Soldier Fly) meal (Zainorahim *et al*.). Likewise, rainbow trout performance did not decrease when Tenebrio molitor was added to their diets (Wissel).

2. Immune Response, Gut Health, and Digestibility

Insect meal appears to improve intestinal health and immunological function in addition to providing digestible protein. Fish immune system modulation and mucosal integrity may be supported by the chitin and antimicrobial peptides found in Black Soldier Fly and Yellow Mealworm diets. According to studies, adding insect meal can enhance intestinal shape, antioxidant capacity, and enzymatic activity, which improves nutritional absorption and disease resistance (Mousavi & Zahedinezhad); Bingqian *et al)*. Furthermore, under controlled circumstances, the digestibility of appropriately prepared insect meals—such as defatted—is on par with or superior to fishmeal (Devic; Zarantoniello).

3. Consumer Acceptance and Fillet Quality

Although insect meal works well for feeding fish, customer approval of fish fed insects depends on how they taste, feel, and look. According to some research, using large amounts of insect meal causes slight alterations in the color or flavor of the fillet, such as deeper pigmentation or a slight metallic aftertaste (Gasco *et al.)*. At inclusion rates below 25%, these effects are typically negligible or controllable, and consumer opinion improves with increased sustainability awareness and label transparency. Crucially, eating fish fillets from insect-fed diets does not harm customers' health and preserves high-quality protein and lipid profiles (Gasco *et al*.).

Barriers to Adoption of Insect Meal in Aquafeed

1. Production Scalability and Automation

Scaling up insect farming to satisfy the volume requirements of industrial aquafeed is one

of the most urgent concerns. Automation and large-scale production technologies are still being developed, despite the fact that insects like the Black Soldier Fly have great feed conversion and environmental benefits. The labor-intensive and small-scale nature of many insect farming businesses restricts their ability to compete on price with the established fishmeal and soy industries. To lower operating costs and increase consistency in product quality, the industry requires innovations in automated raising, harvesting, and processing systems (Tariq *et al).*

2. Consumer Perception and Cultural Resistance

Consumer opposition is still a major obstacle, especially in Western economies, despite the benefits of sustainability. Research indicates that market acceptance may be impacted by cultural beliefs and a psychological aversion to feeding insects to animals that are intended for human consumption. According to Comazzetto, consumer confidence is hampered by false beliefs on food safety, cleanliness, and unnaturalness. To change perception, transparent labeling and public education about the benefits and safety of insect-based diets are crucial.

3. Supply Chain Integration

Insect meal's unreliable availability, disjointed logistics, and restricted market access are all caused by the absence of established supply chains. According to Tiwasing & Pate, the majority of farmers work in siloed systems with tenuous connections to aquafeed producers, which hinders their ability to integrate into larger aquaculture value chains. This discrepancy discourages big feed manufacturers from committing to using insect meal as a primary ingredient and hinders adoption.

4. Need for Species-Specific Formulation Research

A thorough study of the nutritional requirements, digestibility, and physiological tolerances of various aquatic species is necessary to formulate insect-based feeds that are optimum for them. There are, however, knowledge gaps for other species because the majority of insect meal research has concentrated on a small number of species (such as rainbow trout and tilapia). Pennells et al. claim that in order to guarantee peak performance and economic viability across a range of aquaculture systems, focused R&D investment in species-specific formulations is required.

Future Research and Innovation Pathways

1. Genetic Improvement of Insect Strains

To improve characteristics like protein yield, growth rate, feed conversion, and disease

resistance, insects like Hermetia illucens and Tenebrio molitor require advancements in selective breeding and genetic optimization. Recent research supports the use of gene editing techniques and domestication initiatives to produce resilient, quickly growing strains that are especially suited for the production of aquaculture feed on a wide scale (Mboya, 2025; Glencross *et al*., 2024).

2. Biotechnological Processing of Insect Meals (e.g., Enzymatic Hydrolysis)

Biotechnological treatments like enzymatic hydrolysis, fermentation, and wet-blending are becoming more popular as ways to improve nutritional bioavailability and digestibility. These techniques enhance flavor profiles, boost the release of important amino acids from insect proteins, and reduce anti-nutritional elements. For delicate aquaculture species like shrimp and salmon, advancements in spray-drying and hydrolysate preparation are particularly pertinent (Fraijo-Valenzuela & Arias-Moscoso, 2024).

3. Fortification and Blending with Other Feed Sources

Insect meal can be combined with other functional or protein-rich items, such as lupin, rapeseed, microalgae, or fish scraps, to help develop meals that are species-specific and nutritionally balanced. Multi-source protein formulations have been shown to optimize feed conversion ratios, palatability, and sustainability parameters while reducing an excessive dependence on any one ingredient (Zarantoniello, 2022; Maiolo *et al*., 2020).

4. Life Cycle Assessment (LCA) Studies

When comparing the environmental impact of insect-based feeds to alternatives like fishmeal and plants, Life Cycle Assessments (LCAs) are essential tools. Particularly when raised on food or agro-waste, recent life cycle assessment (LCA) studies show that insect meal has a lower carbon footprint, land consumption, and water demand. To support regulatory acceptability and investment decisions, however, more species-specific and region-specific LCA data are required (Tran & Van Doan, 2022; Sarker, 2023; Africa, CGIAR).

Conclusion

With the potential to greatly lessen the ethical and environmental issues related to traditional ingredients like fishmeal and soybean, insect meal offers aquafeed a compelling and sustainable alternative protein source. Studies on a variety of aquatic species, such as tilapia, salmon, catfish, and shrimp, have shown that diets based on insects can maintain fillet quality

and consumer safety while achieving similar growth performance, improved feed conversion ratios, and enhanced immune responses (Zainorahim *et al.,* 2024; Gasco *et al.,* 2019).

Insect farming helps achieve important sustainability goals in addition to providing sustenance. Aquaculture can be in line with the concepts of the circular economy by raising insects like Hermetia illucens and Tenebrio molitor on organic waste, which promotes bioconversion, nutrient recycling, and greenhouse gas reduction (Tran & Van Doan, 2022; Auzins *et al*., 2024).

The genetic improvement of insect strains, biotechnological processing for better digestibility, formulation optimization, and life cycle assessments to standardize sustainability claims are important innovation pathways, but achieving this potential calls for interdisciplinary cooperation between researchers, policymakers, and the private sector (Mboya, 2025; Fraijo-Valenzuela & Arias-Moscoso, 2024).

Insect meal is at the nexus of creativity, adaptability, and accountability as the aquaculture sector throughout the world struggles to feed a growing population while protecting ecosystems. Insect-based feeds have the potential to transform global protein systems by converting waste into value, lowering ecological footprints, and contributing to the creation of a more secure and sustainable food future with sustained investment in research, scaling, and public awareness.

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THE BLACK SOLDIER FLY: THE TINY INSECT POWERING THE FUTURE OF FOOD AND FUEL

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Abstract

One of the most promising insect species for industrial, animal nutrition and sustainable waste management is the black soldier fly (BSF), *Hermetia illucens* (Diptera: Stratiomyidae). Adult BSF flies do not feed, bite or spread illness like pestiferous flies do. Food scraps, animal dung and agro industrial waste are all broken down by their larvae (BSFL), who turn them into biomass and frass that are high in protein and fat. The larvae have a high calcium content, useful medium chain fatty acids such lauric acid, 40–50% protein and 25–35% fat on a dry matter basis making them nutritionally important. These characteristics have made it possible to use them as animal feed for livestock, poultry and aquaculture. Beyond feed, BSF larvae yield chitin, antimicrobial peptides and biodiesel precursors.

Key words: Biodiesel, Black soldier fly, Insect protein, Organic waste management.

Introduction

With the world population expected to reach nearly 10 billion by 2050, a significant challenge arises in providing sustainable food for both people and animals while preserving natural resources. Conventional cattle production produces a lot of greenhouse gasses and needs

a lot of land, water and feed. As a result, finding environmentally suitable substitute proteins has emerged as a top scientific concern worldwide.

The black soldier fly (*Hermetia illucens*) has shown to be an unexpected remedy. Adult BSFs don't bite or carry disease like pest flies do and their larvae are good at recycling organic waste. They produce nutrient rich protein and fat from manure, leftover food and agricultural waste. This procedure transforms trash into value, embodying the circular economy. Because of their superior nutrition, BSF larvae (BSFL) are already utilized in aquaculture and poultry feed. They are similar to meat and fish in that they include fat, protein and necessary amino acids.

Their potential for human ingestion is currently gaining attention which will support global entomophagy trends. Globally, more than 2,000 insect species are consumed and BSFL may soon follow suit. They are perfect for large scale farming because of their versatility, quick development and self harvesting nature. In the end, the black soldier fly represents ethical, circular and sustainable food production.

Life Cycle of the Black Soldier Fly (*Hermetia illucens*)

Under warm tropical conditions, the Black Soldier Fly (BSF) goes through a complete metamorphosis with four main phases in its life cycle: egg, larva, pupa and adult. The cycle takes roughly 40 to 60 days to complete. Every step is crucial to the insect's growth and its part in the recycling process of nature.

Egg

A few days after mating, the female Black Soldier Fly produces 400–500 small eggs, marking the start of the fly's life. These rice grain like, cream colored eggs are typically found in clusters in cracks, fissures or next to organic debris that is decomposing. Instead of standing directly on waste, the female prefers dry areas near it. The eggs get darker as they get older and right before they hatch, they have a tiny black mark. Minute larvae emerge and start feeding as soon as the incubation phase which lasts approximately four to five days is over.

Larval

The BSF life cycle's most active and fruitful stage is the larval stage. The freshly hatched larvae have a little black head, a pink, curved mouth hook, soft bodies and are segmented and pale white in colour. They avoid rigid, fibrous materials like cellulose and lignin, but they are ravenous decomposers that feed voraciously on decomposing organic matter including manure, kitchen trash and other biodegradable materials. Larvae grow quickly to a length of 25–27 mm

during this stage which usually lasts 18–24 days. They have fine body hairs and turn pale brown toward the end of this stage. The effective waste recyclers found in nature, BSF larvae transform a lot of garbage into biomass that is high in nutrients. They contain around 40–45% protein and 25-35% fat making them an excellent and sustainable source of animal feed.

Prepupa

When the larvae reach the prepupal stage, they cease feeding and start to move away from the feeding area in pursuit of a dark and dry location to pupate. Large quantities of fat are stored during this time for usage later on in the non feeding pupal and adult stages. By the end of the about six to eight day prepupal phase, the insect's body has darkened in preparation for transformation.

Pupa

The prepupa sheds its skin and transitions into the pupal stage after locating a suitable dry location. The pupa has a dark, hardened exterior shell and is fully immobile, much like the prepupa. The insect experiences a tremendous transformation inside this shell. The fat reserves that were stored during the larval period provide all of the energy required for this transition. The larva transforms into a fully grown adult fly during this stage, which lasts roughly 10 to 14 days.

Adult

The life cycle of the BSF is completed when the adult emerges at the conclusion of the pupal phase. Adults are thin, wasp like flies with light yellow legs and black bodies. Males tend to look more bronze in color, while females usually have crimson abdomens. Adult flies only sip water and live for five to eight days, unlike their larval counterparts. Their only goal during this short period is to mate and procreate in order to start the next generation. One of nature's most helpful insects, adult BSF are safe for people because they don't bite or carry illness.

Nutritional Value

A sustainable, nutrient rich source of protein and fat, black soldier fly (*Hermetia illucens*) larvae can compete with or even outperform conventional feed sources like fishmeal and soybean meal. Depending on the raising substrate and processing technique, their crude protein composition varies from 40 to 50% and their lipid content from 25 to 35% (dry matter basis). They include vital amino acids that promote muscle growth and metabolism, including leucine, lysine, valine and histidine. They have antibacterial and energy boosting properties because to their medium chain fatty acids particularly lauric acid. Additionally, the larvae offer a healthy

proportion of unsaturated and saturated fats, which facilitates the absorption of nutrients. They improve immune and bone health since they are rich in minerals including calcium, phosphorus, magnesium, zinc and iron.

The nutritional value is further enhanced by vitamins B_1, B_2 and C. Their exoskeleton contains chitin and chitosan which function as bioactive fibres with antibacterial and antioxidant properties. Cellular repair is aided by nucleotides like uridine monophosphate and inosine. Larvae raised on garbage have a higher fat content, whilst those raised on manure have a higher protein content. Processing techniques maintain quality while having a minor impact on composition. All things considered, BSF larvae are a dense, safe and environmentally friendly source of protein that is perfect for aquaculture, livestock and future human diets, all of which promote a sustainable biocircular economy.

Rearing of BSF

Breeding, larval rearing, and processing are the three stages of BSF rearing.

Breeding:

- Adults require roomy flight cages with either artificial or natural light for mating.
- Water is supplied by misting devices.
- Females lay their eggs in cardboard flutes that are placed near damp substrates.

Larval Rearing

- Examples of substrates include food waste, manures and agro industrial waste.
- Plastics and hazardous elements shouldn't be found in waste.
- Substrates are ground into a fine powder before being inoculated with larvae.
- Each container holds 5,000–10,000 larvae depending on the system's size.

Processing

- Mature larvae must be harvested, cleaned and dried in order to be converted into meal or oil.
- Grass is packaged as fertilizer after being cleaned.

Optimized rearing conditions:

A temperature range of 27 to 30°C and a relative humidity of 60 to 70% are suitable for raising Black Soldier Fly. In addition, successful mating activity requires light intensity greater than 200 μ mol m^2/s.

Organic Waste Management by Black Soldier Flies

Larvae of the BSF are essential to the treatment of organic waste. They flourish on a variety of substrates like

- **Municipal organic waste** (household food scraps, restaurant waste).
- **Agro-industrial waste** (fruit processing residues, brewery byproducts, palm oil residues).
- **Livestock manure** (poultry, pig, cattle).

Mechanisms of Waste Reduction

Larvae consume large amounts of food, breaking down and digesting organic materials. Their actions limit pathogen loads, lessen moisture and odour and stop house flies which are disease carrying insects from proliferating. By lowering *Salmonella* and *Escherichia coli* in manure, BSFL can improve biosecurity.

Waste Reduction Efficiency

The Black Soldier By reducing the dry weight of municipal waste by 65–75%, fly larvae contribute significantly to the management of organic waste. About 20% of the trash is effectively transformed into useful larval biomass during this process. The larvae also significantly reduce manure in poultry waste systems, reducing it by at least 50%. As a high value organic fertilizer, frass the leftover substrate enhanced with microbial byproducts and larvae exuviae improves crop yields and soil health.

Applications of BSF

1. Animal Feed

- **Aquaculture**: BSFL meal effectively substitutes fishmeal in the diets of trout, carp, catfish and shrimp without hindering growth.
- **Poultry:** Enhanced meat quality and amino acid composition in broilers and quails, with no adverse effects observed in laying hens.
- **Swine:** A partial substitution of soybean meal promotes normal growth.
- **Pet Food:** Widely utilized in the diets of reptiles, amphibians and exotic birds.

2. Human Consumption

While not common, Black Soldier Fly larvae (BSFL) have been eaten in Sabah, Malaysia. Challenges include cultural views and the connection to waste. Transforming them into powders, oils or textured protein could enhance their acceptance. The nutritional benefits such as high

protein levels, significant calcium content and the presence of antimicrobial fatty acids, highlight their potential for incorporation into human diets.

3. Industrial Uses

Biodiesel: Oil from BSFL is transformed into biodiesel with yields similar to those of plant oils.

Chitin and Chitosan: These compounds are extracted for applications in bioplastics, pharmaceuticals and agriculture.

Organic Fertilizers: Frass improves soil fertility.

Conclusion

One essential insect for sustainable waste and food systems is the black soldier fly. Its larvae convert organic waste into nutrient rich biomass, which is then used as a feed fertilizer and a precursor to biofuel. BSF has unparalleled potential to address the worldwide issues of food security, waste management and climate change because of its balanced nutritional composition, disease suppressive properties and minimal environmental impact. Although overcoming legal, cultural and technological obstacles is necessary to scale its use, BSF has the potential to play a key role in a robust and circular bioeconomy with further study and development.

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AI AND REMOTE SENSING: THE NEW EYES OF INDIAN AGRICULTURE

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Abstract

Agriculture in India is entering an emerging era with the growing use of Artificial Intelligence (AI) and Remote Sensing (RS). These innovations are reshaping the ways farmers observe and manage their crops. Remote sensing, through satellites, drones and field sensors, gathers key data on crop health, soil moisture and environmental conditions. AI analyzes this data to provide timely insights for precision farming. Together, they enable early disease and pest detection, better irrigation planning, yield prediction and efficient use of resources. Organizations like ISRO, ICAR, CropIn and Fasal are driving this digital revolution. Studies show that AI models such as Convolutional Neural Networks (CNNs) can accurately detect crop diseases, reducing costs and environmental impact. Although costly, these innovations offer significant benefits, and adoption is steadily growing despite limited awareness and poor rural connectivity. With ongoing innovation, farmer training and strong policy support, AI and remote sensing can make Indian agriculture more productive, sustainable and climate-resilient.

Keywords: Artificial Intelligence, CNNs, Remote Sensing, sustainable

Introduction: A New Era in Indian Farming

Agriculture has always been the backbone of India's economy. More than half of the country's population still depends on farming for their livelihood. Yet, farmers continue to face age-old challenges such as unpredictable weather, declining soil fertility, pest and disease outbreaks and the rising cost of cultivation. In recent years, however, a silent revolution has

begun to transform our fields, one powered by artificial intelligence and remote sensing technologies. Together, these innovations are becoming the new "eyes" of Indian agriculture, helping farmers to see, decide and act smarter than ever before (Prakash et al., 2024).

Understanding Remote Sensing: Seeing Beyond the Human Eye

Remote sensing refers to the collection of information about the Earth's surface without directly touching it. Satellites, drones and sensors capture images and data about crops, soil and water. These images can reveal details that our eyes cannot see, such as early signs of stress, water shortage or disease (Joshi, 2025).

For instance, a satellite can detect tiny changes in leaf colour or temperature that indicate a disease attack days before it becomes visible. Similarly, drones can fly over fields and take high-resolution images to monitor plant growth or pest infestations (Bagwan, 2024). The advantage is clear, instead of visiting every acre physically, farmers or agricultural officers can get real-time updates on crop health right from their mobile screens or computers.

Artificial Intelligence in Agriculture: Driving Precision and Productivity

While remote sensing helps capture a large amount of agricultural data from satellites, drones, and sensors, AI acts as the "brain" that analyzes this information and converts it into useful insights (Pauzi et al., 2025). AI refers to computer systems capable of thinking and learn like humans, they can process data, detect patterns and take decisions using little human help (Benos et al., 2022). In agriculture, AI has become a robust tool that empowers farmers to and researchers to make faster and more accurate decisions. For example, machine learning algorithms, a subset of AI, can study leaf images to detect crop diseases during initial stages, often preceding symptom manifestation are visible to the naked eye. In the same way, AI-based models can predict crop yields, pest attacks or drought conditions by analyzing environmental, soil and weather data (Chen et al., 2023). These predictive tools help farmers plan irrigation more effectively, use fertilizers efficiently and reduce pesticide use, saving money and protecting the environment (Wang et al., 2024).

AI has also improved access to agricultural advice through chatbots and mobile applications that connect with farmers in local languages. These tools provide timely guidance on fertilizer use, irrigation schedules, pest management, and even market price trends by combining AI with modern agricultural practices, farmers can move from traditional, experience-based decision-making to a more data-driven approach. This shift not only improves productivity

and profits but also adds sustainable farming by ensuring that resources like water, fertilizers and land are used efficiently (Miller et al., 2025).

Smart Synergy: Integrating AI and Remote Sensing in Agriculture

When AI and remote sensing work together, they create a powerful system for smart and sustainable agriculture. Here's how the partnership works:

1. **Data Collection:**
   - Satellites, drones, and ground sensors capture large amounts of data like crop images, canopy temperature, soil moisture and vegetation indices.
   - This provides continuous and large-scale monitoring of agricultural fields.
2. **AI-Based Data Analysis:**
   - AI and machine learning models analyze remote sensing images to detect crop stress, diseases, or nutrient deficiencies.
   - Deep learning models like CNNs can accurately identify disease symptoms such as yellow mosaic or leaf spot from drone or satellite imagery.
   - AI can also interpret vegetation indices like NDVI to monitor crop health, predict yield and assess drought or water stress.
3. **Decision Support for Farmers:**
   - AI-driven systems convert analyzed data into actionable advice, such as:
     "Irrigate this section tomorrow."
     "Apply fertilizer in this area."
     "Spray fungicide in the affected zone."
   - This helps in precision application of water, fertilizers and pesticides.
4. **Improved Efficiency and Sustainability:**
   - The integration of AI and remote sensing reduces costs, saves time and improves yield.
   - It promotes eco-friendly farming by minimizing resource wastage and protecting the environment.
5. **Farmer Empowerment and Accessibility:**
   - AI-powered mobile apps and chatbots share real-time recommendations in local languages, making technology accessible to smallholder farmers.

Applications in Indian Agriculture

a. Disease and Pest Detection

Diseases such as yellow mosaic virus in mungbean or late leaf spot in groundnut can cause severe yield loss. By using drones or satellite imagery, infected patches can be detected early. AI models, like CNNs, can classify disease symptoms on leaves with more than 90% accuracy. Farmers can subsequently implement targeted interventions instead of spraying the entire field, saving both money and effort (Dubey et al.,2025).

b. Crop Health Monitoring

Vegetation indices like NDVI (Normalized Difference Vegetation Index) and GNDVI derived from satellite data indicate how healthy the crops are. A high NDVI means the crop is healthy and green; a low NDVI may signal poor growth or disease stress. AI tools can process these values into simple colour maps, green for healthy, yellow for moderate stress, and red for critical areas, helping farmers act on time (FAO, 2023).

c. Precision Irrigation

Remote sensing data helps in identifying areas with water stress. AI models can predict the right time and amount of irrigation needed. This approach, called precision irrigation, ensures that water is used only where and when required, which is crucial in drought-prone regions (World Bank, 2024).

d. Yield Prediction

AI-based models trained on weather, soil, and satellite data can forecast yield well before harvest. This helps farmers plan storage, marketing and pricing strategies more effectively (ISRO, 2024).

e. Soil Health and Nutrient Management

Sensors and drones can monitor soil moisture levels and nutrient content. AI interprets this data to recommend the right fertilizer dose for each part of the field, improving soil health and reducing excess use of chemicals.

Summary of Literature on Smart Farming Applications Using AI and Remote Sensing

Sr. No.	Function	Description	Challenges and future scope	References
1.	Weeding (Computer vision assisted system)	The weeding mechanism integrates a servo motor with a computer vision system that identifies crop locations and guides the	The system achieved an accuracy of 93.6% using a Haar cascade classifier implemented with the OpenCV open-source	Nanda and Reddy (2018)

		actuator to remove weeds without causing damage to the plants	framework, indicating its potential for future use.	
2.	Soil moisture detection	Accurate temperature regulation using halogen heating technology combined with high-precision weighing capabilities	Durable construction, integrated performance testing, and a complete service package.	(Hanson et al., 2007)
3.	Spraying	In this method, the size of spraying droplets is estimated using a filter paper-based titration approach, and the correlation between the size of coloured spots and the droplet size is determined through regression analysis	Offers a simplified approach for data collection, sampling, droplet measurement, and research on novel plant protection machinery.	Shang et al. (2004)
4.	Crop yield monitoring systems	The system comprises mass flow and volume flow methods, positioned beneath positioned beneath the pivoted auger under the grain tank and at the center of the elevator, respectively utilize weighing-type, impact-type, and radiometric units, whereas Volume flow methods include paddle wheel and optical-type units	The design and fabrication of equipment for a specific crop can be influenced by the sensing approach employed. To ensure accurate monitoring, appropriate signal processing and correction methods should be implemented.	Chung et al. (2016)

Real world examples from India

a. ISRO and remote sensing in agriculture

The Indian Space Research Organisation (ISRO) has played a major role in developing satellite-based agricultural monitoring.

The Bhuvan and FASAL platforms provide crop condition maps, drought alerts, and yield forecasts for major crops across the country.

b. ICAR and smart farming initiatives

The Indian Council of Agricultural Research (ICAR) is promoting AI-driven projects under its "Digital Agriculture Mission." Many agricultural universities, like UAS Dharwad, have begun using drone-based image analysis to detect crop diseases and estimate yield.

c. Private sector innovations

Agri-tech startups such as CropIn, SatSure and Fasal are using AI and remote sensing to deliver customized advisory services to farmers through mobile apps. Farmers receive messages about irrigation, pest alerts, and harvest timing based on satellite data.

Benefits to farmers

1. Early problem detection: Farmers can act before diseases or pests spread widely.
2. Reduced input cost: Targeted spraying and irrigation save money.
3. Better yield and quality: Timely decisions improve productivity.
4. Climate resilience: AI models help farmers plan for weather risks.
5. Market linkage: AI platforms connect farmers directly to buyers and markets.

Challenges in adoption

Despite the potential, several hurdles slow the widespread use of AI and remote sensing in Indian agriculture:

- Lack of awareness among farmers.
- High initial cost of drones and sensors.
- Limited internet connectivity in rural areas.
- Requirement for local language accessibility in mobile applications.

Government programs, extension services and partnerships with startups can help overcome these challenges. Training farmers and providing community level technology centers will make digital farming more inclusive.

Conclusion

AI and remote sensing truly act as the new eyes of Indian agriculture. They allow farmers to see beyond what the naked eye can observe, detecting hidden stress, predicting yield and making smart decisions. With increasing affordability and accessible, they will bring a new green revolution, one driven by data, precision and sustainability.

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BIOCHAR IN THE CIRCULAR ECONOMY: TURNING WASTE INTO VALUE

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Introduction

The global shift toward sustainable and resource-efficient systems has made the circular economy a cornerstone concept in addressing environmental and economic challenges. At its core, the circular economy seeks to redefine growth by decoupling economic activity from the consumption of finite resources and designing waste out of the system. In this evolving landscape, **biochar** a carbon-rich byproduct obtained through the pyrolysis of biomass—has emerged as a pivotal solution bridging waste management, soil health improvement, climate change mitigation, and renewable energy production.

Produced from agricultural residues, forestry waste, animal manure, and other organic materials, biochar holds immense promise as a value-added product that can close nutrient loops and create long-term carbon sinks. By integrating biochar into the circular economy framework, we can transform waste into a sustainable resource, enhance soil fertility, sequester carbon, improve water retention, and even purify polluted environments. This article explores the multifaceted role of biochar in the circular economy, examining its production processes, applications, benefits, challenges, and future prospects.

1. Understanding Biochar: Composition and Properties

Biochar is a stable, carbon-rich material produced through pyrolysis—a thermochemical process that decomposes organic matter in the absence or limited presence of oxygen. The process not only yields biochar but also generates syngas and bio-oil, contributing to the overall energy

efficiency of the system.

Key Characteristics of Biochar:

- **High carbon content** (up to 80-90%)
- **Porous structure**, enhancing water and nutrient retention
- **Alkaline pH**, which can neutralize acidic soils
- **High surface area**, suitable for microbial colonization and adsorption of contaminants
- **Resistance to microbial degradation**, enabling long-term carbon sequestration

The physicochemical properties of biochar are influenced by factors such as feedstock type (e.g., wood chips, crop residues, manure), pyrolysis temperature, and residence time. These characteristics determine its suitability for specific applications in agriculture, waste management, and environmental remediation.

2. The Circular Economy: Principles and Relevance

The circular economy is a regenerative model that emphasizes:

- **Designing out waste and pollution**
- **Keeping products and materials in use**
- **Regenerating natural systems**

Unlike the traditional linear model of "take-make-dispose," the circular economy aims to keep resources in circulation for as long as possible. Biochar aligns with all three principles by:

- Converting organic waste into a usable product (biochar)
- Enhancing soil systems and reducing the need for synthetic fertilizers
- Sequestering carbon in a stable form, thereby regenerating the carbon cycle

3. Feedstock Sourcing: Turning Organic Waste into Biochar

A key tenet of the circular economy is the repurposing of waste. In this context, biochar is a stellar example of waste valorisation. A wide variety of biomass sources can be used to produce biochar:

Agricultural Residues:

- Rice husks, corn stover, wheat straw, and sugarcane bagasse
- Benefits: Widely available and often underutilized

Forestry Waste:

- Sawdust, bark, and wood chips
- Benefits: Can be sourced from logging and timber industries

Municipal Organic Waste:

- Green waste, food scraps, biosolids
- Benefits: Helps divert waste from landfills and reduce methane emissions

Animal Manure:

- Poultry litter, cattle dung, pig manure
- Benefits: Enriches biochar with nitrogen and other nutrients

By converting these waste materials into biochar, significant environmental benefits are achieved, including reduced greenhouse gas emissions, minimized landfill usage, and improved waste handling.

4. Biochar Production and Energy Recovery: A Closed-Loop Process

The pyrolysis of biomass not only generates biochar but also releases volatile gases and condensable vapors, which can be captured and converted into energy-rich byproducts:

1. Syngas (Synthesis Gas):

Used to power engines or turbines for electricity and heat generation.

2. Bio-oil:

A liquid fuel that can be refined for industrial use or further converted to biofuels.

3. Heat Energy:

Recoverable thermal energy can be used in agricultural drying or district heating.

This energy recovery system enhances the circularity of the process, making biochar production not only a method of waste management but also an energy-generating mechanism.

5. Agricultural Applications: Enhancing Soil Health and Productivity

Agriculture is one of the most promising sectors for biochar application. When incorporated into soil, biochar improves physical, chemical, and biological properties.

Soil Health Benefits:

- **Improved water retention** in sandy soils
- **Enhanced cation exchange capacity (CEC)** for nutrient holding
- **Stimulation of beneficial soil microbes**
- **Increased pH in acidic soils**

Crop Productivity:

Studies have shown significant yield improvements in crops like maize, rice, wheat, and vegetables when biochar is applied in conjunction with organic or inorganic fertilizers.

Fertilizer Efficiency:

Biochar enhances nutrient use efficiency by adsorbing nutrients and releasing them slowly, reducing leaching and volatilization losses.

6. Biochar in Wastewater Treatment and Environmental Remediation

Beyond agriculture, biochar has gained recognition for its potential in environmental clean-up due to its adsorptive properties.

Applications:

- **Heavy Metal Removal:** Adsorbs metals like lead, cadmium, chromium from contaminated water and soils
- **Nutrient Recovery:** Removes and recycles nutrients like nitrogen and phosphorus from wastewater
- **Pesticide and Pharmaceutical Removal:** Biochar can adsorb persistent organic pollutants

By integrating biochar into wastewater treatment plants, we can reduce pollution and recover resources in a closed-loop system, fulfilling circular economy objectives.

7. Climate Change Mitigation through Carbon Sequestration

Biochar is recognized as a powerful tool for **carbon dioxide removal (CDR)**. When applied to soils, biochar resists degradation and stores carbon for hundreds to thousands of years.

Benefits:

- Long-term **carbon sequestration**
- **Reduction in nitrous oxide and methane emissions** from soils
- **Offsetting fossil fuel emissions** when pyrolysis energy is used as a renewable source

According to estimates, global-scale biochar application could sequester over 1 billion tonnes of CO_2 annually, contributing significantly to climate goals.

8. Biochar in Circular Bioeconomy and Industrial Symbiosis

Biochar plays a critical role in **circular bioeconomy systems**, where biological resources are sustainably managed and reused across sectors.

Case Examples:

- **Agro-industrial symbiosis:** Agro-waste from one industry is converted into biochar, which is used in another sector (e.g., horticulture, livestock feed)

- **Urban waste loops:** Municipal solid waste is converted into biochar and reused in green infrastructure (e.g., green roofs, tree pits)
- **Construction materials:** Biochar is being explored as a component in building materials like cement and asphalt, reducing embodied carbon

Such cross-sectoral applications strengthen the economic viability of biochar while minimizing resource extraction and waste generation.

9. Policy Frameworks and Market Development

Despite its proven benefits, the adoption of biochar on a large scale requires supportive policies, market incentives, and certification mechanisms.

Key Areas of Focus:

- **Policy Incentives:** Carbon credits, subsidies for biochar production, waste management support
- **Standards and Quality Control:** Establishing biochar grading and certification systems (e.g., IBI, EBC)
- **Research and Innovation Funding:** Investment in pilot projects, scalability research, and life cycle assessments

Governments and international bodies have started recognizing biochar as a component of climate-smart agriculture and sustainable waste management.

10. Challenges and Limitations

Despite its potential, several challenges must be addressed for biochar to become a mainstream component of the circular economy:

1. Economic Viability:

High production costs and limited demand in some regions hinder widespread adoption.

2. Feedstock Supply Chain:

Logistical and seasonal constraints in biomass collection and transport can affect consistency.

3. Technical Knowledge:

Lack of awareness among farmers, waste managers, and policymakers slows deployment.

4. Environmental Risks:

Improperly produced biochar can contain contaminants or negatively affect soil microbiomes.

Mitigating these issues through education, policy, and research will be key to realizing biochar's full potential.

Conclusion

Biochar represents a transformative opportunity to operationalize the principles of the circular economy turning waste into a resource, regenerating natural systems, and reducing environmental footprints. By leveraging agricultural, forestry, and municipal biomass waste, we can produce biochar to improve soil health, sequester carbon, generate renewable energy, and purify ecosystems. However, realizing the full potential of biochar requires multi-stakeholder collaboration, supportive policy frameworks, rigorous scientific validation, and public awareness. As we face intensifying climate and resource crises, integrating biochar into circular systems offers a scalable, scientifically grounded, and ecologically sound pathway toward sustainability. It is not merely a product but a solution—a link between waste management, agriculture, energy, and climate resilience in the 21st century.

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BIODIVERSITY OF WESTERN GHATS

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Abstract

The Western Ghats, a mountain range running parallel to India's western coast is recognized as one of the world's eight biodiversity hotspots. It harbours an exceptionally high level of species richness and endemism including over 5000 flowering plants, 139 mammals, 508 birds, 179 amphibians and numerous reptiles and fish species. The region's unique tropical evergreen forests, montane grasslands, shola forests and freshwater ecosystems provide crucial habitats for diverse flora and fauna many of which are threatened or endangered. The southern Western Ghats acts both as a "museum" preserving relict lineages and a "cradle" generating new diversity.

Keywords

Western Ghats, biodiversity hotspot, endemism, phylogenetic diversity, habitat fragmentation, conservation strategies, museum and cradle, microhabitats

Introduction

The Western Ghats, also known as the Sahyadri Hills, are a UNESCO World Heritage Site and a globally recognized biodiversity hotspot. Older than the Himalayas, these mountains extend for about 1,600 km parallel to India's western coast, traversing Kerala, Tamil Nadu, Karnataka, Goa, Maharashtra, and Gujarat. Because of its complex topography, climatic gradients, and geological history, the region hosts exceptionally high biological diversity and endemism, making it one of the 36 global biodiversity hotspots Acting as the origin for major

peninsular rivers and a moderator of the monsoon climate, the Ghats are not only a hydrological lifeline but also an evolutionary "ecotone"—a region that fosters unique ecological and evolutionary processes



Unique biodiversity richness and endemism

- The Western Ghats are home to more than 5,000 species of flowering plants, over 500 bird species, around 139 mammals, 179 amphibian species, 157 reptile species, and 219 fish species. Levels of endemism are exceptionally high: over 54% of tree species, 65% of amphibian species, 62% of reptiles, and 53% of fish are endemic to the region
- .The region includes at least 325 globally threatened species, such as the Lion-tailed Macaque, Nilgiri Tahr, and Nilgiri Langur

Floristic and Faunal Richness & Endemism

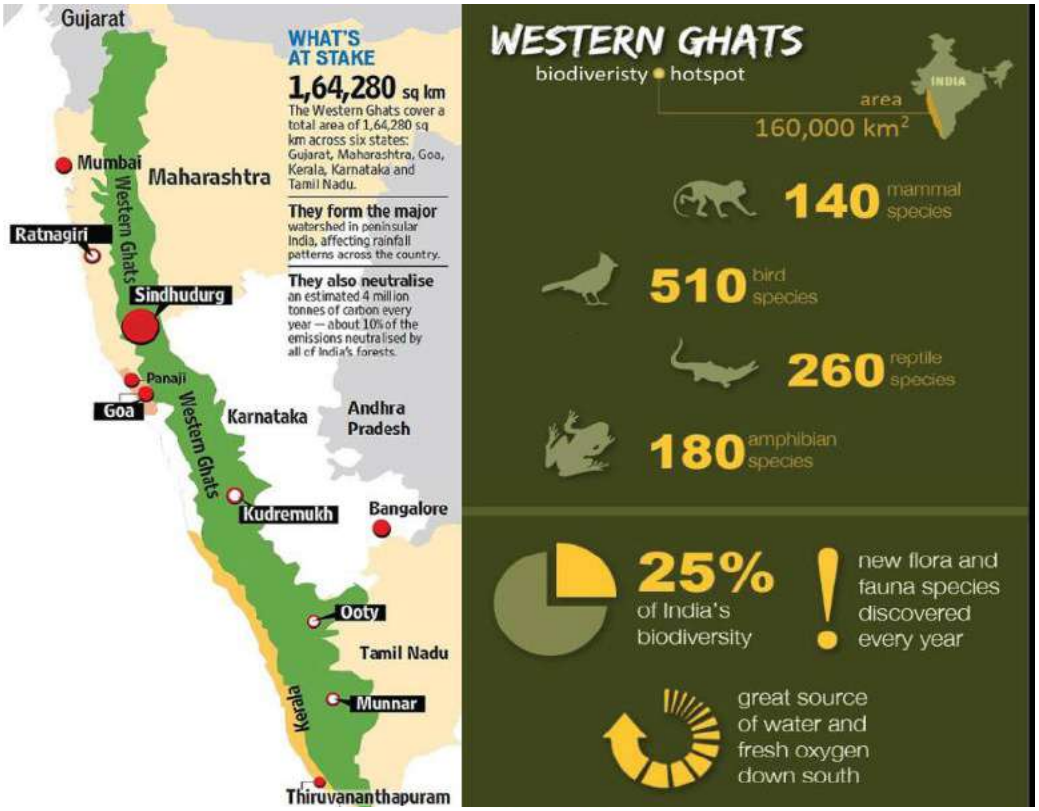
- The Western Ghats harbor over ~5,800 species of flowering plants, of which about 2,100 species are endemic to this region (i.e. ~36%)
- In fauna, the diversity is similarly striking: among amphibians, ~75 % endemism is observed; reptiles ~62 %; fishes ~41 %; mammals ~12 %; birds ~4 % endemism in this region (based on combined flora-fauna databases).
- Invertebrate groups are especially rich. For example, in a study of centipedes (soil predatory arthropods), distinct hotspots of phylogenetic endemism were found, and a latitudinal diversity gradient was observed (diversity declining from south to north) .
- In plants, the southern Western Ghats retains both ancient lineages and recently diversified taxa effectively acting as both a “museum” (preserving old lineages) and a “cradle” (where speciation continues) of diversity

Spatial / Phylogenetic Patterns & Drivers

- The Palghat Gap (~30 km wide region) constitutes a major biogeographic break in the Western Ghats, often structuring species turnover and biotic assemblages across its north

and south sides (seen in arthropods, plants)

- Phylogenetic diversity analyses (e.g. in centipedes) show that considering phylogeny (not just species counts) reveals deeper patterns: e.g. relative phylogenetic endemism can identify regions harboring older lineages that might be overlooked by species counts alone



- Microhabitats such as lateritic plateaus (e.g. Kas Plateau) support numerous endemic or restricted plant taxa, heavily influenced by soil properties, seasonality, and hydrological micro parameters. Because these plateau microhabitats are small and sensitive to disturbance, they are especially vulnerable to anthropogenic change
- Long-term paleoecological studies (e.g. pollen and charcoal analyses) suggest that human-managed agroforestry landscapes and sacred groves have coexisted for centuries, aiding biodiversity persistence and forest regeneration under appropriate management regimes

- Mismatch between protected area boundaries and microhabitat occurrence: some endemic species occur outside formal reserves or in very small patches that escape formal protection.
- Socioecological pressures: local communities depend on forest resources, sacred groves, and non-timber forest products. Balancing livelihood needs and conservation is nontrivial.

Ecological feature:

- Mountain range includes diverse ecosystems such as tropical wet evergreen forests montane grasslands and unique shola forests-high altitude stunted forest patches interspread with grasslands.
- The western ghats serve important hydrological functions as well feeding several major rivers like the Krishna , Godavari, and Cauvery which support approximately 245 million people in peninsular India

Evolutionary and Geographical Importance

- The Ghats serve as a rich living laboratory for speciation, shaped by ancient geological events like the breakup of Gondwanaland and later isolation of the Indian Plate.
- High geo-climatic stability in the south allows for persistence and diversification of lineages, whereas the north, despite lower diversity, features high local endemism.

Socio-economic and Ecological Roles

- The forests act as watersheds for major rivers like Krishna, Godavari, Tungabhadra, and Kaveri, supporting agriculture, fisheries, and water supply for millions.
- Economically, they sustain non-timber forest products, spices, and medicinal plants critical for local livelihoods

Discussion

Threats and Conservation Challenges

- The principal threats to biodiversity in the Western Ghats are habitat fragmentation, land-use change (agriculture, plantations, mining), infrastructure development, and climate change.
- Northern Ghats suffer more biodiversity loss due to greater human interference, while southern regions retain more intact ecosystems.

- Inadequate ecological research outside protected areas and on less-studied taxa (like invertebrates and lower plants) remains a crucial gap.

Conservation Efforts

- The region is safeguarded by a mosaic of national parks, wildlife sanctuaries, reserved forests, and legislations such as the Indian Wildlife (Protection) Act of 1972 and the Forest Conservation Act of 1980.
- Community-led conservation, sacred groves, and recent habitat restoration initiatives are helping to counteract habitat loss.
- The serial approach adopted for World Heritage status recognizes biodiversity differences across the landscape, ensuring protection of multiple representative habitats.

Conclusions

The Western Ghats' biodiversity is both a national and global treasure, featuring exceptional species richness, endemism, and ecological functions vital for environmental stability and human welfare. Sustained research, habitat protection, restoration, and well-enforced policies are critical to conserving this biodiversity hotspot for future generations. The conservation of this fragile mountain chain must remain a priority to preserve its ecological and evolutionary legacies.Gaps remain in taxonomic knowledge, phylogenetic resolution, and long-term ecological monitoring; addressing these is essential for robust conservation and sustainable management.

Moving forward, a synergistic approach combining field ecology, molecular phylogenetic, spatial modelling, and participatory conservation offers the best hope for safeguarding the intricate biodiversity of the Western Ghats

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Introduction

Brinjal or Eggplant**,** a fruited vegetable crop of Solanaceae family is an important global vegetable, cultivated in most of the countries of the world. Brinjal has a wide genetic diversity due to its worldwide cultivation. In fact, every geographical area has a distinct type of cultivated brinjal that are linked with its cultural and culinary properties that are specific to the geographical area. Brinjal germplasm have enormous source of many useful genes that are very important for Brinjal Improvement.

2. WILD RELATIVES OF BRINJAL

Specific related wild species of Brinjal have unique source of resistance traits that are highly needed for enhancing the yielding ability as well as quality attributes. The following wild species of Brinjal have genetic potential source for some of the biotic and abiotic resistance.

Table 1. Different wild species of *Solanum* and their source of resistance to biotic and abiotic stresses (Ram, 2006)

S. No.	Species Name	Source of resistance
1.	*Solanum incanum*	Closest progenitor; source of resistance to shoot and fruit borer (SFB), bacterial wilt and drought
2.	*Solanum insanum*	Domestication ancestor; contributes anthocyanin pigmentation, vigour and SFB tolerance
3.	*Solanum torvum*	Rootstock for bacterial wilt resistance, nematode resistance and salt tolerance

4.	*Solanum aethiopicum*	Source of SFB resistance, fruit hardness and virus resistance
5.	*Solanum macrocarpon*	Contributes tolerance to drought, nematodes and leaf spot diseases
6.	*Solanum sisymbriifolium*	Wild relative used in root-knot nematode resistance and trap cropping
7.	*Solanum integrifolium*	Fruit colour, prickliness and insect resistance traits
8.	*Solanum viarum*	Donor of mite resistance, spiny fruit traits and adaptation to marginal areas
9.	*Solanum indicum*	Contributes resistance to Fusarium wilt, root-knot nematodes and gall midge
10.	*Solanum surattense* (*S. xanthocarpum*)	Medicinal traits, spines and insect pest resistance
11.	*Solanum elaeagnifolium*	Used for drought resistance, flower morphology improvement and insect tolerance
12.	*Solanum virginianum*	Contributes hardiness and resistance to borers and wilt
13.	*Solanum trilobatum*	Source of spiny plant type and adaptation to arid zones
14.	*Solanum melongena* var. *esculentum*	Cultivated type with variation in shape, size, colour and yield
15.	*Solanum melongena* var. *serpentinum*	Contributes slender fruit type, taste and early flowering
16.	*Solanum linnaeanum*	Donor of nematode resistance, used in grafting trials
17.	*Solanum nigrum*	Weed type; contributes resistance to early blight and leaf spots
18.	*Solanum bahamense*	Salt tolerance, dense pubescence and insect resistance
19.	*Solanum mammosum*	Used for ornamental traits and study of fruit development
20.	*Solanum caripense*	Studied for fruit biochemical content and cold tolerance
21.	*Solanum khasianum*	Source of solasodine (alkaloid); used in hybridization for secondary metabolite traits

22.	*Solanum lyratum*	Provides resistance to Phomopsis and anthracnose
23.	*Solanum pseudocapsicum*	Ornamental species; used in floral and fruiting habit studies
24.	*Solanum gilo*	African eggplant; provides disease resistance and dense canopy structure
25.	*Solanum ferox*	Strong pubescence and high pest resistance
26.	*Solanum quitoense*	Tropical species; under study for unique fruit taste and pest resistance
27.	*Solanum scabrum*	Leafy vegetable in Africa; used in cytogenetic and breeding experiments
28.	*Solanum hirtum*	Resistance to whiteflies and thrips; source of CMS

3. CROSSABILITY AMONG *SOLANUM* SPECIES

Crossability among some of the important species has been reviewed by Rao, 1979. He studied crossability among ten species and reported that *S. melongena* cultivar as female parent hybridized with *S. melongena* variety *S. insanum*, *S. incanum*, *S. integrifolium* and *S. gilo* and resulted in viable seeds. It produced only shrunken seeds with *S. khasianum* and did not hybridize with *S. indicum*, *S. zuccagnianum* and *S. sisymbrifolium*. *S. melongena* as male parent hybridized with *S. indicum* and produced a number of hybrids.

Among 22 Indian species, a group of 5 related species – *S. melongena*, *S. incanum*, *S. coagulans*, *S. xanthocarpum*, *S. indicum*, and *S. macrocarpum* – occur in India. Crosses of *S. melongena* with these wild species show variable crossability. The status of viability of Fertilization and hybridization is given below.

- *S. melongena* × *S. melongena var. incanum* → Viable seeds
- *S. melongena* × *S. integrifolium* → Viable seeds
- *S. melongena* × *S. gilo* → Viable seeds
- *S. melongena* × *S. indicum* → Unsuccessful
- *S. melongena* × *S. xanthocarpum* → Unsuccessful
- *S. melongena* × *S. khasianum* → Fruit set but shrunken seed

Crosses were compatible within and between the first and second groups, but were otherwise incompatible. From various reports, it appears that *S. melongena* is more closely related to *S. incanum* than to any other species.

Table 2. Cross compatibility of different *Solanum* spp. with *Solanum melongena*

S. No	Section	Wild Species	Status of hybridization with *S. melongena*
1.	*acanthophora*	*S. capsicoides*	No germination of seeds
		S. mammosum	Abnormal seeds
		S. viarum	Virtually sterile hybrids
2.	*anisantherum*	*S. pubescens*	Virtually sterile hybrids
3.	*campanulata*	*S. campanulatum*	Abnormal seeds
4.	*croatianum*	*S. heinianum*	No fruit set
5.	*cryptocarpum*	*S. sisymbriifolium*	Death of hybrid seedlings
6.	*ischyracanthum*	*S. dennekense*	No fruit set
7.	*lasiocarpa*	*S. stramonifolium*	No fruit set
8.	*melongena*	*S. aculeastrum*	Parthenocarpic fruits
		S. beaugleholei	Parthenocarpic fruits
		S. cerasiferum	Partially fertile hybrids with normal seeds
		S. chippendalei	Death of hybrid seedlings
		S. cinereum	Virtually sterile hybrids
		S. clarkiae	No viable hybrid embryos
		S. dasyphyllum	Partially fertile hybrids with normal and empty seeds
		S. dioicum.	Parthenocarpic fruits
		S. diversiflorum.	Parthenocarpic fruits
		S. incanum, Group A (*S. campylacanthum*)	No seed germination
		S. incanum, Group B (*S. delagoense*)	Viable fertile hybrids
		S. incanum	Viable fertile hybrids

		Group C (*S. incanum*)	
		S. incanum group D (*S. lichtensteinii*)	Viable, but partially fertile hybrids
		S. linnaeanum	Viable but partially fertile hybrids
		S. macrocarpon	Viable but partially fertile hybrids
		S. marginatum.	Virtually sterile hybrids with no seed set
		S. melanospermum.	Partially fertile hybrids
		S. phlomoides	No viable hybrid embryos
		S. richardii	Partially fertile hybrids with normal and empty seeds
		S. sessilistellatu	Partially fertile hybrids with normal and empty seeds
		S. tudununggae	Parthenocarpic fruits
		S. virginianum	Hybrid partially fertile
9.	*monodolichopus*	*S. coagulans*	Virtually sterile hybrids with empty seeds
		S. dubium Fresen.	Partially fertile hybrids with normal and empty seeds
		S. lidii	Hybrid partially fertile
		S. verspertilio	No fruit set
10.	*oliganthes*	*S. aethiopicum*	Viable, partially fertile hybrids
		S. anguivi	Partially fertile hybrids with normal and empty seeds
		S. burchellii	Partially fertile hybrids with normal and empty seeds
		S. capense.	Partially fertile hybrids with normal and empty seeds
		S. catombelense	Partially fertile hybrids with normal and empty seeds
		S. coccineum	Partially fertile hybrids with normal and empty seeds
		S. cyanoperpurpeum	Partially fertile hybrids with normal and empty seeds
		S. dinteri	Partially fertile hybrids with normal and empty seeds
		S. forskalii (= *S. albicaule*)	Partially fertile hybrids with normal and empty seeds

		S. hastifolium.	Partially fertile hybrids with normal and empty seeds
		S. kurzii	Partially fertile hybrids with normal and empty seeds
		S. lamprocarpum	Virtually sterile hybrids with no seed set
		S. myoxotrichum	Parthenocarpic fruits
		S. pyracanthos	No germination of seeds
		S. rigescens.	Partially fertile hybrids with normal and empty seeds
		S. rigescenoides.	Partially fertile hybrids with normal and empty seeds
		S. rubetorum	Partially fertile hybrids with normal and empty seeds
		S. supinum	Partially fertile hybrids
		S. toliarae	Parthenocarpic fruits
		S. tomentosum	Partially fertile hybrids with normal and empty seeds
		S. trilobatum.	Parthenocarpic fruits
		S. violaceum	Partially fertile hybrids
		S. grandiflorum	Virtually sterile hybrids
		S. giganteum	Parthenocarpic fruits with no seed set
		S. goetzii	Virtually sterile hybrids
		S. hispidum	Virtually sterile hybrids
		S. schimperianum	Parthenocarpic fruits
		S. torvum	Viable, but sterile hybrids

4. GERMPLASM CONSERVATION IN BRINJAL

The International Board for Plant Genetic Resources (IBPGR, renamed International Plant Genetic Resources Institute –IPGRI- in 1991 and Bioversity International in 2006) has included eggplant (in the broad sense) in the list of priority species whose genetic resources suffered genetic erosion, as early as 1977 (Grubben, 1977). In the same momentum, IBPGR published eggplant descriptors in 1988: these descriptors, suitable for all cultivated eggplants, are available online (http://www.ipgri.cgiar. org/). Large collections of several hundreds to over one thousand accessions have been made available by national inputs, in particular in countries where eggplant is a traditional vegetable, such as in India (collection held by the National Bureau of Plant Genetic Resources, NBPGR, New Delhi,), China (Institute of Vegetables and Flowers, IVF,

Beijing), Taiwan (AVRDC) and Japan (National Institute of Agro biological Sciences, NIAS, Tsukuba). In the 1980s and 1990s IPGRI backed up some national initiatives by sponsoring collecting missions of eggplants in Asian countries such as India, Sri Lanka, Bangladesh, Nepal, Thailand (Wivutvongvana et al., 1984) and Bhutan.

The Asian collections contain mostly *S. melongena* accessions, but also some wild or other locally cultivated *Solanum* species. Some of these collections are already on line accessible for passport and characterization data (e.g. http://www. avrdc.org/germplasm.html for AVRDC and http://www.gene.affrc.go.jp/plant/index. html for NIAS). Collecting missions were also organized under the IPGRI auspices in Middle East, Africa, Mediterranean and other countries (L. Maggioni, pers. com.). The collection in Africa (Lester et al. 1990) dealt with the three cultivated eggplants (*S. melongena, S. macrocarpon* and *S. aethiopicum*) as well as with some other locally cultivated species and wild germplasm. Safety duplicates were transferred to the Birmingham Solanaceae collection (University of Birmingham, UK) and to the Center for Genetic Resources (CGN) in The Netherlands (these accessions were regenerated in 2000-2005 by the EGGNET group).

In The United States, USDA assembled an eggplant collection, located in Griffin (Georgia); the passport, description and evaluation data are on line available (http://www.ars-grin.gov). In Mediterranean and continental Europe, many countries have gathered eggplant germplasm: a survey realized in 2000 by the European Cooperative Program for Plant Genetic Resources (ECP/GR) has identified the main stakeholders (in terms of number of accessions) and estimated eggplant genetic resources held in Europe as about 6000 accessions (Daunay et al., 2003). The funding of the Eggplant Network project (EGGNET, 2000-2005) by the European Community has allowed seven countries to join their efforts for coordinating the management of eggplant genetic resources.

Globally about 21,000 eggplant accessions were maintained in various global germplasm conservation centers. The key important global Germplasm resource conservation for Egg plant includes

1. National Bureau of Plant Genetic Resources, New Delhi, India:
2. National Genebank for Vegetable Germplasm Resources, Beijing, China:
3. Institute of Vegetable Crops, IVC, Nanjing and Hangshu, China:

4. Asian Vegetable Research and Development Center (AVRDC) Shanhua, Taiwan:

5. Polytechnic University of Valencia, Valencia, Spain

6. National Centre for Genetic Resources and Biotechnology, Ibadan, Nigeria

7. Plant Genetic Resource Centre, Entebbe Uganda

8. The National Institute of Agrobiological Sciences (NIAS), Tsukuba, Japan:

9. The Vavilov Research Institute of Plant Industry, St. Petersburg, Russia:

10. The World Vegetable Centre (WVC), Tainan, Taiwan

11. USDA-ARS, Texas, USA

12. Royal Botanic Garden, Kew, United Kingdom

13. Centre for Genetic Resources, Wageningen, Netherlands

14. National Research Institute for Agriculture, Food and Environment (INRAE), Paris, France

15. Leibniz Institute of Plant Genetics and Crop Plant Research (IPK) Corrensstr, Gatersleben Saxony-Anhalt Germany

Conclusion

Eggplant is the only Solanaceae (with potato) to be included in the list of crops covered under the multilateral system defined by the International Treaty (IT) for Plant Genetic Resources for Food and Agriculture, provided they are under the management and control of the Contracting Parties and in the public domain. A standard Material Transfer Agreement (MTA), to be used for facilitated access of genetic resources that are part of the multilateral system. This means that the international exchange of eggplant genetic resources is facilitated, when compared with the species that are not covered by the multilateral system.

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POPULAR AND PROMISING VARIETIES OF GROUNDNUT FOR CULTIVATION IN INDIA

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Introduction

Groundnut (*Arachis hypogaea* L.) is commonly called the poor man's nut. It is a leguminous crop plant which is widely cultivated in the tropics and subtropics between 40°N and 40°S latitudes. Groundnut is an important oilseed crop in India, occupying first position in terms of area and second in terms of production after soybean. It plays a major role in bridging the vegetable oil deficit in the country. The peanut was probably first domesticated and cultivated in the valleys of Paraguay. It is an annual herbaceous plant growing 30 to 50 cm (1.0 to 1.6 ft) tall. The seeds of groundnut are also used extensively as an animal feed supplement due to their high protein content. Groundnut is available throughout the year due to a two-crop cycle, harvested in March and October. However, in India, it is grown mostly under rain-fed conditions, and nearly 80% of annual acreage and production comes from the Kharif crop (June-October).

Among the surveyed states, the highest yield of 2179 kg/ha was estimated for Rajasthan, followed by 1647 kg/ha for Gujarat, 1453 kg/ha for Madhya Pradesh, 1279 kg/ha for Karnataka, 1079 kg/ha for Maharashtra, 830 kg/ha for Uttar Pradesh and 429 kg/ha for Andhra Pradesh. The national average yield was estimated at 1498 kg/ha. The combined production of these seven states was estimated at 68,30,666 MT, which accounted for about 90% of the estimated national productionGujarat contributed 52.25 lakh tonnes, accounting for about 40% of India's groundnut production in 2024, as per APEDA. Rajasthan produced 21.27 lakh tonnes (16.31%), followed by Madhya Pradesh with 14.35 lakh tonnes (11%). Tamil Nadu reported 4.46 lakh tonnes

(3.42%), Uttar Pradesh 4.29 lakh tonnes (3.30%), Karnataka 3.26 lakh tonnes (2.46%), and Andhra Pradesh 3.23 lakh tonnes (2.44%). Telangana's output was 0.23 lakh tonnes, while the total contribution of other states was estimated at 6.26 lakh tonnes (4.8%) (APEDA, 2024).

GROUNDNUT RESEARCH STATIONS IN INDIA:

Institute	Location	Established	Key Contributions	Notes
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)	Hyderabad/Patancheru, with regional centres in Mali and Malawi	1976	Led groundnut genetic improvement, germplasm acquisition, breeding programs, and collaboration with African and Asian NARS	Expanded regional programs in Mali and Malawi since the late 1990s
Indian Institute of Oilseeds Research (IIOR)	Hyderabad	1977	Successor of AICORPO; focused on multiple oilseeds including groundnut; operated until groundnut delinked in 1979	Formerly Directorate of Oilseeds Research
Directorate of Groundnut Research (DGR)	Junagadh	1979	First specialised ICAR commodity research centre for groundnut; focuses on productivity enhancement; upgraded in 2009	Formerly NRCG, elevated to Directorate status
Oilseeds Research Station (ORS), Tindivanam	Tindivanam	1935 (upgraded 1962)	Conducts AICRP experiments, front-line demonstrations, breeder and TFL seed production for groundnut	Under the Tamil Nadu Agricultural University since 1982

Recent Varieties Released by ICRISAT, Hyderabad.

Groundnut breeding efforts by ICRISAT and its partners are reshaping peanut farming across South Asia, with new varieties tailored to farmers' needs and consumer demands. From Bangladesh's BARI Chinabadam 12, which offers early maturity and disease resistance, to India's Girnar series rich in heart-healthy oleic oil, these innovations promise both higher yields and better nutrition. Varieties like GG-40 and Kalinga Groundnut 101 stand out for their adaptability—whether in drought-prone regions or under high-input conditions—while Tamil Nadu's VRI releases continue to support farmers with stable productivity and strong pest resistance. Together, these varieties not only secure better incomes for farmers but also meet the rising demand for healthier, quality peanuts in domestic and global markets.

Variety	Type	Avg. Yield (Kg/ha)	Oil Content (%)	Key Feature
BARI Chinabadam-12	Spanish Bunch	2000–2200	–	Early maturity, high shelling %, disease resistance, suited for Bangladesh
Girnar 4 (ICGV 15083)	Virginia Bunch	3218	53	High oleic oil (78.5%), resistant to leaf spot, rust.
Girnar 5 (ICGV 15090)	Virginia Bunch	3124	53	Similar resilience as Girnar 4 with high oleic oil (78.4%)
GG-40 (ICGV 16668)	Spanish Bunch	3321	51	Stable yield, oleic acid 78.4%, adapted to multiple states
Kalinga Groundnut 101	Medium-bold type	2234–4167	~50	Drought-tolerant, longer shelf life, boosts cattle milk yield
VRI 4	Bunch	1660–2171	47	Rust-tolerant, high-sugar kernels, strong in irrigated conditions
VRI (Gn) 5	Bunch	2133–2384	–	Profuse branching, red testa, dormancy advantage, high shelling %

Varieties from the oilseeds research station, Tindivanam:

Groundnut improvement programs in Tamil Nadu have contributed significantly to India's peanut diversity, offering varieties adapted to both rainfed and irrigated conditions. Since the early 1940s, a series of TMV varieties have been released, followed by VRI types, each tailored to needs such as drought tolerance, oil quality, branching habit, or kernel traits. Early introductions like TMV 1, 2, and 3 focused on adaptability and drought resistance, while later varieties like TMV 10 combined high yield and oil content. The more recent VRI lines, such as VRI 4 and VRI (Gn) 5, offer superior shelling percentage, disease tolerance, and farmer-friendly features like dormancy and better branching. Together, these varieties represent decades of steady progress in delivering groundnuts that meet the challenges of climate, farmer livelihoods, and consumer quality.

Groundnut Varieties from ICAR-Directorate of Groundnut Research, Junagadh

Groundnut farming in India has witnessed remarkable progress over the decades, thanks to dedicated breeding programs led by the Directorate of Groundnut Research (DGR), Junagadh. These efforts have produced a range of varieties that address farmer needs such as higher yields, disease resistance, drought tolerance, and better oil quality, while also suiting diverse agro-climatic areas.

Early milestones

The journey began with Girnar 1 (1988), a Spanish variety that was resilient to both diseases and drought. It introduced strong resistance to early and late leaf spots, rust, collar rot, and even *Aspergillus flavus*, while also withstanding water stress — making it one of the first widely adaptable groundnut varieties.

Expanding options for different regions

In 2008, Girnar 2, a bold-seeded Virginia bunch type, was released for north-west India, particularly the sandy soils of Rajasthan, Punjab, and Uttar Pradesh. With a shelling percentage of 69% and 51% oil, it quickly caught farmer interest due to its bigger seed size — a trait much in demand in local markets. Shortly after, Girnar 3 (2010) arrived as a high-yielding Spanish bunch for eastern states such as Odisha, West Bengal, and Manipur. Its medium-bold kernels, combined with 2–3 weeks of seed dormancy and tolerance to late-season drought, solved the issue of seed spoilage and improved storage.

Varieties developed from collaborating centres

In Gujarat, GG 5 (1996) became popular as a short-duration (100-day) Spanish type, while GG 7 (2001) built upon that success with tolerance to rust, late leaf spot, and the devastating Peanut Bud Necrosis Disease (PBND). This variety, maturing in 96–105 days, exemplifies how breeding targeted both yield and protection from widespread diseases. From Rajasthan, HNG 10 (1998), supplied through DGR lines, gave farmers a Virginia bunch variety suited to both irrigated and rainfed conditions. With 51% oil and reliable yields, it became a dependable option for kharif growers.



Girnar 1



Girnar 2



Girnar 3



HNG 10



GG 5



GG 7 (38)



Raj Mungfali 3 (RG 559-3)

Meanwhile, AK 159 (2002), released in Maharashtra and Madhya Pradesh, offered medium maturity (105–115 days) along with good yield potential. Developed from DGR

breeding material, it gained ground as a strong regional choice. Raj Mungfali 3 (2015) brought a high-yielding Virginia type to Zone I, encompassing Rajasthan, Punjab, and Uttar Pradesh. Derived from a complex cross, it further expanded the choices available to farmers in north India's challenging kharif season.

New Groundnut Varieties Driving Prosperity: Releases Linked with IIOR, Hyderabad

Groundnut, fondly known as the *"king of oilseeds"*, continues to be a game-changer for farmers across India. With rising demand for edible oil, healthy snacks, and export-quality kernels, new varieties are being released every year to keep pace with both farmer needs and market expectations. The Indian Institute of Oilseeds Research (IIOR), Hyderabad, along with collaborating state agricultural universities, has played a key role in releasing groundnut varieties that combine high yield, better oil content, shelling percentage, and disease resistance.

The latest popular releases shaping the peanut fields of India are detailed below:

Pratap Mungphali 3 (UG 116) – Udaipur's Pride

Released in 2020 by MPAUT, Udaipur, this Spanish Bunch variety is fast gaining ground in multiple states. Farmers benefit from its impressive average pod yield of 3388 kg/ha in both kharif and summer seasons. Apart from high productivity, it is moderately tolerant to early and late leaf spots, rust, collar rot, and dry root rot. Its built-in resilience to insect pests like *Spodoptera litura*, leaf miner, and thrips makes it farmer-friendly. With 47% oil content and 70% shelling out-turn, it is highly suited for commercial cultivation across Rajasthan, Gujarat, Karnataka, Tamil Nadu, Andhra Pradesh, and Telangana.

GG 37 (Sorath Gaurav) – A Summer Performer

Also introduced by JAU, Junagadh in 2022, GG 37 delivers an impressive yield of 3218 kg/ha in summer when other crops underperform. With 48.9% oil and 73% shelling, it produces kernels with excellent processing quality. For growers aiming at summer cultivation in Rajasthan, Gujarat, Tamil Nadu, and beyond, GG 37 is proving to be a reliable option.

GG 38 (Sorath Navin) – Gujarat's New Star

Recently released in 2022 by JAU, Junagadh, GG 38 is another Spanish Bunch type gaining popularity. It yields 2966 kg/ha during kharif and performs steadily across semi-arid states. Offering 48.9% oil content and 72.4% shelling, it ensures profitable returns to farmers. Its adaptability makes it a promising choice across Western and Southern markets.

GG 40 (ICGV 16668) – The High-Oleic Peanut

This Spanish Bunch variety, released in 2022, goes beyond yield to serve the health-conscious market. With 3321 kg/ha pod yield in kharif and recorded 78.4% oleic acid and only 3.56% linoleic acid, GG 40 is ideal for producing heart-healthy peanut oil. With 51% oil and 63% shelling percentage, it appeals to both farmers and processors who target niche premium segments.

VRI 9 (VG 13163) – A Tamil Nadu Specialised Release

Developed at TNAU, Vridhachalam (2022), VRI 9 is targeted towards Tamil Nadu farmers. Suited for kharif season with a pod yield potential of 2526 kg/ha, the Spanish Bunch variety shows moderate resistance to leaf spot and rust diseases. Its oil content (47–49%) and shelling percentage (70–72) make it attractive both locally and for regional markets.

VRI 10 (VG 17008) – The Early Maturing Choice

The latest release from TNAU (2023), VRI 10, brings a combination of early maturity, disease resistance, and good yield. With 2535 kg/ha potential during kharif, this Spanish Bunch variety is moderately resistant to late leaf spot, rust, sucking pests, and defoliators. Farmers also value its oil content of 46–48% and high shelling (70–72%), making it a practical and profitable choice for Tamil Nadu cultivation.

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BLOCKCHAIN TECHNOLOGY AS A BREAKTHROUGH IN THE FOOD SUPPLY CHAIN: KNOW THE JOURNEY OF YOUR FOOD

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Introduction

We are living in an era where a lot of consumers are very much concerned about the safety, quality and impact on health, with respect to the food they consume. Foods labelled as natural or organic are increasingly finding space among consumer demands. It is understood that price is not a concern for such consumers, who prefer chemical free and natural food.

Terms like “green”, “organic”, “natural”, etc. have been part of marketing and sales parlance for many years. And the general public gets swayed by such marketing “terms” , pushing them to buying decisions, due to lack of information to validate such claims, which are mostly hollow.

But what if there is a way to distinguish if the food labelled as “100% organic” is real or fake? And you could track the complete journey of your food from farm to your table by scanning a single QR code on your food package? This is where the emerging technology called the blockchain plays a crucial role. Blockchain technology facilitates transparency, safety, quality and sustainability of food products throughout the supply chain.

The Food supply chain and its challenges

In simple terms, a food supply chain can be defined as an interconnected network of different organizations which transmit food from the producer to the consumer (Figure 1). Thus a food supply chain may include a chain of stakeholders namely producers, farmers, manufacturers, dealers, wholesalers, distributors, retailers, government agencies and consumers. Each stakeholder in the food supply chain system has a different role and are actively contributing to the proper functioning of the supply chain. Since the food supply chain is

interconnected, a disruption at any point in the chain will affect the overall functioning of the food supply chain resulting in delayed distribution or other constraints across the chain. The global population is expected to grow to around 8.5 billion in 2030, 9.7 billion in 2050, and 10.9 billion in 2100 (UN). There is huge pressure on the food supply chain in order to ensure timely delivery of quality food in the necessary quantity to meet the demands of this ever increasing population.

As food supply chain management brings together critical components like information flow, logistics and warehousing, investment strategies, and the trade of goods and services, efficient food supply chain management is the key for addressing food insecurity and public health challenges. Food supply chains become more complex due to the globalization of food trade which increased the risk of food frauds and the concerns of consumers about food safety and reduced customer trust. This emphasizes the need for greater transparency and traceability in the food supply chain.

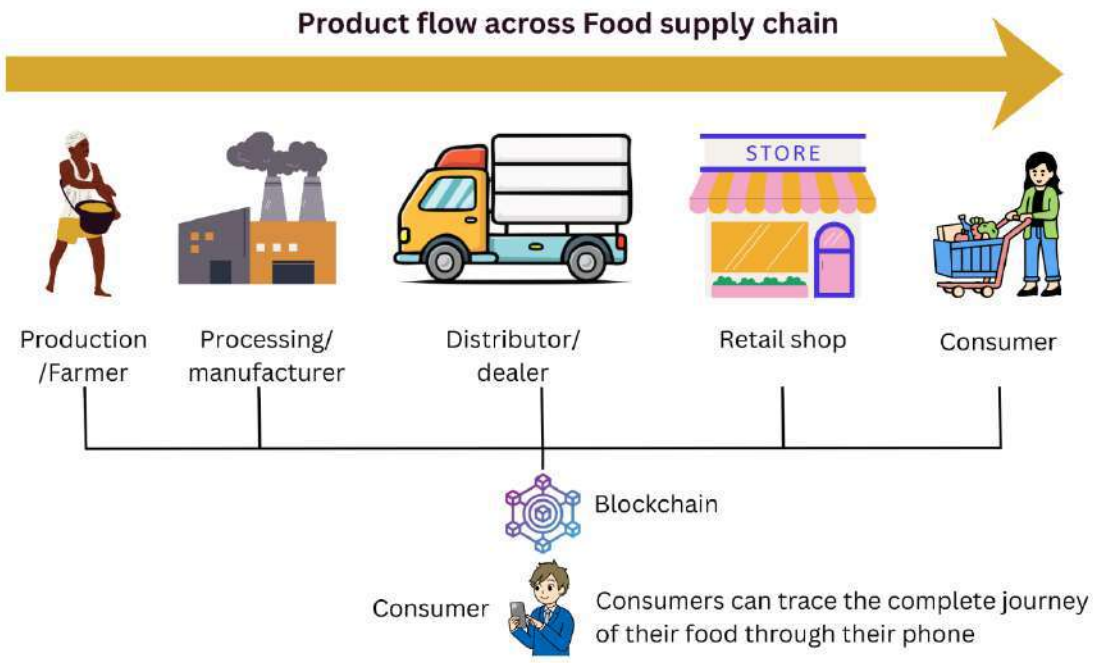


Figure 1. Product flow across the food supply chain and blockchain technology intervention

Blockchain technology

A blockchain is a digital ledger which stores transaction data as a series of blocks (Figure 2). Immutability, security, quality assurance, and transparency are the inherent features of a

blockchain. Blockchain in the food supply chain is built on a distributed ledger that records all transactions and events across the supply chain. This ledger consists of time stamped and encrypted data blocks, linked in chronological order. Each block contains a batch of transactions validated according to a predefined consensus protocol. Supply chain participants/stakeholders interact with the blockchain through role-specific web or mobile applications, ensuring secure and transparent data exchange throughout the system.

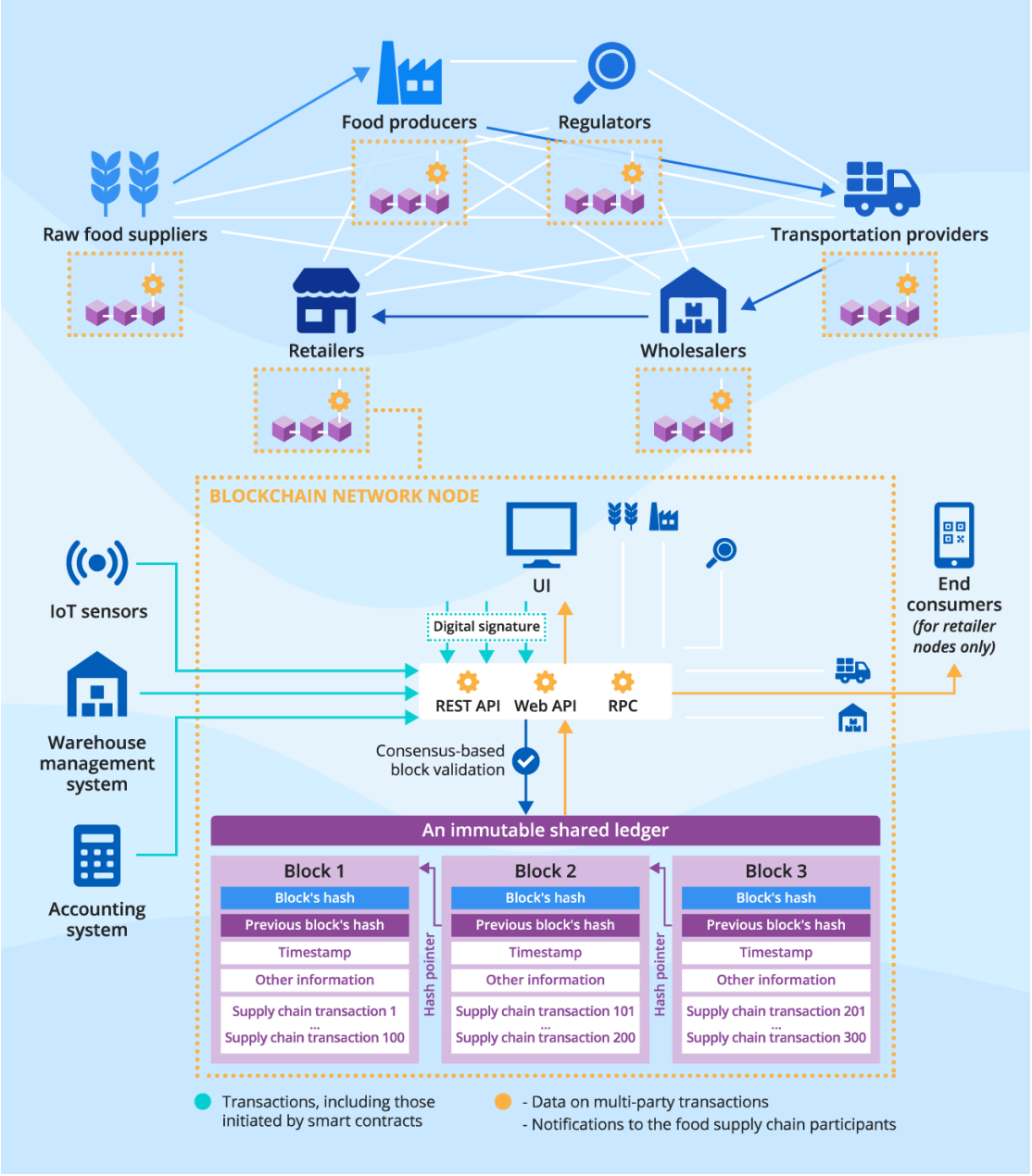


Figure 2. A sample architecture of blockchain for the food supply chain

(Source: ScienceSoft-https://www.scnsoft.com/blockchain/food-supply-chain#info)

According to projections, the global blockchain market applied to the food supply chain is set to grow from $840 million in 2025 to $4.04 billion by 2029, reflecting a CAGR of 48.3%. Challenges within the food supply chain such as food fraud, safety risks and limited transparency and traceability are the key factors fueling this growth.

Blockchain technology is gaining traction in the food supply chain due to its ability to address persistent issues related to transparency, traceability, and trust. Conventional food supply chains are often fragmented, with multiple intermediaries and limited visibility across different stages—from production and processing to distribution and retail.

Blockchain introduces a digital ledger,which is decentralized and tamper-proof, where each transaction/ process such as harvesting, processing,shipping,storage, distribution etc. are securely recorded in real time. The immutability of the ledger facilitates back tracking of the food source within seconds, which is crucial for ensuring food safety, responding quickly to contamination outbreaks, and reducing the scope of recalls. Automatic processes can be executed with the help of smart contracts

Additionally, blockchain helps combat food fraud by verifying the authenticity of food claims such as organic certification, origin, or ethical sourcing. It also simplifies compliance with regulatory requirements by automating documentation and audit trails. By enhancing trust and accountability among all stakeholders, from farmers to consumers, blockchain not only improves operational efficiency but also enhances consumer confidence in food quality and safety. The list below outlines the types of data each stakeholder is responsible for entering into the blockchain.

Raw Food Suppliers: Input data regarding the origin and initial movement of food products throughout the supply chain.

- Farm or source identification (e.g., farm ID, location)
- Crop/livestock type and variety
- Harvest date and time
- Farming practices (e.g., organic, pesticide use)
- Initial quality assessments
- Batch or lot number
- Handover details to the next entity (e.g., processor or transporter)

Food Manufacturers: Share detailed information on ingredients, processing methods, and production practices.

- Supplier and ingredient details
- Manufacturing process records
- Processing dates and times
- Batch/lot numbers for traceability
- Quality control test results
- Packaging and labeling information
- Storage and handling data prior to distribution

Food Inspectors & Certification Bodies: Validate and verify documentation related to product origin, quality, and compliance with safety standards.

- Inspection reports
- Certification documents (e.g., organic, HACCP, ISO)
- Product testing results (e.g., for contaminants)
- Compliance verification timestamps
- Auditor identity and certification authority

Transportation & Logistics Providers: Record real-time data on the location, handling, and storage conditions of food products during transit.

- Pickup and delivery timestamps
- Route information (e.g., GPS tracking)
- Temperature and humidity logs during transit
- Vehicle and container IDs
- Chain-of-custody records
- Handling conditions and deviations, if any

Food Product Distributors: Monitor supply chain activities to ensure responsible sourcing, maintain product quality, and uphold food safety standards.

- Inventory and warehousing records
- Quality control checks on received products
- Traceability data (e.g., linking batch numbers across suppliers and manufacturers)
- Storage condition monitoring (e.g., cold chain compliance)
- Distribution logs and destination tracking

End Consumers: Access transparent, verifiable information about food provenance to confirm authenticity and make informed purchasing decisions.

- Access to summarized, readable data such as:
    - Product origin (farm, region)
    - Ingredient sourcing
    - Certification badges (organic, non-GMO, etc.)
    - Safety and quality test results
    - Environmental or ethical sourcing information
    - Supply chain journey (farm to shelf)

Advantages of blockchain technology

- Enhanced traceability and transparency
- Food safety and quality
- Food fraud prevention
- Enhanced customer trust
- Regulatory compliance
- Sustainable and ethical sourcing
- QR code enabled access to blockchain data

Conclusion

Blockchain technology revolutionises the food supply chain by enhancing transparency, traceability, and trust among stakeholders. One of its primary uses is improving traceability, allowing food products to be tracked in real time from farm to table. This is particularly valuable in the event of contamination, as blockchain enables rapid identification of the source, helping to contain outbreaks and minimize product recalls. Blockchain also helps to mitigate food fraud by verifying the authenticity of claims such as organic certification, geographical origin, or fair-trade status with the help of immutable digital ledger. The use of smart contracts automates transactions between parties, ensuring timely payments and reducing reliance on intermediaries.

Blockchain technology is still in its early stages of development and needs to overcome challenges such as energy consumption, interoperability (i.e. communicating different blockchain-based systems), scalability, and legal issues (Mohamed and Aboul). These limitations must be addressed for blockchain to be fully effective and sustainable in the food supply chain.

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BANANA PSEUDOSTEM SAP: NOVEL UNDERUTILIZED RESOURCE

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Introduction

Banana pseudostem is usually discarded as waste after the harvesting of bananas. Waste banana pseudostem fibers are widely utilizing for paper and textile industries, but the sap extracted from the stem during fiber extraction is remains underutilized. In reality, this sap is a hidden treasure, rich in bioactive compounds, nutrients, and functional properties, and can be utilize in multiple industries.

Banana pseudostem sap (BPS) is a watery liquid extracted when the outer leaf sheaths of banana pseudostem are crushed. Initially it was considered as a waste product, but recent studies proved that it is a nutrient-rich liquid contains bioactive molecules, minerals, fibers and natural chemicals. Sap will be initially clear liquid but darken with oxidation over time, and being recognized as a sustainable resource.

Banana pseudostem sap is rich in carbohydrates, particularly soluble sugars, and contains various minerals like potassium and magnesium, which can be beneficial as a fertilizer supplement. It also contains phenolic compounds, including tannins and flavonoids, which contribute to its antimicrobial and dyeing properties. Other significant components include nitrogen, phosphorus, and calcium.

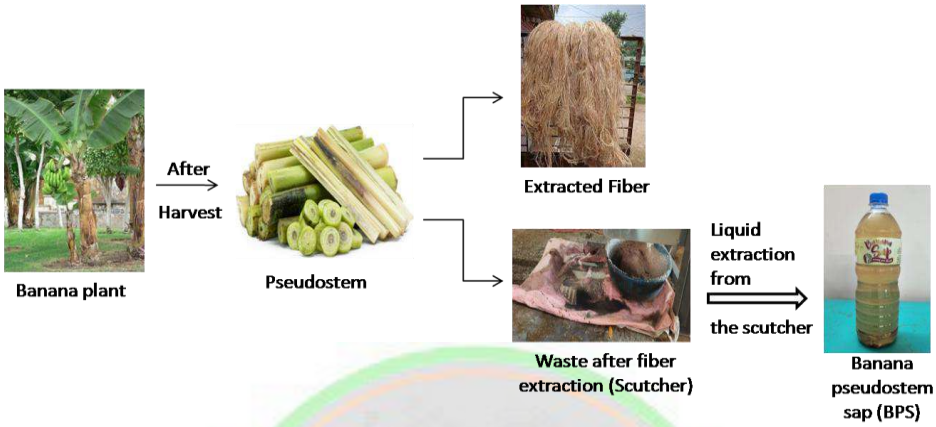
1. Major chemical components of Banana pseudostem sap are

i) **Carbohydrates:** Rich in soluble sugars like glucose, xylose, mannose, galactose, and arabinose.

ii) **Minerals:** High in potassium, magnesium, and also contains sodium and calcium.

iii) **Phenolic compounds:** Contains tannins, flavonoids (like naringin, catechin, and epicatechin), and other polyphenols.

iv) **Other organic compounds:** Includes nitrogenous substances, proteins, and compounds like proanthocyanin and anthocyanin.



Composition of BPS

Nutrients	Nitrogen, Phosphorus, Potassium, calcium, iron, magnesium and trace elements
Bioactive compounds	Polyphenols, Flavanoids, tannins and antioxidants
Pigments	Xanthophylls and anthocyanins
Other components	Natural sugars and organic acids

2. Applications of Banana pseudostem sap are

Banana pseudostem sap has diverse applications, which has been briefed below

Food Industry

Recent studies found many applications of sap in food industries. One of the major reasons of food spoilage is microbial contamination. Packaging of food plays a major role in food preservation. Packaging film can be made from BPS. This innovative packaging solution reduces pollution, improves food preservation, and supports the circular economy, making it ideal for the growing demand for green food packaging (Muthukumarasamy, K., 2025 et al). BPS can be used as energy drink as it contains many minerals like sodium, potassium, calcium and magnesium. BPS is a source of bioactive compounds, natural colorants and flavoring agents. Therefore, it can be use as a natural colorant and flavoring agent in beverages and bakery products. It is having antioxidant properties and also it is a potential source of nutraceuticals and health supplements.

Textile and dyeing

Banana pseudostem sap can be used in the textile industry for sustainable applications like creating natural dyes, acting as a mordant to fix dyes, or being a component in flame-retardant finishes. It can also be processed into a textile binder, which is a sustainable alternative to commercial binders. These uses add value to a waste product and can help the industry reduce its environmental impact. BPS has some special properties, including its ability to cause permanent staining on cloth and fiber, along with anti-bleeding and antioxidant properties. Hence, BPS can serves as a natural dye for eco-friendly fabrics. Also it could serve as a good mordant. This could reduce the cost of buying and using synthetic dyes (Dezomeku et al., 2012). As BPS contains natural chemicals and bioactive compounds, it has the ability to soften and condition banana fiber, making it more flexible and easier to process. It can act as an eco-friendly alternative to chemical finishes in fabrics.

Agriculture

BPS can be utilized as liquid fertilizer as it contains high concentration of potassium and micronutrient content. The BPS-based organic liquid fertilizer is enriched with both macro and micro nutrients and has the ability to naturally generate plant growth regulators such as cytokinin and gibberellic acid during its preparation (Abro et al., 2023). Studies show that BPS is an effective biofertilizer in the cultivation of onion, spinach and garlic. It also improves soil health and enhances the yield and nutrient uptake of the leafy vegetables. The enriched BPS can be used as a foliar spray, serving as a supplementary source of nutrients to further improve nutrient uptake. Furthermore, BPS act as a biopesticide due to the bioactive compounds it contains which exhibit insect-repellent and antimicrobial properties and help protect crops from pests and diseases. It has been reported that about 12000 lit of sap is available from one hectare of banana cultivation. Rich in potassium and iron it can be added with required quantity of nutrients and hormones to produce effective liquid fertilizer. It can be used as growing medium. Studies have shown that 10% aqueous solution of fresh sap can improve root length, shoot length, biomass, and chlorophyll content in seedlings. Applying the sap as a foliar spray can enhance vegetative growth, improve nutrient uptake, and increase crop yield

Pharmaceuticals and Cosmetics

BPS can also be used for medicinal purpose. As it contains saponins, flavonoids and tannins it exhibit antioxidant, antimicrobial and anti-inflammatory properties. It also contains

lectins, that promote skin cell growth, suggesting potential applications in wound healing. Also it can be utilize to reduce blood pressure, diabetes, kidney stone and arthritis. Its antiseptic properties are beneficial for treating insect bites or stings.

The antioxidant and bioactive compounds of the sap make it a promising ingredient for herbal cosmeceutical and nutraceutical products, including skin nourishment products.

Environmental uses

BPS can be effectively used in waste water treatment because it naturally contains bioactive compounds and other chelating agents. These compounds have multiple functional groups that can bind with heavy metal ions such as lead, nickel, present in waste water. It can act as a natural coagulant, similar to alum. By employing cost-effective production strategies, high-moisture, low-sugar sap can be convert into bioethanol, and it proves the renewable energy potential of BPS (Gupta, P. K et al., 2024).

3. Sustainability Benefits

- ✓ **Zero waste utilization:** Usually, after fiber extraction, the scutcher is discarded. But, converting it into sap transforms this waste into a high value product.
- ✓ **Eco-friendly alternative:** It helps reduce the dependence on chemical fertilizers, synthetic dyes and other chemicals in food industry through its alternative applications.
- ✓ **Rural Entrepreneurship:** Instead of treating these byproducts as waste, farmers can process into high value products and this creates new revenue streams, in addition to the income they already earn from banana fruits.
- ✓ **Circular economy:** By utilizing all the wastes into value products, farmers achieve minimal waste generation and ensure that resources are fully used. This promotes sustainable banana cultivation with minimal waste.

4. Equipment for extraction of Banana pseudstem sap

Equipment for banana pseudostem sap extraction includes mechanical extruders or decorticators for crushing the pseudostem to separate sap and fibers, a press machine to squeeze the sap out of the crushed material, and a filtration system to remove solid particles from the sap. Some manual methods also exist, where a sharp object is used to scrape and collect the sap. Mechanical Extruder/Decorticator is machine with a rotating drum and high-speed rotating blades or beating action that crushes the pseudostem to separate the fibers and sap. Subsequently, Press Machine is used to apply pressure on the crushed or separated pseudostem material to

extract the sap efficiently. ICAR Central Institute of Agricultural Engineering, Regional Station , Coimbatore has developed a package of equipment which includes continuous feed banana fibre extraction equipment , conveyer system to convey the extracted scutcher to the sap extraction system

5. Future prospects

With further research and technological developments, BPS can find more applications in bioproducts and sustainable industries. Large-scale extraction units can be developed, and the scaling up and refining of BPS can transform this agriculture waste product into a valuable multi-industry raw material.

Conclusion

Beyond their limited use in small-scale fiber applications, banana pseudostem is underutilized. However, BPS is now emerging as a resource of immense industrial value. BPS is rich in nutrients, bioactive compounds, and functional properties and can find many applications in various industries such as food, agriculture, textiles, pharmaceuticals and cosmetics. Its utilization not only promotes sustainability by reducing waste and offering alternatives to chemicals, but also provides new opportunities for farmers. By further studies on its applications may find more eco-friendly solutions, and BPS is truly stands as a promising natural resource.

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INNOVATIVE APPROACH TO TREE CUTTING USING ELECTRIC DRIVE MECHANISM

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Abstract

The tree cutting machine is a modern mechanized device designed to reduce human effort and improve the efficiency of cutting trees and logs. This machine operates on mechanical and electrical principles, integrating a motor-driven blade or chain mechanism to perform precise and quick cutting operations. It minimizes manual labor, reduces the time required for cutting, and ensures uniformity in wood cutting processes. The design prioritizes portability, energy efficiency, and safety, making it suitable for use in forestry, agriculture, and urban maintenance. The development of such machines enhances productivity in the timber and wood industries and makes a significant contribution to sustainable forestry management.

Keywords: Tree cutting machine, wood cutting, mechanized logging, motorized saw, forestry equipment, portable cutter, timber processing, automation in agriculture.

Introduction

One of the most important tasks in forestry, agriculture, and landscaping is cutting trees. Traditionally, trees were cut manually with axes or hand saws, which required more physical labor, more time, and increased the risk of accidents. The development of tree-cutting machines as a result of technological advancements has significantly altered the process of harvesting and maintaining wood. A machine designed to cut trees and logs with the least amount of human labor possible is known as a tree cutting machine. These machines use hydraulic systems, electric motors, or engine-powered blades to ensure quick and precise cutting. They are designed to guarantee safety during operation, reduce employee exhaustion, and boost productivity. The development of such machines, which contribute to time savings, improved precision, and

sustainable resource management, is a significant step toward modernization in agriculture and forestry. Modern tree cutting machines are becoming more compact, portable, and friendly to the environment as a result of ongoing development, making them suitable for both commercial and small-scale applications.

COMPONENTS

1.Frane or Body:

The main supporting structure that holds all the components together. It provides stability and durability to the machine.

2. Cutting Blade or Chain:

The most important part used for cutting trees or branches. It is made of high-strength steel or alloy to withstand heavy loads and ensure smooth cutting.

3. Motor or Engine:

Provides the necessary power to rotate the cutting blade or chain. It can be electric, petrol, or diesel-powered depending on the design.

4. Power Transmission System:

Comprises belts, pulleys, or gears that effectively transfer power from the motor to the cutting mechanism. 5. System of Handling and Control: Used by the operator to guide, control, and adjust the cutting process safely and comfortably.

5. Shield or Guard of Safety:

Protects the user from flying wood chips and prevents accidental contact with the blade during operation.

6. Base Stand or Wheels:

Provides mobility and balance to the machine, making it easier to move and operate in different locations.

7. Fuel Storage Tank or Battery:

Supplies energy to the motor or engine. In electric models, rechargeable batteries are used for portable operation

WORKING CONSTRUCTION

The motor or engine begins rapidly rotating the cutting blade through the transmission system when the machine is turned on. The machine is positioned close to the to-be-cut tree

trunk or branch by the operator, who applies constant pressure. The rotating blade or chain cuts through the wood smoothly, reducing manual effort and cutting time.

The safety guard and handle design shield the operator, and the motor's power ensures uniform cutting. Once the cutting operation is complete, the machine can be turned off, and the blade stops immediately for safety.

This mechanism makes it possible to cut trees quickly, safely, and effectively, making them suitable for use in agriculture, forestry, and landscaping.

The tree cutting machine is constructed with a strong and durable metal frame that supports all the main components. The cutting mechanism is mounted on the front of the frame and consists of a chain saw or sharp circular blade. Through a power transmission system like gears or belts, this blade is driven by an electric motor or gasoline engine. The handle and control unit are fitted ergonomically to ensure safe handling and smooth operation by the user. The machine has wheels or a portable base stand for mobility. A safety guard protects the operator from accidental contact with the blade and wood particles in some models. The fuel tank or battery pack is positioned to balance the weight and provide continuous power to the motor.

TYPES

1. **Chainsaw**

A quick-cutting, portable machine with a motor-driven chain. Simple: Handheld tool that slices through wood with a fast-moving chain.

2. **Hydraulic Tree Cutter**

Uses hydraulic power to cut or fell trees efficiently.

Simple: Machine that uses strong fluid pressure to chop trees.

3. **Circular Saw Tree Cutter**

Equipped with a circular blade to cut tree trunks precisely.

Simple: Machine with a spinning disc that cuts trees.

4. **Mechanical Feller Buncher**

A large machine that grabs and cuts multiple trees at once.

Simple: Big machine that holds and cuts trees in a group.

5. **Pole Saw**

A small saw on a long pole for cutting high branches.

Simple: a saw with a long handle for cutting tall branches.

6. Reciprocating Saw Tree Cutter

Uses a back-and-forth motion blade to cut trees.

Simple: Machine with a moving blade that slices trees slowly

SPECIFICATION

Tree cutting machines are made to cut, trim, or fell trees quickly and effectively. The main points, despite the fact that its specifications may vary by type, are as follows:

1. Energy Source Can be petrol, electric, or hydraulic.

Determines the machine's cutting speed and portability.

2. Cutting Capacity

Maximum tree diameter it can cut (usually in cm or inches).

Determines how easily trees can be handled.

3. Blade Type and Size

The chainsaw's length, such as 14 to 24 inches Blade diameter (e.g., 300–600 mm): circular saw affects the precision and efficiency of the cutting.

4. Power for the motor or engine either in kW or horsepower (horsepower). Higher power allows faster cutting of thicker trees.

5. Both portability and weight determines transport and handling ease. For small-scale use, light machines are easier to use, whereas heavy machines are best for industrial work.

6. Safety Features

Anti-vibration handles, chain brakes, guards.

Ensures operator safety during cutting operations.

ADVANTAGE

1. Time-Saving

Tree cutting machines can cut trees much faster than manual methods, significantly reducing labor time.

2. Worker Productivity When compared to manual cutting, fewer workers are required, resulting in lower labor costs and effort.
3. Precision Cutting

The machine cuts precisely and evenly, causing the least amount of damage to the surrounding areas.

4. Safety

Reduces the risk of injuries associated with manual chainsaws or axes. Workers can work from a safer distance.

5. Versatility

Suitable for cutting a wide range of trees, from small shrubs to large trees, of all sizes and types.

6. Consistency

Ensures uniform cutting, which is especially crucial for landscaping or commercial logging.

7. Cost-Effective in Long Run

Maintenance and operational efficiency reduce overall costs over time, despite the high initial investment.

8. Friendly to the Environment Operation Electric or hybrid engines are used in some modern machines to reduce emissions and fuel consumption.

DISADVANTAGES

1. High Cost at First Tree cutting machines are expensive to purchase, making them less accessible for small-scale users or farmers.

2. Requirements for Maintenance The machine needs to be serviced and maintained on a regular basis to stay in good working order, which costs more overall.

3. Energy and fuel consumption Machines powered by gasoline or diesel use fuel, which can have an impact on the environment and raise operating costs.

4. Competency Requirement To operate the machine safely and effectively, operators must receive appropriate training. Lack of skill can lead to accidents.

5. Mobility is limited on rough terrain. Some machines may not work well in hilly areas, dense forests, or uneven land.

6. Pollution and Sound Diesel or gasoline machines can be noisy and produce emissions that can be disruptive to the environment.

7. Dependence on Spare Parts Finding replacements in the event of a component failure can be challenging or costly, resulting in downtime.

APPLICATION

1. Management of forests and harvesting timber
2. Agricultural land clearing
3. Urban landscaping and garden maintenance

4. Construction site preparation
5. Management of disasters (removing fallen trees)
6. Safety and prevention of fires
7. The wood and commercial timber industry

FUTUER SCOPE

1. Robots and automation Integration of AI and robotic systems can allow fully automated tree cutting, reducing the need for manual labor.

Smart sensors can detect tree size, type, and optimal cutting angle for efficiency.

2. Sustainable and eco-friendly technology The creation of solar- and electric-powered machines can lessen their impact on the environment. Machines with precise cutting reduce waste and minimize damage to surrounding vegetation.

3. Enhanced Security Features Advanced safety features, such as proximity sensors, anti-vibration systems, and automatic shutoff, may be included in future machines. Reduced human intervention will lower workplace accidents in forestry operations.

4. Versatility and efficiency Machines could handle multiple tasks like cutting, trimming, and chipping simultaneously.

Portable and modular designs will make them usable in both urban and remote forest areas.

5. Integration with Analytics and Data Digital monitoring systems can track machine performance and predict maintenance needs.

Forestry management can use data from machines for sustainable logging planning.

6. Global Market Expansion

Growing demand for timber, biofuel, and urban tree management will expand the market for advanced tree cutting machines.

Conclusion

Due to their efficiency, precision, and safety, tree cutting machines have revolutionized forestry, agriculture, and landscaping. These machines promote sustainable and eco-friendly tree management in addition to reducing labor and time thanks to technological advancements. Their versatility, ease of operation, and potential for automation make them an indispensable tool for modern forestry and urban landscaping. Tree cutting machines will play a crucial role in shaping tree management practices that are safer, quicker, and better for the environment as technology continues to advance.

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FROM SALINE TO BARREN: INDIA'S GROWING SOIL EMERGENCY

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Introduction

India's agricultural future is under serious threat. Over the last few decades, salt-affected soils have been expanding steadily, converting once-fertile lands into less productive and even barren areas. This is not just a localized issue it's becoming a national emergency that affects food security, income, ecosystems, and livelihoods.

How Big Is the Problem?

- India currently has about **6.7 million hectares** of salt-affected land. Out of this, about **2.95 million hectares** are **saline soils** and the remaining (≈ 3.77 million ha) are **sodic soils**.
- Salt-affected lands could more than **double** by 2050, reaching nearly **16.2 million hectares**, if current trends continue unchecked.
- States with highest salt-affected areas include **Gujarat** (≈ 2.23 million ha), **Uttar Pradesh** (≈ 1.37 million ha), **Maharashtra** (≈ 0.61 million ha), **West Bengal**, and **Rajasthan**. Together, these five states account for about **75%** of India's salt-affected soils.

Several interlinked factors contribute to the worsening salt crisis:

1. **Poor Drainage and Waterlogging**

   In many irrigated areas, water isn't draining well. This allows salts in the groundwater or irrigation water to accumulate in root zones.

2. **Excessive or Unsustainable Irrigation**

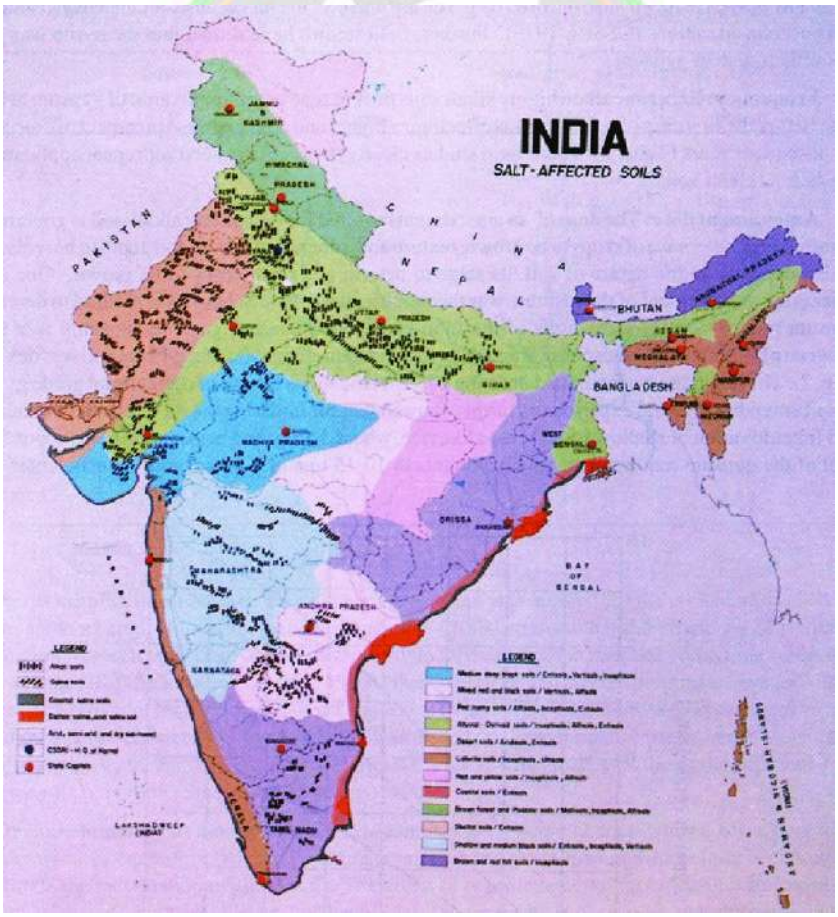
   Using large amounts of water (especially poor quality water) without leaching or flushing out salts makes the problem worse. Saline or brackish groundwater is often used in some regions.

3. **Natural Causes and Climate Factors**

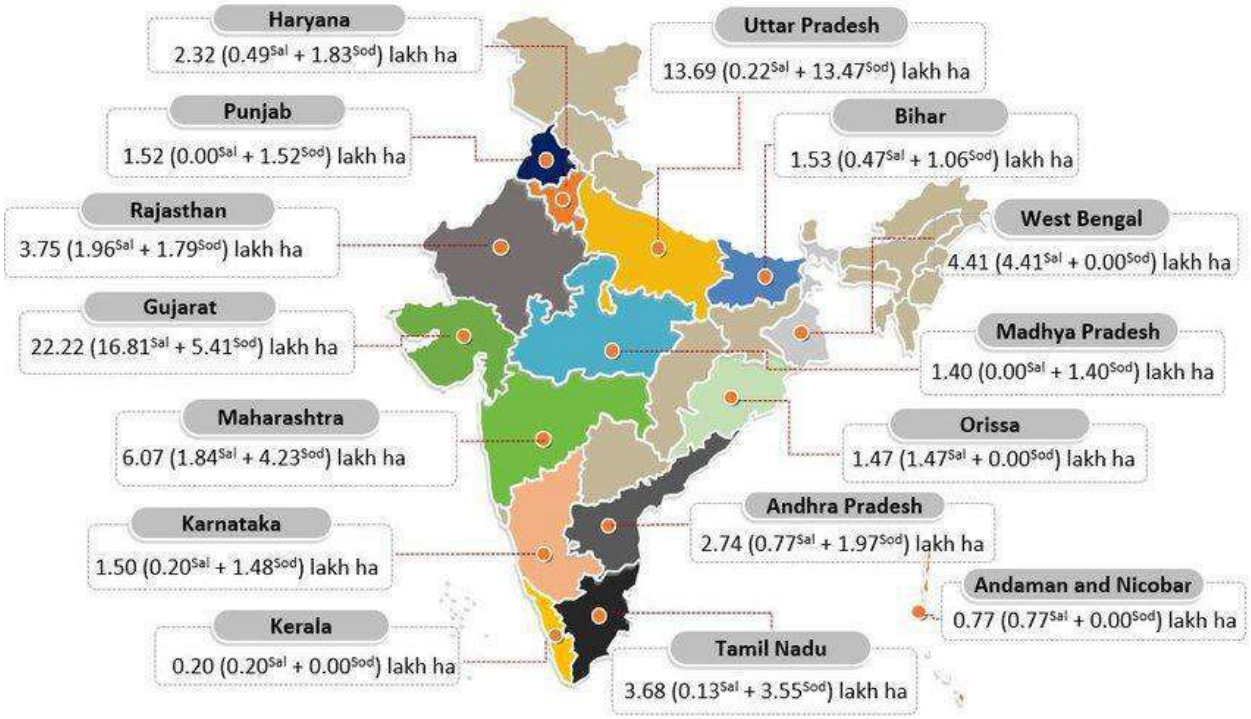
   Coastal intrusion, proximity to salt-bearing groundwater, evaporation in arid / semi-arid regions amplify salinization. Climate change may exacerbate evaporation, sea level rise, erratic rainfall, etc.

4. **Land Use Practices**

   Lack of crop rotation, overuse of chemical fertilisers, not maintaining organic matter, over-cultivation of salt-sensitive crops in vulnerable soils.



State-wise extent of salt-affected soils in India (million ha). Source: Sharma *et al.* (2004)



Consequences: When Soil Becomes Salted

The impacts of increasing salinity and sodicity are serious and wide-ranging:

- **Reduced Crop Yields & Economic Losses**

  India loses millions of tonnes of agricultural production each year due to soil salinity. One estimate puts the loss at **₹23,000 crore** (base 2015) annually.

- **Land Degradation and Barren Areas**

  As salinity worsens, soil structure deteriorates. Soil becomes compacted, less able to hold water, root growth is inhibited, and eventually land may stop being usable for many crops.

- **Food Security Risks**

  With increasing salt-affected land, fewer lands are reliably productive, which threatens food supply especially of staple crops sensitive to salinity.

- **Environmental & Social Costs**

  Salt-affected soils also affect biodiversity (soil microbes, plants), degrade ecosystems, reduce income for farmers, lead to livelihood losses, possibly forced migration from severely affected areas.

Despite scale of the problem, there are solutions. Here are practices and policies that help:

Strategy	What It Involves
Reclamation using chemical amendments	For sodic lands, using gypsum or other calcium containing materials to replace sodium; improve soil structure.
Improved drainage systems	Sub-surface drainage, creating proper drainage channels in waterlogged areas so salts can be flushed away.
Salt-tolerant crop varieties	Developing or using crop varieties which can tolerate higher salt levels. Helps maintain production even in degraded soils.
Use of organic matter	Manure, compost, bio-fertilisers help retain soil structure, improve water holding capacity, reduce salt stress.
Policy & National Targets	Government target to restore **26 million hectares** of degraded lands (which includes salt-affected lands) by 2030

To prevent more land from being lost, India must act with urgency:

1. **Scale up Soil Mapping & Monitoring**
   Use remote sensing, soil surveys, GIS tools to identify and monitor salt-affected areas early.
2. **Improve Water Management**
   Better irrigation planning; avoid over-irrigation; ensure flushing/leaching when needed; manage groundwater quality.
3. **Promote Salt-Resilient Farming**
   Use crops and varieties that tolerate salinity; mix cropping; agroforestry; crop rotation.
4. **Increase Farmer Awareness & Support**
   Extension services must teach farmers to recognize early signs of salinity, adopt reclamation practices, use organic inputs, etc.
5. **Government Policies & Investments**
   Subsidies/incentives for reclamation, provision of inputs (gypsum, organic manure), improving drainage infrastructure; strong regulation of groundwater and irrigation water quality.

6. **Research & Innovation**

   Continue R&D into better reclamation methods, use of salt-tolerant microbes, improved crop varieties, affordable and locally adapted technologies.

Conclusion

"From Saline to Barren" is not just a poetic phrase it describes a real threat facing millions of hectares of Indian farmland. If soil salinity continues to increase, the consequences will ripple through food production, farmer incomes, rural economies, and overall national wellbeing. But it is still possible to reverse this trend. With timely action, science and policy working together, and farmer engagement, India can reclaim much of the degraded land, restoring productivity and securing its agricultural future.

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GAS SENSING FILMS IN INTELLIGENT PACKAGING FOR SPOILAGE DETECTION

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Introduction

Advancements in Fraudspro is revolutionary step towards safeguard food safety and quality monitoring as intelligent packaging . In this landscape, gas sensing films have shown the greatest potentialities to detect volatile organic compounds (VOCs) and gases formed during food spoilage processes . This advanced materials gap between traditional passive packaging and active monitoring system providing continuous control of food quality along the value chain.

Basic Principles of Gas-Sensing Films:

For gas-sensing films, they work on different detection principles which are specific for target gases and application requirements. Key mechanisms are chemiresistive sensing, where the electrical conductivity undergoes changes upon exposure to gases; colorimetric detection with visible coloring and available electrochemical processes generating measurable electric outputs.

Chemiresistive Mechanisms:

Chemiresistive gas sensors use materials whose electrical resistance is modified upon exposure to certain gases. For instance ZnO, SnOâ,, and TiOâ,, metal oxide semiconductors (MOS) are used as a sensor in which they also display excellent sensitivity to the gases that emitted due to food spoilage. The sensing process usually consists of the adsorption and desorption from gas molecules to senor surface, causes changes in charge carrier concentration followed by their effect on electrical conductivity.

Colorimetric Detection:

Colorimetric sensors allow rapid, visual detection of gaseous analytes through color

changes and are often ideal for consumer use due to being simple enough that regular users can make measurements with high accuracy. These systems utilize pH-dependent dyes, redox indicators or natural colorants that change colors upon exposure to particular gases[6][3]. These include bromophenol blue-based films which change colour in response to pH changes due to ammonia emissions and can be used for detecting volatile nitrogen compounds from spoiled meat .

Gas Sensing Films Based on Material Systems:

Performance of gas sensing films is largely dominated by the selection of active materials that combines a range types from metal oxide to conducting polymer and natural pigment or their hybrids.

Metal Oxide Sensors:

Metal oxide semiconductors continue to be the most commonly investigated class of materials for gas sensing applications, owning to their high sensitivity, stability, and versatility. The use of nanostructured metal oxides has an appealing feature due to its larger surface area and better kinetics for gas adsorption. Recent developments have led to the formation of heterostructures such as the TiOâ,,/Tiâ,ƒCâ,,Tx heterostructure, which has ultra-low detection limits for ammonia and is significant for monitoring freshness of fish, pork, and shrimp.

The use of a NiCoâ,,Oâ,„-ZnO composite sensor is another remarkable advancement in sensing materials, as it demonstrated improved response and recovery times for trimethylamine detection. All materials work based on changes of conductivity when the gas is adsorbed/desorbed onto/ from the substrate. The presence of the different metal oxides alters and increases the sensors sensitivity and selectivity.

Systems of Conducting Polymers:

Conducting polymers have unique advantages to offer, including flexibility, processability, and ability to operate at room temperature. These materials can detect ammonia gas, which is a leading indicator of spoiled meat, and are especially useful for detecting gases released from spoiled food products. Additionally, polymer-based sensors can be easily implemented in flexible packaging films, which may have applications for direct food contact.

Sensors Based on Natural Pigments :

Natural pigments derived from plant materials are being more widely recognized as sustainable, colorimetric gas sensors . Anthocyanins derived from plant materials such as red

cabbage, rose petals, and other materials can be utilized as pH indicators that change colour based on gases produced when food spoils. Bio-based sensors have the unique advantages of being bio-degradable, non-toxic and inexpensive .

Petunia dye obtained from natural petunia flowers exhibits highly sensitive colorimetric response to sulfur dioxide (SOâ,,) gas with limits of detection down to 1.52 ppm[85]. Natural pigment systems are especially useful for applications when sensor materials are in direct contact with food products.

Fabrication Techniques and Processing Methods

The fabrication of gaseous sensing films utilizes a variety of processing techniques which all confer separate advantages with respect to scalability, costs and performance capabilities.

Solution-Based Processing:

Solution-based methods are widely used to fabricate gas-sensing films; for instance, spin-coating, drop-casting and print-based inks for ink-jet printing are all significant methods. These techniques provide good control of film thickness and composition with a high degree of compatibility with flexible substrates. The ink-jet printing in particular has illustrated good promise for the large scale production of colorimetric oxygen sensors, made with materials such as toluidine blue and hydroxypropyl methylcellulose, and is notable for this use.

Gas sensing films have various applications depending on the type of food product, as each type presents its own unique set of issues and requirements for spoilage detection.

Layer-by-Layer Assembly:

The advantage of the layer-by-layer assembly methods is the ability to create multilayer sensing films with control over composition and structure [85]. This technique allows the use of multiple sensing materials within a single film layer, which may allow for multiple gas detection capabilities.

Polymer Precursor Methods:

The polymer precursor method has been shown to be very effective and offers advantages for the synthesis of perovskite-type oxide thin films for gas sensing. This is a wet-chemical synthesis approach that has advantages over dry processing approaches like sputtering.

Meat and seafood products are especially susceptible to spoiling due high levels of protein and moisture. Generally, gas sensing films for these applications target ammonia, hydrogen sulfide, and trimethylamine as spoilage indicators for protein degradation. The flexible

sensing system for evaluating lamb freshness is an example of a recent gas sensor flexible packaging and has real-time monitoring capabilities based on temperature and impedance.

Application:

Monitoring fresh produce requires a sensor that can detect ethylene, carbon dioxide and other gases associated with ripening and spoilage. Modified Atmosphere Packaging (MAP) systems for fruits often utilize a gas transmission rate monitoring system to assess the MAP system to ensure that their system maintains optimal levels for the fruit.

Dairy products often spoil due to the detection of a specific compound, which is why gases can be detected with the right designed sensing films. To assess spoilage of dairy products, multiple sensor arrays can be installed to monitor more than one indicator of spoilage at the same time.

Integration into Packaging Systems

The successful use of gas sensing films requires thoughtful integrations and system design to be compatible with current packaging systems and retain sensing abilities.

Film Integration Methods :

Gas sensing films can be implemented into packaging using a few different methods, including direct incorporation within packaging materials, using adhesive labels, or compartmentalization. Each approach has different benefits and challenges, related to manufacturing complexity, cost, and performance.

Wireless Communication Systems :

Up and coming, many gas sensing films include wireless communication features to allow for remote monitoring and data transfer. One such example is a successful trial incorporating near-field communication (NFC) for monitoring spinach spoilage, which is controlled by user smartphone interaction.

Consistency and Longevity:

It is essential to have long-term consistency under packaging conditions meaning long term stability under varying temperature, humidity or mechanical stress for viable commercial viability. Sensors can maintain performance over long periods, thanks to strong material design and environmental compensation systems.

Outstanding Challenges and Limitations :

Despite the advances made to use gas sensing films, challenges continue to limit their

successful and wide spread use in intelligent packaging applications.

Sustainable & Biodegradable Systems:

Concerns for the environment continue to grow, developing biodegradable and environmentally friendly sensing materials. Sensors utilizing natural pigments and biodegradable polymeric matrices (both fully biodegradable or partially biodegradable) offer a sustainable alternative to petrochemical-based synthetic materials.

Multi-Modal Sensing Platforms:

Future systems will likely have fully integrated, multifunctional (multi-modal) sensing capabilities (i.e. gas; temperature; mechanical stress), to accommodate a wider range of monitoring that would provide a thorough monitoring of the package or product.

Conclusion:

Gas sensing films are a revolutionary technology in intelligent packaging, enabling real-time food freshness and spoilage detection like never before. The combination of new materials, advanced fabrication processes, and new communication technologies allows for holistic solutions that improve food safety, mitigate food waste, and improve the efficiency of the food supply chain. There are still challenges relative to costs, stability, and regulatory approval, but researchers and developers are focusing on solving these issues. The intersection of nanotechnology, artificial intelligence, and sustainable materials science is serving as a foundation for next-generation sensing films that will play critical roles in future food packaging systems.

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SPEED BREEDING AND REDUCING BREEDING CYCLE TIMES IN INDIA

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Abstract

Speed breeding is an innovative approach to accelerate crop improvement by enabling multiple generations per year under controlled environmental conditions. In India, this technique is gaining prominence through newly established facilities capable of supporting more than four generations annually for crops such as wheat, rice, soybean, pea, and tomato. These controlled environments allow precise regulation of light, temperature, and humidity, which facilitates rapid growth, early flowering, and faster seed development. The technology supports agricultural scientists, plant breeders, and biotechnologists in developing high-yielding and nutrient-enriched varieties, thereby enhancing India's capacity for climate-resilient and sustainable agriculture. The initiative is led by the National Agri-Food Biotechnology Institute (NABI) and aligns with national programs including the Atal Jai Anusandhan Biotech (UNaTI) Mission and Poshan Abhiyan. By reducing the breeding cycle time, speed breeding enables faster deployment of superior crop varieties and strengthens the nation's food security framework.

Keywords: Speed breeding, India, NABI, climate-resilient crops, plant biotechnology

1. Introduction

Traditional plant breeding in India, particularly for staple crops such as wheat, rice, and pulses, typically requires 8–10 years to develop and release a new variety. This extended timeframe limits the ability of breeders to respond rapidly to emerging challenges, including climate variability, pest outbreaks, and changing nutritional demands. With growing pressure on agricultural productivity to meet the needs of a rapidly expanding population, faster breeding methods are increasingly essential.

Speed breeding, first introduced at the University of Queensland (Watson et al., 2018), has emerged as a transformative solution to accelerate the crop improvement process. By manipulating environmental factors such as photoperiod, temperature, and light intensity, breeders can significantly reduce the generation time of crops. In India, this approach has become particularly relevant for northern states with short growing seasons, including Punjab, Haryana, Himachal Pradesh, and the Union Territory of Jammu & Kashmir. These regions often face climatic constraints that limit the number of crop cycles achievable under traditional conditions.

The establishment of dedicated speed breeding facilities in India, led by institutions such as the National Agri-Food Biotechnology Institute (NABI), has enabled researchers to exploit this technology for multiple crops. The integration of speed breeding with modern genomic tools, including marker-assisted selection, genomic selection, and gene editing, further enhances its potential to accelerate the development of high-yielding, stress-tolerant, and nutritionally improved varieties.

2. Principles of Speed Breeding

Speed breeding relies on creating controlled growth environments that optimize the developmental rate of plants. The primary factors manipulated include photoperiod, temperature, humidity, and light spectrum. By extending the duration of light exposure—often to 20–22 hours per day—plants can undergo accelerated photosynthesis, leading to faster vegetative growth and earlier flowering.

Temperature regulation is equally important; optimal thermal conditions allow for enhanced metabolic activity and rapid seed maturation. Humidity control minimizes stress and prevents disease incidence, while precise nutrient management ensures continuous growth without limitations. In some advanced setups, automated irrigation and fertigation systems support consistent nutrient delivery, reducing variability between generations.

Through these interventions, breeders can achieve multiple crop generations per year. For example, wheat and chickpea lines have been successfully grown under Indian test conditions to produce up to five generations annually. Similarly, rice varieties have shown promising responses when grown in controlled light and temperature regimes. The acceleration of the breeding cycle not only reduces the time needed for varietal release but also allows for more rapid evaluation of genotypic and phenotypic traits, facilitating better selection decisions.

3. Progress of Speed Breeding in India

3.1 Institutional Developments

India has recognized the potential of speed breeding to revolutionize crop improvement, leading to the establishment of dedicated facilities across the country. The National Speed Breeding Facility at the Indian Council of Agricultural Research – Indian Agricultural Research Institute (ICAR-IARI), New Delhi, inaugurated in 2024–25, represents a major milestone. This facility provides precisely controlled environments capable of supporting multiple crop generations annually, allowing researchers to accelerate breeding programs for wheat, rice, maize, chickpea, and other economically important crops.

In addition to ICAR-IARI, several State Agricultural Universities (SAUs) have implemented speed breeding initiatives. Punjab Agricultural University (PAU), Ludhiana, is developing predictive breeding pipelines for both cereals and horticultural crops, including guava. Tamil Nadu Agricultural University (TNAU), Coimbatore, has adapted the technology for tropical crops such as rice and pulses, optimizing light and temperature regimes suitable for their growth. The National Agri-Food Biotechnology Institute (NABI) in Mohali, Punjab, continues to lead efforts integrating speed breeding with biotechnological approaches to enhance both yield and nutritional quality.

These institutions collectively provide a framework for national adoption of speed breeding, enabling breeders across different agro-climatic zones to benefit from accelerated crop improvement cycles.

3.2 Crop-Specific Applications

- Wheat: Development of rust-resistant and early-maturing wheat varieties with up to five generations per year.
- Rice: Accelerated flowering and seed set for submergence tolerance, drought resistance, and early maturity.
- Pulses: Shortened life cycles in chickpea and pigeonpea facilitate faster disease resistance screening.
- Horticultural Crops: Guava, tomato, and brinjal evaluated for faster generation turnover and uniformity.

3.3 Integration with Modern Breeding Tools

- Genomic Selection (GS): Predictive pre-selection of elite genotypes.

- Gene Editing (CRISPR/Cas9): Faster fixation of edited alleles.
- High-Throughput Phenotyping (Phenomics): Automated measurement of growth and stress traits.
- Artificial Intelligence (AI): Optimized growth parameters and predictive breeding decisions.

3.4 Regional Relevance

Northern states such as Punjab, Haryana, Himachal Pradesh, and Jammu & Kashmir benefit particularly due to short growing seasons, enabling continuous genetic improvement despite seasonal constraints.

4. Benefits of Speed Breeding in India

Benefit	Impact
Accelerated Varietal Development	Faster evaluation and release of superior crop varieties
Climate-Resilient Crops	Rapid development of drought, heat, and disease-tolerant lines
Integration with Advanced Tools	Combines genomics, CRISPR, and phenomics for higher genetic gain
Resource Efficiency	Reduced land, labor, and field resource requirements
Food Security and Nutrition	Rapid deployment of high-yielding, nutrient-rich varieties

5. Challenges and Limitations

- High Infrastructure Costs: Controlled environment facilities require significant investment.
- Energy Demand: Continuous lighting and climate control increase operational costs.
- Crop-Specific Limitations: Photoperiod sensitivity and flowering responses vary.
- Technical Expertise: Skilled personnel needed for environment management and genomics integration.
- Policy and Adoption Barriers: National scaling requires institutional coordination, funding, and incentives.

6. Future Prospects

6.1 Speed Breeding 3.0

- Integration of AI, IoT, and automated phenotyping for predictive growth management

and real-time breeding decisions.

6.2 Regional Expansion

- Establishment of hubs across diverse agro-climatic zones for year-round breeding and faster varietal development.

6.3 Integration with Policy Initiatives

- Linkage with national programs like UNaTI Mission and Poshan Abhiyan for nutrition-focused breeding.

6.4 Sustainable Approaches

- Development of solar-powered and modular controlled environment systems to reduce energy costs and environmental impact.

Conclusion

Speed breeding provides a transformative method for accelerating crop improvement, shortening breeding cycles, and developing climate-resilient, high-yielding, and nutrient-enriched crop varieties in India. Strategic investment, integration with genomics and AI, and support from national programs can ensure that this technology strengthens food security and sustainable agricultural development. Expansion of facilities and adoption across multiple states will position India at the forefront of global crop improvement initiatives.

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PALMYRA TREE: A FORGOTTEN TREASURE

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Abstract

The Palmyra tree (*Borassus flabellifer*), known in many places as the toddy palm or "tree of life," has been a silent companion to human life for thousands of years. From its sweet fruits and refreshing sap to its strong leaves and timber, every part of the tree has served people. In villages across South and Southeast Asia, it was once the center of daily life and culture. But today, this tree is slowly fading from memory. This article tells the story of the Palmyra tree its gifts, its role in people's lives and why it still matters in our modern world.

Introduction

If you grew up in a village, you may remember summer days when elders offered you the tender, jelly-like fruit of the Palmyra palm, cool and sweet against the heat. Or perhaps you have seen jaggery being made from its sap, with a rich aroma filling the air (Piras *et al.*, 2025). For many communities in India, Sri Lanka, Thailand and other countries, the Palmyra tree was once

like a family member providing food, drink, shelter and even medicine. But in today's fast-moving world, where supermarkets and processed foods dominate, the Palmyra tree is often forgotten. Yet this tall palm, standing proud in dry lands, still has much to teach us about survival, sustainability and tradition (Drijvers and Han JW., 2023).

A Tree That Gives Without Asking

The Palmyra tree can live for over a hundred years. It grows tall, with a crown of fan-shaped leaves that sway in the wind. It needs little care and can survive in hot, dry climates where other crops struggle. That is why farmers once called it their "safety tree" (Behera *et al.*, 2022). Every part of the tree is useful. The tender fruit, known as *nungu* in Tamil, is a natural summer cooler. The golden pulp of the ripe fruit is sweet and filling. Its sap, tapped from the flower stalks, becomes a refreshing drink in the morning or turns into jaggery when boiled. The leaves make mats, baskets, fans and even the old palm-leaf books where knowledge was once written. The trunk is strong enough for beams and rafters in houses (Raja and Rubina., 2022). Nothing from the Palmyra goes to waste making it truly a "tree of life."

Medicine in a Palm

Our ancestors saw the Palmyra not only as food but also as medicine. In traditional systems like Ayurveda and Siddha, the roots were boiled to cure stomach problems. The young fruit was believed to cool the body. The jaggery was said to be healthier than refined sugar, rich in iron and minerals. Long before tablets and syrups came in bottles, villagers trusted the Palmyra to heal everyday ailments naturally (Smith *et al.*, 2013).

The Heart of Village Culture

The Palmyra tree is deeply woven into culture and identity. In Tamil Nadu, folk songs praise it as a wish-fulfilling tree. In villages, people gathered under its shade, drank its fresh sap at dawn and celebrated festivals with sweets made from its jaggery. Palm leaves once carried the wisdom of entire generations. Scriptures, poems and medical texts were etched on palm-leaf manuscripts that lasted for centuries. Imagine a single tree carrying both the sweetness of fruit and the knowledge of history! Economically, the Palmyra supported families. Craftsmen made household items from its leaves, farmers earned from jaggery and its wood stood strong in homes. For rural people, this tree was not just useful it was survival itself (Sommer and Michael., 2017).

A Guardian of Nature

Beyond culture and economy, the Palmyra tree is a silent guardian of the environment. Its deep roots bind the soil and help conserve water. It grows naturally without the need for chemical fertilizers or pesticides.

In a time when climate change makes farming uncertain, the Palmyra offers hope. It thrives in harsh conditions, showing us that sustainable crops need not be high-tech they can be as old as this forgotten palm (Prasad *et al.*, 2013).

Why Did We Forget It?

Sadly, the Palmyra tree no longer gets the respect it once had. Urban life has pushed it aside. Younger generations prefer soft drinks to palm juice and white sugar has replaced palm jaggery in many kitchens. Commercial crops like sugarcane bring faster profits, so farmers plant fewer Palmyras. As a result, this treasure is fading away. If we lose it, we lose not just a tree but a whole way of life.

Conclusion

The Palmyra tree is not only a palm it is a living story of how humans and nature can share life together. For thousands of years, it gave food, medicine, shade, knowledge and culture. It stood tall through droughts, storms, and wars, quietly serving people. Calling it a “forgotten treasure” is true but it is not too late to remember. Planting more Palmyra palms, encouraging palm products, and teaching children about its value can bring this tree back into our lives. If we care for it, the Palmyra will continue to stand tall, reminding us that real treasures are not in gold or jewels but in the living gifts of nature.

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SCIENTIFIC PREPARATION OF VERMICOMPOST AND ITS ENRICHMENT

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Introduction

Vermicomposting is the process of using earthworms to decompose organic waste into nutrient-rich humus known as worm castings or vermicompost. The process relies on the digestive activities of earthworms, particularly species like *Eudrilus eugeniae* and *Eisenia fetida* which consume organic material and convert it into vermicompost.

The following are key stages in vermicomposting:

1. **Ingestion of Organic Material**: Earthworms ingest organic waste such as food scraps, plant residues, and manure. The organic matter passes through their digestive system, where it is partially broken down by microorganisms in their gut.
2. **Digestion and Excretion**: After digestion, the organic matter is excreted as vermicast, which is rich in essential nutrients and beneficial microorganisms. The excreted material is typically dark, granular, and odourless.
3. **Maturation**: Over time, the worm castings mature into a highly stable form, which is rich in nutrients like nitrogen, phosphorus, potassium, calcium, and magnesium. Vermicompost is considered one of the best natural fertilizers due to its high nutrient content and ability to improve soil structure.

Factors Affecting Vermicomposting

The efficiency of vermicomposting depends on several factors:

- **Type of Organic Material**: The type of feedstock significantly impacts the quality of the vermicompost. Earthworms tend to favor decomposing plant materials, while some species can handle manure, food scraps, or other organic waste.

- **Temperature**: Vermicomposting requires temperatures between 15-30°C for optimal earthworm activity. Higher temperatures may cause stress to the earthworms, while lower temperatures can slow down the process.
- **Moisture**: Earthworms require a moist environment to survive and perform efficiently. Moisture levels between 60-80% are optimal.
- **pH**: A neutral to slightly alkaline pH (6.5-8) is most suitable for earthworm activity. Extreme pH levels may harm the worms and reduce vermicomposting efficiency.

Enrichment of Vermicompost

Similar to compost, vermicompost can be enriched to enhance its nutrient content and effectiveness as a soil amendment. Enrichment methods for vermicomposting include:

- **Addition of Beneficial Microorganisms**: Inoculating the worm bin with beneficial bacteria or fungi can help speed up the degradation process and improve the microbial diversity of the vermicompost.
- **Use of Organic Additives**: Adding specific organic additives such as algae, seaweed, or food scraps rich in certain nutrients can boost the nutrient profile of the final product.
- **Temperature and Humidity Control**: Maintaining optimal conditions for earthworms, such as temperature and humidity, can ensure that the vermicomposting process is efficient and that the resulting vermicompost is of high quality.

Vermicomposting methods

Excreta produced by earthworm from organic wastes are known as vermicompost. Although it is neither manure nor compost, because end product is not the result of decomposition, it is customarily called as vermicompost.

Vermicomposting is a method of composting with worms and differs from conventional composting in several ways. In vermicomposting, there is a saving of nearly two months in composting time compared to conventional compost. Vermicompost is rich in nutrients, microbial activity and enzymes. In general, there are two methods of vermicomposting under field conditions.

1. Vermicomposting of wastes in field pits.
2. Vermicomposting of wastes on heaps

For production of vermicompost, open permanent pits of 10 feet length x 3 feet width x 2 feet deep were constructed under the tree shade, which was about 2 feet above ground to

avoid entry of rainwater into the pits. Brick walls were constructed above the pit floor and perforated into 10 cm diameter 5-6 holes in the pit wall for aeration. The holes in the wall were blocked with nylon screen (100 mesh) so that earthworms might not escape from the pits. Partially decomposed dung was spread on the bottom of the pits to a thickness of about 3-4 cm. This was followed by addition of layer of litter/residue and dung in the ratio of 1:1 (w/w). A second layer of dung was then applied followed by another layer of litter/crop residue in the same ratio up to a height of 2 feet. Two species of epigeic earthworm viz., *Eisenia fetida* and *Perionyx excavatus* were inoculated in the pit.

Moisture content was maintained at 60-70% through-out the decomposition period. Jute bags (gunny bags) were spread uniformly on the surface of the materials to facilitate maintenance of suitable moisture regime and temperature conditions. Watering by sprinkler was often done. The materials was allowed to decompose for 15-20 days to stabilize the temperature because to reach the mesophilic stage, the process has to pass the thermophilic stage, which comes in about 3 weeks. Earthworms were inoculated in the pit or heap with 10 adult earthworms per kg of waste material and a total of 500 worms were added to each pit or heap. The materials were allowed to decompose for 110 days. The forest litter was decomposed much earlier (75 to 85 days) to farm residue (110 + 5 days).

Silpaulin Portable Vermi-bed:

For production of vermicompost, silpaulin portable vemi-bed of 12 feet length X 4 feet width X 2 feet deep were kept under the tree shade, which was about ½ feet above ground to avoid entry of rainwater into the beds. In portable vermi-bed, partially decompose organic wastes was added crop residues and dung in the ratio of 1:1 (w/w).

Table 1: Chemical composition of vermicompost and P-enriched vermicompost prepared from soybean straw

Parameters	Vermicompost	P-enriched vermicompost
Ash (%)	51.0	52.5
TOC (%)	27.2	26.5
C/N ratio (%)	14.3	13.6
N (%)	1.90	1.95
P_2O_5 (%)	2.05	4.0

K_2O (%)	0.80	0.86
WSC (%)	0.94	0.88
Mn (ppm)	500	540
Zn (ppm)	100	100
Cu (ppm)	44	46

Singh *et al*., (2005)

Two species of earthworms viz., *Eisenia fetida* and *Perionyx excavatus* were inoculated in the bed. Moisture content was maintained at 60-70% through- out the decomposition period. Jute bags (gunny bags) were spread uniformly on the surface of the materials to facilitate maintenance of suitable moisture regime and temperature conditions.

Vermicompost Production Methodology

i) Selection of suitable earthworm: Locally available earthworms aren't suitable for the purpose as they are not voracious eaters. While, exotic species of earthworm used for the purpose as they are voracious eaters and hence produce large manure quickly. For vermicompost production, the surface dwelling earthworm alone should be used. The earthworm, which live below the soil, is not suitable for vermicompost production. The African earthworm (*Eudrillus eugenia),* Red worms (*Eisenia fetida)* and composting worm (*Perionyx excavatus)* are promising worms used for vermicompost production. All the three worms can be mixed together for vermicompost production. The African worm (*Eudrillus eugenia)* is preferred over other two types, because it results in higher production of vermicompost in short period of time and produce more young ones in the composting period.

ii) Selection of site for vermicompost production: Vermicompost can be produced in any place with shade, high humidity and cool. Abandoned cattle shed or poultry shed or unused buildings can be used. If it is to be produced in open area, shady place is selected. A thatched roof may be provided to reduce loss of moisture from substrate. The waste heaped for vermicompost production should be covered with moist gunny bags.

iii) Containers for vermicompost production: A cement tub may be constructed to a height of 2½ feet and a breadth of 3 feet. The length may be fixed to any level depending upon the size of the room. The floor of the tub is made to slope like structure to drain the excess water from vermicompost unit. A small sump is necessary to collect the drained water.

In another option over the hand floor, hollow blocks / bricks may be arranged in compartment to a height of one feet, breadth of 3 feet and desired length to have quick harvest. In this method, moisture assessment will be very easy. No excess water will be drained. Vermicompost can also be prepared even in wooden boxes, plastic buckets or in any containers with a drain hole at the bottom.

iv) Vermicompost bed: A worm bed (3 cm) can be prepared by placing saw dust or husk or coir waste or sugarcane trash in the bottom of tub / container. A layer of fine sand (3 cm) should be spread over the worm bed followed by a layer of garden soil (3 cm). All layers must be moistened with water.

v) Waste selection for vermicompost production: Animal wastes, crop residues, green manures, vegetable market waste, flower market waste, agro industrial waste, fruit market waste and all other bio degradable waste are suitable for vermicompost production. All waste should be pre-digested with cow dung for 15-20 days before they are used in vermicomposting.

vi) Putting the waste in the container: The pre-digested waste material should be mixed with cattle dung and placed into the tub / container up to brim. The moisture level should be maintained at 60%. Over this material, the selected young Earthworm are released uniformly. For every 0.5 Cum of bed, 1 kg of young worm (1000 No's.) is required. There is no necessity that earthworm should be put inside the waste. Earthworm will move inside on its own.

vii) Watering the vermibed: Daily watering is not required for vermibed. But 60% moisture should be maintained throughout the period. If necessity arises, water should be gently sprinkled over the bed rather than pouring the water. Watering should be stopped a week before the harvest of vermicompost.

ix) Harvesting vermicompost: The compost will be ready in 30-45 days indicated by round granular size of particles and black colour. In the tub method of composting, the castings formed on the top layer are collected periodically. The collection may be carried out once in 3-4 days with hand. The casting will be scooped out and put in a shady place as heap like structure. The harvesting of casting should be limited up to the layer where earthworms are seen.

x) Harvesting earthworm: After the vermicompost production, the earthworm present in the tub / small bed may be harvested by trapping method. In this method, before harvesting the compost, small, fresh cow dung ball is made and inserted inside the bed in five or six places. After 24 hours,

the cow dung ball is removed. All the worms will be adhered into the ball and can be used for next batch of composting.

xii) Storing and packing of vermicompost: The harvested vermicompost should be stored in dark, cool place. It should have minimum 40% moisture. Sunlight should not fall over the composted material. It will lead to loss of moisture and nutrient. It is advocated that the harvested compost material is openly stored rather than packed in over sac. Packing can be done at the time of selling. If it is stored in open place, periodical sprinkling of water may be done to maintain moisture level and also to maintain beneficial microbial population. Vermicompost can be stored for one year without loss of its quality, if the moisture is maintained at 40% level.

Vermiculture: Instead of artificially growing vermicompost in troughs, the earthworms could also be released in a heap of biomass directly. They feed on biomass and convert it into heap of black mass of fecal excreta similar to vermicompost. This *insitu* growing of earth worms is called Vermi culture.

Vermiculture can be practically adopted in any place of farm where moisture and shade can be maintained. To facilitate easy vermiculture, the biomass can be sprinkled with dung slurry.

Vermiwash: Advances in vermiculture technology have recently led to novel products like vermiwash. This product has now not only caught the attention of commercial vermiculturists but also the farmers. Farmers in their own way have started collecting vermiwash for foliar application. For preparation of vermiwash, one-kilogram adult earthworms devoid of casts (approximately numbering 1000-1200 worms) is released into a trough containing 500 ml of lukewarm distilled water (37°C-40°C) and agitated for two minutes.

Earthworms are then taken out and again washed in another 500 ml at room temperature (+ 30°C) and released back into the tanks. The agitation in lukewarm water makes the earthworms to release sufficient quantities of mucus and 55 body fluids. Transferring into ordinary water is to wash the mucus sticking still on to their body surface and this also helps the earthworms to revive from the shock. The surface of their bodies release some plant growth promoting substances and bacterial population during such wash. Hence vermiwash is useful spray to promote the plant growth. However, in practice, even a wash from vermicompost is considered as vermiwash. Sometimes drained water from vermicompost pit is also used as vermiwash.

Comparison of Compost and Vermicompost

Aspect	Compost	Vermicompost
Decomposition Agent	Microorganisms (aerobic bacteria and fungi)	Earthworms and microorganisms in the gut
Process Time	Longer, usually 2-4 months	Shorter, typically 1-2 months
Nutrient Content	Lower nutrient content	Higher nutrient content (N, P, K and micronutrients)
pH	Slightly alkaline to neutral (7-8)	Slightly alkaline (7-8)
Use	General soil amendment and erosion control	Fertilizer and plant growth stimulant

Conclusion

Organic manures application plays a vital role in maintenance of chemical, biochemical and biological properties of soils, besides supplementing macro and micro nutrients to crop. The deficiency of micro nutrients particularly of Zn, Fe, B, Mn, Cu and Mo is becoming a yield limiting factor in most of the soils. Efficient decomposition process brings down the composting period from six to eight months to 2 - 3 months. Composting technologies *viz;* use of microbial multibio-inoculums such as cellulose decomposers (*Paecilomyces fusisporus* and *Aspergillus awamori*), P- solubilizers (*Bacillus polymyxa* and *Pseudomonas striata*) and free living N-fixer (*Azotobacter chroococcum*), earth worm inoculation (*Eudrillus euginea*, *Eisenia fetida* and *Perionyx excavatus* as prominent composting earthworms), enrichment with pyrite, rock phosphate and zinc sulphate for recycling of organic wastes into nutrient enriched compost. Enriched compost helps to produce higher yields of crops, quality of produce and maintain fertility status of soils. The use of enriched manure in field crops is also economically viable and safe to environment.

Future research should focus on improving the efficiency of composting and vermicomposting processes, exploring new types of organic waste for recycling, and developing cost-effective enrichment methods. Further investigation into the synergistic use of compost and

vermicompost in soil health management, as well as the application of advanced technologies like microbial consortia and bioreactors, can offer new insights into optimizing organic waste recycling for sustainable agriculture and environmental protection

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SWEET FLAG- A TRADITIONAL MEDICINAL PLANT

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Abstract

Acorus calamus (Sweet flag) has a long history of use and has numerous traditional and ethnomedicinal applications. Since ancient times, it has been used in various systems of medicines such as Ayurveda, Unani, Siddha, Chinese medicine, etc. for the treatment of various aliments like nervous disorders, appetite loss, bronchitis, chest pain, colic, cramps, diarrhea, digestive disorders, flatulence, gas, indigestion, rheumatism, sedative, cough, fever, bronchitis, inflammation, depression, tumors, hemorrhoids, skin diseases, numbness, general debility and vascular disorders. Various therapeutic potentials of this plant have been attributed to its rhizome. A number of active constituents from leaves, rhizomes and essential oils of *A. calamus* have been isolated and characterized. Of the constituents, alpha and beta-asarone are the predominant bioactive components. Various pharmacological activities of *A. calamus* rhizome such as sedative, CNS depressant, anticonvulsant, antispasmodic, cardiovascular, hypolipidemic, immunosuppressive, anti-inflammatory, cryoprotective, antioxidant, antidiarrheal, antimicrobial, anticancer and antidiabetic has been reported. Genotoxicity and mutagenecity of beta and alpha-asarone is reported, which limits their use at high dosage.

Introduction

The fragrant medicinal plant *Acorus calamus Linn*., belongs to family Acoraceae (Araceae) commonly known as "Sweet flag," is widely recognised for its therapeutic benefits. It is semiaquatic, perennial, herb with creeping rhizomes. It grows up to 6 feet tall, aromatic,

sword-shaped leaves and small, yellow/green flowers with branched rhizome. The leaves of *Acorus calamus* have a lemony scent as well as the roots have a sweet fragrance. *Acorus calamus* has long been known for its medicinal value, and has been cultivated in Asia for this reason.





It has a long run usage in the history of the traditional Indian and Chinese systems of medicine. The plant is found in the northern temperate and subtropical regions of Asia, North America, and Europe. The plant's rhizomes have been attributed with several Ethnomedical and Ethno botanical purposes. This plant is used in the treatment of various problems like nervous disorders, appetite loss, bronchitis, chest pain, colic, cramps, diarrhoea, digestive disorders, flatulence, gas, indigestion, rheumatism, sedative, cough, fever, bronchitis, inflammation, depression, tumours, haemorrhoids, skin diseases, numbness, general debility and vascular disorders.

Chemical and medicinal properties of Sweet flag:

A number of active constituents from leaves, rhizomes and essential oils of *A. calamus* have been isolated and characterized. The active constituents such as phenyl propanoids, sesquiterpenes and monoterpenes as well as xanthone glycosides, flavones, lignans, steroids obtained from the plant has been proved to show various pharmacological activities such as insecticidal, larvicidal, antibacterial, mutagenic, cytotoxic, hepatoprotective, anticonvulsant, neuroleptic, smooth muscle relaxant and smooth muscle stimulant activity. Alpha and beta-asarone are the predominant bioactive components.

Various pharmacological activities of *A. calamus* rhizome such as sedative, CNS depressant, anticonvulsant, antispasmodic,cardiovascular, hypolipidemic, immuno suppressive, anti-inflammatory, cryoprotective, antioxidant, antidiarrheal, antimicrobial, anticancer and antidiabetic has been reported. The leaves are used on wounds to kill worms. The

stem is used in cough, cold and toothache. It is also used for protection against smallpox, ringworm in respiratory and gastrointestinal tract diseases. Root bark is used as an antidote to snakebite. The powdered rhizome is used as an insecticide for the destruction of fleas, bedbugs, moths, lice, etc...

Soil and climate

For sweet flag plantation, it requires water logged soil and generally it prefers to grow in shallow water or in a very moist loamy soil. It gives best result when grown in sandy, clayey and alluvial soil of river banks. To bring soil to fine tilth, first fields are watered well with mixture of FYM (Farm Yard Manure) and green leaf manure. Then ploughing is done two to three times. The land should be prepared before the onset of monsoon. The best time for planting the crop is March-April. It requires the pH ranging from 5 to 7.

Propagation and planting

Sweet flag is Propagation is mainly done through roots/rhizomes and seeds. The rhizomes are first cut into smaller pieces and then sprouted rhizomes are planted. The rhizome should be gathered in early spring or in October and November. Dirt and bitter rootlets should be removed and the rhizome should be dried quickly in a warmed room. For planting, use seed rate of 44400 per acre. Roots of 5-6 cm, firm and free from any damage or infection is used. Seeds should be planted during the fall or winter in a greenhouse.

The spadix will turn brown as the seed ripens in late summer or early fall. Seed can be planted immediately or stored in low humidity refrigeration. The flowering head, produced from the side of the stalk, consists of a fleshy spike sometimes three and half inches long and about 1/2 inch in thickness, closely covered with very small, greenish yellow flowers, which appear from May to July.

Fill a 2-inch deep tray with an organic soil mix, scatter seed sparsely on the surface and press firmly into the soil. Do not bury further than 1/8 inch deep. Keep the soil from moist to saturate. Seed does not require stratification and germinates in less than 2 weeks. When plants reach 3 to 4 inches, transplant them into individual pots. Pots can be placed in shallow water or irrigated frequently to maintain very moist to saturated conditions.

When propagation is done through seeds then it is sown in greenhouse. First fill a tray with organic soil and then firmly press the seeds in soil. Moist the soil until it starts germinating. The germination takes place in around 2 weeks. With adequate moisture seed can also be planted

in spring through early summer or in a cold frame late summer through fall. Keep soil very moist to saturated, sweet flag does not tolerate droughty conditions. It should be planted where it will be in full sun to partial shade.

Avoid flooding of newly established plants or seeded areas. The planting should be done in the month of July- August but the best time to plant the crop is second fortnight of June. The plant spacing should be around 30 x 30cm distance. The rhizomes are sown at the depth of 4cm.Direct sowing of sprouted rhizomes or seeds on bed are usually practised. Transplant the seedlings when it reaches 1 foot height during spring in the main field.

Other inter cultural practices:

Starter fertilizers may be used indoors to improve early growth until transplanted to main field into a rich soil. At the time of land preparation, apply FYM@ 6 t /acre and mix well in soil. Apply fertilizer dose of N:P:K @18:5:5kg/acre in form of Urea@39kg, SSP@32 and MOP@9kg/acre. Apply one third dose of nitrogen, full dose of phosphorus and potash as a basal dose. Remaining amount of nitrogen should be given after one and two months after planting. In rainy season, irrigation should not be done. In dry season, apply irrigation with interval of 2-3 days. In initial period the water standing will be up to 5cm and then it is increased to 10 cm.

Pest and their control:

Slug damage:- It is the damage caused by the slug on the leaves of the plant. They feed themselves on fresh leaves of plant. Application of metaldehyde or iron phosphate is used to get rid from slugs.

Mealy bugs:- Caused by Lepidocephalus and Pseudococcus. The leaves start yellowing and withering. Application of Methyl parathion@10ml or Quinalphos@20ml in 10L of water is done on roots and shoots of the plant.

Disease and their control:

Leaf spot:- The fungal discolored spots occur on the leaves of the plant. Application of Captan@10g and Chlorpyrifos @20ml/10L should help to control the leaf spot.

Harvesting and post harvest management

Plant starts yielding by 6-8 months after sowing. Harvesting is done when the lower leaves dry and turns yellow in color as it indicates its maturity. Before harvesting the field should be partially dried so that digging will be easier. The leaves also possess the aromatic properties of the rhizome, but to a lesser extent. Leaves are not employed as a medicine. Rhizomes should

be harvested for medicinal use in early spring before new growth, or late autumn. Collect when large and firm, generally after 2 to 3 years of growth, before becoming hollow. The crop produces 1-1.5 tons of dry rhizome per acre.

After harvesting, cleaning is done. After cleaning rhizomes are cut into 5 to 7.5 cm of size. Then rhizomes are air dried and are beaten and rubbed. The rubbing is done 2-3 times. After rubbing, packing is done for transportation. The useful products are made by processing such as extract, oil, powder etc.

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INTEGRATING NANOTECHNOLOGY WITH NEMATOLOGY:ADVANCES AND FUTURE PROSPECTS

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Abstract

The integration of nanotechnology with nematology represents a novel and rapidly emerging interdisciplinary field that holds significant promise for sustainable agriculture and crop protection. Nematodes, particularly plant-parasitic species, are among the most destructive agricultural pests, causing severe yield losses worldwide. Traditional management practices, including chemical nematicides, often pose environmental and health hazards, highlighting the need for eco-friendly alternatives. Nanotechnology offers innovative solutions through the development of nanopesticides, nanosensors, and nanocarriers that enable precise detection, targeted delivery, and controlled release of active agents against nematodes. Recent advances demonstrate the potential of metallic and polymer-based nanoparticles in enhancing nematicidal activity, improving soil health, and reducing chemical residues. Furthermore, nanotechnology facilitates early diagnosis of nematode infestations through biosensing platforms, enabling timely interventions. Despite these promising applications, challenges remain in terms of nanoparticle toxicity, environmental persistence, cost-effectiveness, and regulatory frameworks. Future research should focus on designing biodegradable, safe, and highly efficient nanomaterials, coupled with field-based validation for practical adoption. The convergence of nanotechnology and nematology not only opens new avenues for sustainable pest management but also contributes to global food security by minimizing losses and promoting environmentally responsible practices.

Keywords: Nanotechnology, Nematology, Nanopesticides, Nanosensors, Food Security

Introduction

Plant-parasitic nematodes (PPNs) are microscopic roundworms that cause extensive agricultural damage by feeding on plant roots, disrupting water and nutrient uptake, and predisposing plants to secondary infections. Global yield losses due to nematodes are estimated to exceed US $100 billion annually, making them one of the most serious threats to agricultural productivity. Traditional management practices rely heavily on synthetic nematicides, many of which are either banned or restricted due to their environmental and health risks. Alternative methods, including biological control and resistant crop varieties, offer partial solutions but remain insufficient for large-scale application.

Nanotechnology, dealing with materials in the 1–100 nm range, provides novel opportunities to overcome these challenges. Its potential lies in delivering targeted, efficient, and eco-friendly solutions. Applications of nanotechnology in nematology include the use of nanopesticides for nematode suppression, nanocarriers for controlled release of bioactive compounds, nanosensors for early detection, and nano-enabled fertilizers for strengthening plant resilience. This paper reviews recent advances in integrating nanotechnology with nematology, examines current limitations, and explores future prospects for sustainable pest management.

Literature Review

Research on the application of nanotechnology in plant protection has grown rapidly in the last two decades. Studies have shown that silver nanoparticles, zinc oxide nanoparticles, and carbon-based nanomaterials can exhibit direct nematicidal activity. For example, silver nanoparticles have been reported to damage the cuticle and disrupt metabolic processes in Meloidogyne incognita, a major root-knot nematode. Similarly, nanoencapsulation techniques have been applied to improve the delivery of plant-derived nematicidal compounds such as neem oil and essential oils, ensuring prolonged activity in the soil.

Beyond direct nematode control, nanosensors based on gold nanoparticles or quantum dots have been developed for detecting nematode presence through root exudates and soil signatures, enabling real-time monitoring and timely interventions. These advances underscore the growing role of nanotechnology in precision agriculture and nematode management.

Applications of Nanotechnology in Nematology

- Nanopesticides:
- Metallic nanoparticles (Ag, ZnO, TiO_2) show direct nematicidal effects.

- Nanoformulated chemical nematicides increase bioavailability and reduce dosage.
- Encapsulation enhances stability of natural nematicides (e.g., neem, garlic extracts).
- Nanocarriers and Controlled Release Systems:
- Nanocarriers (lipid-based, polymeric, or clay nanoparticles) deliver nematicides in a controlled manner, minimizing leaching and environmental contamination.
- Smart-release systems respond to soil pH, temperature, or root exudates for targeted action.
- Nanosensors for Detection and Monitoring:
- Nano-biosensors detect nematode DNA, proteins, or metabolites for early diagnosis.
- Soil health sensors integrated with nanotechnology provide real-time nematode monitoring.
- Plant Health and Resistance Enhancement:
- Nanofertilizers enhance plant vigor and root defense mechanisms against nematode invasion.
- Nanoparticles can act as elicitors of plant defense pathways, strengthening innate resistance.

Challenges and Limitations

- Despite promising results, several challenges hinder widespread adoption:
- Toxicity: Nanoparticles may negatively impact non-target organisms, soil microbiota, or accumulate in food chains.
- Environmental Persistence: Long-term effects of nanoparticles in soil ecosystems remain unclear.
- Cost and Scalability: High production costs limit farmer-level adoption in developing regions.
- Regulatory Concerns: Lack of standardized safety assessments and approval guidelines for nano-based agricultural products.

Future Prospects

- The integration of nanotechnology into nematology is expected to evolve through:
- Development of biodegradable and green-synthesized nanoparticles using plant extracts or microbial processes.

- Application of multi-functional nanoplatforms that combine detection, control, and soil health improvement.
- Interdisciplinary collaborations between nanotechnologists, nematologists, and policymakers for sustainable implementation.
- Establishment of regulatory frameworks and risk assessment protocols to ensure safe deployment.
- Field trials and commercialization of nano-enabled nematode management solutions.

Conclusion

The convergence of nanotechnology and nematology represents a transformative step in sustainable agriculture. By enabling early detection, targeted control, and reduced reliance on harmful chemicals, nanotechnology offers promising solutions for nematode management. While challenges related to toxicity, cost, and regulation persist, future innovations in green nanotechnology and integrated pest management strategies are expected to overcome these barriers. With continued research and interdisciplinary collaboration, nanotechnology can play a pivotal role in enhancing crop protection, safeguarding soil health, and ensuring global food security.

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POPULAR AND PROMISING HYBRIDS AND VARIETIES OF BRINJAL FOR CULTIVATION IN INDIA

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Introduction

Brinjal improvement in India have been taken up by national as well as state level institutions such as ICAR-Indian Institute of Vegetable Research (IIVR), Varanasi, Uttar Pradesh, ICAR-Indian Agricultural Research Institute (IARI), New Delhi, ICAR-Indian Institute of Horticultural Research (IIHR), Bengaluru, Karnataka, Tamil Nadu Agricultural University (TNAU), Coimbatore-641003, Tamil Nadu, G. B. Pant University of Agriculture and Technology (GBPUAT), Pantnagar, antnagar Udham Singh Nagar-263 145 Uttarakhand, Dr. YSR Horticultural University (DYSRHU), Venkataramannagudem West Godavari Distt, Andhra Pradesh, Punjab Agricultural University (PAU), Ludhiana, Punjab, Kerala Agricultural University (KAU), Thrissur, Kerala, University of Agricultural Sciences (UAS), Bengaluru, Karnataka, University of Agricultural Sciences (UAS), Dharwad, Karnataka, Bidhan Chandra Krishi Viswavidyalaya (BCKV), West Bengal, Dr. YSR Horticultural University Andhra Pradesh, Punjab Agricultural University (PAU), Ludhiana and MAU (Marathwada Agricultural University), Parbhani, Maharashtra. In Tamil Nadu, the research stations of Tamil Nadu Agricultural Universities viz., Vegetable Research Station, Palur, Cuddalore District, TNAU, Tamil Nadu, Horticultural College and Research Institute, Coimbatore, TNAU, Tamil Nadu, Horticultural College and Research Institute, Periyakulam, TNAU, Tamil Nadu and Horticultural College for Women, Navalur Kuttapattu, Trichirapalli, TNAU, Tamil Nadu were involved in Brinjal Improvement. In this article we are to discuss the important popular and promising Brinjal hybrids and varieries for cultivation in India.

2. INDIAN AGRICULTURAL RESEARCH INSTITUTE (IARI), NEW DELHI

DBL-02: A non-spiny selection with erect branches and light purple pigmentation, developed by selection. Bears long violet-purple fruits (80–90 g). Maturity in 55 days. Yield: 40 t/ha.

Pusa Ankur: This semi-erect, 65 cm tall variety with 6–8 branches was developed through selection, producing oval-round, small-sized (60-80g), bark purple, attractive fruits. Fruits are small, oval-round, bark purple, glossy and very attractive, weighing each 60-80g. It is an early bearing and becomes ready for first picking 45 days after transplanting. Its fruits do not lose colour and tenderness even on delayed pickings.

Pusa Anmol: Developed from hybridization (Pusa Purple Long × Hyderpur), it produces 80% higher yield than Pusa Purple Long. Yield: 62 t/ha.

Pusa Anupama: Evolved through resistant breeding and selection, it has medium-tall plants with slightly violet-tinged stems, purple-ribbed leaves. Produces cylindrical, tender purple fruits in clusters (3–5). Resistant to bacterial wilt. First picking in 65–70 days. Yield: 370 q/ha.

Pusa Bindu: A variety developed *via* selection; it grows up to 55–60 cm tall with green leaves. Fruits occur in 4–5 fruit clusters, each weighing around 125 g. Yield: 250–300 q/ha.

Pusa Hybrid-5: An F_1 hybrid, it is vigorous, non-spiny with semi-erect branches, producing long, dark purple glossy fruits. Maturity in 80–85 days. Yield: 520–540 q/ha.

Pusa Hybrid-6: Developed through F_1 hybridization, this variety is non-spiny, semi-erect, branched with partially pigmented leaves. Bears round, violet-purple glossy fruits (200–250 g). Early bearing in 85–90 days. Yield: 450–470 q/ha.

Pusa Hybrid-9: An F_1 hybrid, developed with green, non-spiny plants, strong erect branches, and light pigmentation. Fruits are oval-round, glossy dark purple (300 g). First picking in 90 days. Yield: 675–700 q/ha.

Pusa Kranti: Developed by hybridization and selection from (Pusa Purple Long × Hyderpur) × Wynad Giant. Fruits are oblong, 15–20 cm, dark purple with green calyx and fewer seeds. Yield: 275–300 q/ha.

Pusa Purple Cluster: Bred using pedigree method, this variety has a purple stem, purplish green foliage, is non-spiny. Fruits are 10–12 cm, deep purple, borne in 4–9 fruit clusters. Field-resistant to bacterial wilt. First picking in 60–65 days. Yield: 250 q/ha.

Pusa Purple Long: A selection developed through pure line selection, it bears long (20–25 cm), purple, glossy and tender fruits. It is an early maturing variety ready for picking in 100-110 days. Suitable for summer and autumn. Yield: 280–310 q/ha.

Pusa Shyamla: Bred using selection method, it produces long, glossy, dark purple fruits (80–90 g). Maturity in 50–55 days. Yield: 390 q/ha.

Pusa Upkar: Derived through pure line selection, this semi-upright plant reaches 70 cm in height with 5–6 branches and greenish purple leaves. Fruits are round (9 cm diameter), dark purple, about 300 g each. Yield: 650–670 q/ha.

Pusa Uttam: Bred through selection, it is semi-upright, vigorous, branched, with a green appearance and occasional pigmentation. Flowers are in bluish violet clusters. Fruits are oval, large (250–300 g), dark purple, and solitary. Yield: 425–450 q/ha.

3. INDIAN INSTITUTE OF HORTICULTURAL RESEARCH (IIHR), BENGALURU

Arka Anand: This F_1 hybrid was developed through hybridization. Plants are tall and spreading with green stem and foliage. Fruits are green, long (22–24 cm), with green fleshy calyx, borne in clusters (3–4). First harvest is done at 60–65 days after planting. Suitable for both kharif and rabi seasons. Yield is 60–65 t/ha. Resistant to bacterial wilt under Bengaluru conditions.

Arka Navneet: A high-yielding F_1 hybrid developed through hybridization, it produces large (450 g) purple oblong fruits. Free from bitter principles with very good cooking qualities. Crop is ready for picking in 150-160 days Average yield is 65–75 t/ha in 160 days.

Arka Sheel: This variety was developed through pure line selection. It bears medium-sized fruits with deep shining purple skin and green fleshy calyx. Fruits are borne solitarily. Average yield is 38 t/ha.

Arka Kusumakar: Bred through selection, this variety has small green fruits borne in clusters, with soft texture and good cooking quality. Spreading plant habit with green stem & green leaves. Flowers white green small fruits borne in cluster. Soft texture with good cooking quality. Crop is ready for picking in 140-150 days. Average yield is 40 t/ha.

Arka Shirish: Developed by selection, this variety bears green, extra-long fruits, borne solitarily. Average yield is 39 t/ha.

Arka Nidhi (BWR 12): Developed through selection for bacterial wilt resistance, this variety produces purple tender fruits with slow seed maturity and non-bitter taste. Average yield is 48.5 t/ha.

Arka Keshav (BWR 21): This bacterial wilt resistant variety was developed through selection. It bears red-purple glossy fruits with green calyx, purple-veined green leaves, and light purple-green stems. Fruits are tender, with slow seed maturity and no bitterness. Yield is 45 t/ha.

Arka Neelkanth (BWR 54): Bred through selection, this variety bears tender fruits with slow seed maturity and no bitter principles. It is resistant to bacterial wilt. Yield is 43 t/ha.

BPLH-1: This high-yielding F_1 hybrid was developed by hybridization. Plants are tall and spreading with a purple tinge on green foliage. Fruits are purple, long (20–22 cm) with green calyx, borne in clusters (3–4). First harvest is in 60–65 days. Suitable for kharif and rabi seasons. Yield is 50–55 t/ha. Resistant to bacterial wilt.

Selection-2: An advanced breeding line derived through pedigree selection from the cross IHR-500A × IIHR 571 (F_7). Plants are dwarf to medium-tall with green foliage and both cluster and solitary bearing habit. Fruits are round to slightly oval (7.5–8.5 cm × 8.5–9.5 cm), purple striped, weighing 80–100 g. Fifty to fifty-five days to 50% flowering; first harvest in 55–60 days. Yield is 30–35 t/ha in 130–140 days. Resistant to bacterial wilt.

3. INDIAN INSTITUTE OF VEGETABLE RESEARCH (IIVR), VARANASI

Kashi Sandesh: This medium, round-fruited brinjal variety was developed through pure line selection. The plants have green stems, purplish-green leaves, and purple flowers appearing 45 days after transplanting. Fruits are purple, medium-sized, and round with an average length of 12.4 cm, diameter of 10.2 cm, and weight of 225.3 g. First picking starts 76 days after transplanting. It yields an average of 780 q/ha and is suitable for cultivation across India.

Kashi Taru: Developed through selection, this variety is tall and erect with dark green leaves and stems. Plants grow to 120–130 cm and start flowering 45–50 days after transplanting. Fruits are long, purple, about 31 cm in length and 5 cm in diameter. First harvest occurs at 75–80 days. Yields range between 700–750 q/ha and it is recommended for Uttar Pradesh and Jharkhand.

Kashi Prakash: Bred through selection, this semi-upright plant has green stems and leaves. Fruits are oblong with light green spots and a spiny calyx, weighing about 190 g. Picking starts 80–82 days after transplanting. It yields 65–70 t/ha and is mainly suitable for Uttar Pradesh and Jharkhand.

Kashi Komal: This semi-upright variety was developed through selection. Plants grow to 90–100 cm with light green stems and leaves. First flowering is observed 35–40 days after transplanting. Fruits are long, light purple with soft texture, averaging 13 cm in length and 3 cm

in diameter. First picking is done 65–70 days after transplanting. Yields average 800 q/ha and the variety is suitable across India.

Kashi Long: This long-fruited variety was developed through selection. It features cylindrical, shiny purple fruits and erect, spreading plants with good fruit setting ability. Appreciated for cooking quality and consistent field performance, especially in moderate climates.

Kashi Abhiyog (IIVRBL-1): Bred through pedigree selection, this is a mid-season variety producing oval to oblong, deep purple fruits with a green calyx. It balances yield and pest tolerance, showing moderate resistance to shoot and fruit borer. Fruits are uniform, firm, and preferred in markets for their appearance.

Kashi Anmol: This early-maturing variety was developed through selection. It yields long, slender purple fruits and is known for consistent yield, attractive shape, and moderate pest resistance. Suitable for open-field cultivation, it performs well across seasons.

4. TAMIL NADU AGRICULTURAL UNIVERSITY (TNAU), COIMBATORE

CO 1: Developed through pure line selection. Oblong fruits, medium-sized, pale green with white base, soft seeded. Suitable for southern districts. Yield: 24 t/ha.

CO 2: A selection variety. Fruits are oblong with brown stripes. Grown in Coimbatore and Periyar districts. Yield: 35 t/ha.

PKM 1: A mutation-derived variety. Small fruits (6–8 cm) with green stripes. Drought tolerant and suitable for long-distance transport. Yield: 34.75 t/ha.

MDU 1: Developed through selection. Bears round, bright purple fruits weighing about 280 g. Preferred in Madurai and Trichy regions. Yield: 34 t/ha.

PLR (BR) 2: A local selection from Sevanthampatti. Produces oval, dark purple fruits with a pink tinge and glossy appearance. Yield: 38 t/ha.

TNAU Brinjal VRM 1: A pure line selection from Elavambadi, Vellore. Bears oval, glossy pink fruits with a green tinge. Resistant to leaf spot, verticillium wilt, and epilachna beetle. Cluster bearing. Yield: 40–45 t/ha.

PPI 1: A selection variety. Produces oblong pale green fruits. Moderately resistant to wilt and shoot and fruit borer. Yield: 45 t/ha.

KKM 1: A pure line selection from Kulathur local. Bears small, milky white egg-shaped fruits in clusters of 2–4. Yield: 37 t/ha in 130–135 days.

COBH 1: An F1 hybrid developed by crossing EP 45 × CO 2. Bears medium oblong dark violet fruits weighing 60–65 g. Duration: 120–130 days. Yield: 56.4 t/ha. Adaptable to Coimbatore, Erode, Salem, *etc*.

COBH 2: An F1 hybrid developed from EP 65 × Pusa Uttam. Bears medium oblong glossy violet fruits. Moderately tolerant to shoot and fruit borer. Yield: 58 t/ha in 120–130 days.

VRM 2: A pure line selection. Bears attractive deep purple fruits that are round to oval in shape. Flesh is tender with moderate seed content. Moderately resistant to shoot and fruit borer. Yield: 38–40 t/ha. Suitable for Tamil Nadu.

PLR 1: A selection variety. Bears small to medium, egg-shaped purple fruits. Fruits mature in 8–10 days and fetch premium price. Preferred in Cuddalore, Chengalpattu, and Chennai. Yield: 25 t/ha.

MDU 2: A selection variety suitable for Madurai and southern districts. Bears attractive, purple, oval medium-sized fruits with soft texture and good cooking quality. Yield: 36 t/ha.

CO 3: Developed through hybridization (CBE SM-13 × HD 2). Matures in 140–150 days. Fruits are long, light purple with white stripes, and have good market appeal. Moderately resistant to fruit and shoot borer. Average yield: 48.5 t/ha. Suitable for the western zone of Tamil Nadu.

5. KERALA AGRICULTURAL UNIVERSITY (KAU), THRISSUR

Surya (SM 6-7): Developed through selection. Resistant to bacterial wilt. Bears small, purple, oval fruits. Suitable for cultivation in Kerala.

wetha (SM 6-6): A selection variety. Resistant to bacterial wilt. Bears small, white, elongated fruits. Adapted to conditions in Kerala.

Haritha: Developed through selection. Resistant to bacterial wilt. Produces long, light green, elongated fruits with long duration. Adapted to Kerala.

Neelima: A hybrid developed from the cross Surya × SM 116. Resistant to bacterial wilt with protracted fruiting habit. Bears round to oval purple fruits. Yield: 62 t/ha.

6. GOVIND BALLABH PANT UNIVERSITY OF AGRICULTURE AND TECHNOLOGY (GBPUA&T), PANTNAGAR

Pant Samrat: Developed through selection. Tall and robust with purplish green foliage. Bears long (80–100 cm) purple fruits in clusters. First picking at 70 days. Resistant to phomopsis blight and bacterial wilt. Yield: 30 t/ha.

Pant Rituraj: A selection variety. Bears round, purple fruits with slight tapering. Suitable for winter and summer cultivation. A prolific bearer. Yield: 30 t/ha.

7. Punjab Agricultural University (PAU), Ludhiana

Jamuni Gol (S 16): Developed through selection. Bears long, plumy, and shining purple fruits.

Punjab Barsati: A selection variety. Produces medium-long, shining purple fruits. Tolerant to fruit borer. Fruits are medium, long and purple with average yield of 35.5 t/ha.

Punjab Neelam: A selection variety. Bears long, purple fruits.

Punjab Sadabahar: A selection variety. Bears long, black-purple fruits.

8. MAHATMA PHULE KRISHI VIDYAPEETH (MPKV), RAHURI (MAHARASHTRA)

Krishna: Developed through selection. Tall and hardy plants resistant to lodging. Bears egg-shaped spiny purple fruits with white stripes. Suitable for kharif and summer seasons. Yield: 480 q/ha.

Phule Harit: A selection variety. Bears green fruits with a white patch at the apical end. Suitable for kharif and summer. Yield: 200 q/ha.

Phule Arjun: Developed through selection. Bears green fruits with purple and white stripes. Fruits are oval and spiny. Suitable for kharif and summer. Yield: 450 q/ha.

Manjri Gota: Manjri Gota Released from MPKV, Rahuri, Maharashtra. The variety has a dwarf and spreading growth habit. The fruits are medium-large, round and purple coloured with white stripes. Upon maturity, the fruits attain a golden yellow colour. Average yield is 15- 20 t/ha.

Vaishali: The variety has a dwarf and spreading type of growth habit. Fruits are oval in shape purple in colour with white stripes. The stalks of the fruits bear spines. Crop is ready for first picking within 60 days after transplanting. Average yield is 30 t/ha.

9. ANNAMALAI UNIVERSITY, TAMIL NADU

Annamalai 1: A selection variety. Aphid-resistant. Bears oblong, deep purple fruits with few thorns on the calyx. Suitable for Vellore, Villupuram, Thiruvannamalai, Chengalpattu, and Chennai regions. Yield: 20–22 t/ha.

10. EXOTIC VARIETIES:

UK Table Purpose Black Beauty, Florence Purple, Blacknite, Caspar, Long Purple, Black Beauty.

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SUSTAINABLE ORGANIC AGRICULTURE PRACTICES FOR ENHANCING SMALL MILLETS PRODUCTION

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Introduction

Millets particularly small millets are in a situation of crisis in India. The period between 1961 and 2016 saw a dramatic decrease in cultivated area under millets (80% for smallmillets, 46% for finger millet, 59% for sorghum and 23% for pearl millet) and 76% decrease intotal production of small millets .A significant decrease in per capita availability of allmillets despite high productivity gains for some varieties and a steep fall in overall milletsconsumption. Similar trends can be seen in Tamil Nadu too.

Why be concerned about millets?

Millets share a set of characteristics which make them unique amongst cereals. Millets grow under dry conditions, can cope with relatively poor soils and require few external inputs.They are a staple food with superior nutritional qualities compared to other cereals. Used asdual-purpose crops,f ood and fodder and they make strong economic sense in mixed farming systems.

Organic cultivation in millet crops

Land selection

The land selected should not be cultivated with the same crop in the previous season. Millets can be grown in poor to fertile soil. The crop can tolerate salinity better than any other crops. The selected land should be free from volunteer plants. The land should not be cultivated with same crop in the previous season. Land should be ploughed 2 - 3 times to get fine tilth and levelled.

For rainfed crop, 50 kg pungam cake and 250 kg vermicompost should be applied as basal manure just before sowing. First top dressing should be done at 20 – 25 days after sowing using 250 kg/ acre of enriched vermicompost. At 40 – 45 days after sowing apply 25 kg pungam cake and 250 kg vermicompost per acre (60 kg pungam cake and 600 kg vermicompost per hectare) as second top dressing. Spray 10% tender coconut water at the time of flower initiation. All the above mentioned inputs should be applied to the rainfed crop only when the soil is wet. . (Source CIKS,2010).

Application of FYM or Compost

Farm yard manure (FYM) is well recognized and considered as balanced bulky organic manure which increases the moisture retention of the soil and helps in dissolution of nutrients. FYM although not useful as a sole source of nutrients, is good complimentary and supplementary source to mineral fertilizer was stated by Shankar Lal Golada (2012) **.** Spread 12.5 t/ha of FYM or compost or composted coir pith evenly on the unploughed field and then plough and incorporate in the soil. Do not spread and leave the manure uncovered in the field as nutrients will be lost.

Seed treatment in millets - Bijamrita solution

A natural solution for effective protection against pest, diseases and fungi. Wrap 5 kg quantity of cow dung in a large cloth and bind it by tape. Put it in 20 liters of water for up to 12 hours. Take one liter of water and add 50 gm of lime to it and let it stabilize overnight. Next morning, squeeze all of the liquid in the bundle of cow dung out of the bundle and into a bucket, compressing it at least thrice, so as to collect a concentration of cow dung. Add a handful of soil to this liquid solution and stir it well. Then add 5 liters of cow urine or human urine to the solution and add the lime water, stirring all together, making is called Bijamrita.Spread this solution on the seeds of any crops, treating these seeds well by hand, drying them well, and using them for sowing. The micro-organisms and nutrients added this way will make the seedlings that emerge more vigorous .

Seed treatment with Azospirillum may be done @ 3 packets/ha (600 g/ha) and 3 packets (600 g/ha) of Phosphobacteria or 6 packets of Azophos (1200 g/ha).

Soak seeds of finger millet in *Panchagavya* (35 ml in one litre of water) for 7 – 8 hours before sowing for the production of disease free seedlings.(Mix the seeds with the extract of *Ashwagandha* and *Datura* (for 1 kg seeds, pound 250 gms of *Ashwagandha / Amukura*

(Withania somnifera) roots and 50 gms of *Datura / Oomathai (Datura metel)* leaves by adding water) and shade dry before sowing. This will help in the production of healthy and disease free seedlings.(agritech.tnau.ac.in)

Nursery preparation

Sow the treated seeds in a nursery with planting materials as a mixture of sand, soil and compost (1:1:1). Area of nursery: 40 sq. meters for every one acre to be cultivated. Dimensions of the nursery bed: 1 meter with the length appropriate for the desired nursery area bed should be 9 to 12 inches above ground level. Application of VAM culture (*Glomus fasciculatum*) at 100 g/m2 in the nursery and also treat with Azospirillum and Phosphobacterium as seed treatment, seedling dip and field application to reduce the reniform nematode population in ragi (agritech.tnau.ac.in)

Seed selection and Sowing

Millets is a season bound crop and the best season to take up sowing is and June - July and December - January. Seeds used for seed production should be of good quality certified seeds from an authentic source. Seeds should be healthy with required germination percentage. Recommended seed rate is 4 kg/acre (10 kg/ha). Selected seeds should be treated with *Azospirillum* @ 125gms/kg of seeds.

Sowing of seeds: Put the seeds into nursery soil at a depth of 1/2 inch, and keep the spacing about 3 to 4 inches between the seeds.

Care for seeds: Cover the seeds with **vermicompost**, and then sprinkle Jiwamrita regularly over the nursery to keep the soil functioning well.

Preparation of organic manure – (Jiwamrita solution)

A Jiwamirtha solution is prepared by adding 10 liters of water in a barrel and add 5 kg of cow dung and 5 liters of cow urine to the water added with 250 g of jaggery (raw unrefined sugar), 250 g of pulse flour, and a handful of soil from the bund of the field or termite soil and stir the solution well. Let it ferment for 48 hours in the shade, and it will be ready for use after this. To use, add 1 liter of solution to 20 liters of water at the time of use. For every 1 acre of land, use 200 liters of this diluted solution.

Weeding operation in organic millets:

Remove any weeds by hoeing with a cycle hoe or with a hand weeder in between the rows. This removes unwanted weeds and also aerates the soil, helping the plants to grow faster.

This should be done 3 times at intervals of 10-15 days was reported in (Pradhan,2010). Sprinkle Jiwamrita after weeding operation over. Mixing of 1 liter of Jiwamrita preparation with 10 liters of water, instead of using undiluted solution. After weeding, pull a straight round pole or bamboo over the plants, bending them over gently. This gentle 'trolling,' by bending the plants over at the base, will stimulate the growth of more tillers & roots from the plant.

Organic way to control diseases and pest management in millets:

Non-chemical disease management :

Sl.No	Disease	Control methods
1.	Ragi blast *(Pyricularia grisea)* Foxtail millet blast - (attacks at the early vegetative phase)	Crush and apply the bark of *Careya arborea* @ 2-3 kg and boil 1 kg of wild Tulsi leaves in 2 litres of water and spray this solution @ 2 ml/litre of water for twice at 15 days interval.
2.	Mottle streak virus of ragi – (attacks at all the growth stages of the crop)	Spray the fermented cow's urine (fermented for one week) over the crops to control bacterial and fungal diseases, spray a solution of cow's urine (1 litre) and buttermilk (1 litre) diluted with 8 litres of water and spray 300 ml of sweet flag extract mixed with 1 litre of cow's urine and 8.7 litres of water to control the disease spread
3.	Ragi *(H.nodulosum)*, maize leaf spot *(Curvularia lunata)* - (attacks at the early vegetative phase)	Treat the seeds with 20% mint leaf extract for 24 hours, spread the leaves of *Cleistanthus collinus* @ 25 quintals/ha the field and allow them to decay and irrigate after three days.

Non-chemical pest management :

Sl.No	Pests	Control methods
1.	Foxtail millet Foxtail millet worm *(Spodoptera frugiperda)* – Infestation is more in lushy vegetative growth phase)	Spraying of neem leaf extract (5 kg neem leaves grounded in boiled water and diluted to 100 litres) can reduce the worms attack
2.	Pink stem borer of Ragi *(Sesamia inferens)* – (attacks in the later vegetative phase)	Plough deeply soon after harvest to destroy the eggs and pupae, apply neem cake @ 42 – 50 kg/ha as basal manure, using pheromone traps to attract and destroy male adult moths and using *Trichogramma* cards
3.	Root aphid of ragi *(Tetraneura nigriabdominalis)* – (attacks in the vegetative phase)	Sprayg garlic extract (100 gms crushed and mixed with 50 litres of water) or apply manure prepared using *Adhatoda* vasica.

Green manuring

Green manuring has also shown good results where the conditions are favorable for this practice,where the season is longer than required by the ragi crop but insufficient for two crops, or where a shorter rainy season, again inadequate for cropping, occurs before the major rains set .Sunhemp *(Crotalaria juncea)* is sown at the rate of 40 lb of seed per acre as soon as the monsoon breaks. After about a month the sunhemp crop has grown to a height of 30 in and is ploughed in. Transplanting of the ragi crop from a nursery can be carried out a week later. This practice has increased yields by as much as 350 kg/ha of dry grain.

Impact of mulching in small millets

Mulching refer to the use of crop residues , manures and leaf litter as well as conveniently available poly ethylene sheets with or without shallow tillage for the purpose of reducing run off , soil loss and evaporation loss to increase productivity and reduce weed menace in millets . In regions of low rainfall , mulching help in conserving moisture in the soil profile and in high rainfall areas reduced run off and soil loss and which are reflected in crop yield. The application of 2000 kg of crop residue mulches reduces weed growth and decrese the labour needed for weeding by 25-30.Farmers' microsite applications of Crop residue mulch not only augment the yields per unit of applied CR, but also reduce the increase in time required for weeding because the mulched surface to be weeded is smaller.

Role of intercropping systems in millets

Nutrient uptake was higher in pigeonpea when it is sown alone in ingle rows than in paired rows in the proportion of 1:3 rows of fingermillet between the paired rows. Intercrop had higher nutrient requirement than their repective pure stands.

Conclusion

Development and adoption of modified tillage and crop establishment practices aimed at resource conservation have a long term and broader perspective , which go beyond yield improvement. Zero tillage and surface maintained crop residues result in resource improvement and increase the higher yield in millets. Organic farming practices which initiate change in physical, chemical and biological properties, which in turn affect root growth and crop yield. Successful adoption of conservation technologies , crop residue management, organic way to control pests and diseases and nutrient management techniques for a wide range of crops and cropping systems enhance the sustainable way of improving higher productivity in millets in the future scenario.

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CLIMATE-RESILIENT CROPS: BUILDING FUTURE FOOD SECURITY IN A WARMING WORLD

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Abstract

Agriculture is at the frontline of climate change, facing severe threats from increasing temperatures, erratic rainfall, droughts, floods, and salinization of soil. Ensuring food and nutritional security for a growing global population requires urgent adaptation strategies, among which the development of **climate-resilient crops** stands as a cornerstone. Climate-resilient crops are genetically and physiologically capable of maintaining productivity under multiple stresses. This article explores the scientific principles, technological innovations, and policy frameworks driving the development of such crops, with particular emphasis on global initiatives and Indian experiences. As the world faces a warming future, fostering resilience through crop genetics, biotechnology, and integrated management practices will be central to sustainable agriculture.

Keywords: Climate change, climate-resilient crops, food security, sustainable agriculture, drought tolerance, CRISPR, climate-smart agriculture, genomics, traditional knowledge

1.Introduction

Climate change represents one of the most serious challenges to global food systems in the 21st century. The Intergovernmental Panel on Climate Change (IPCC, 2023) estimates that global temperatures have already risen by approximately **1.1°C above pre-industrial levels,** leading to declining agricultural yields in many regions. In India, agriculture contributes nearly

18% to GDP and employs more than **45% of the population,** making it highly vulnerable to climatic variability.

Erratic monsoons, unseasonal rainfall, and prolonged droughts have disrupted cropping patterns across the country. Wheat yields decline sharply with each degree rise in temperature during grain filling, while paddy fields are affected by both droughts and floods. Thus, ensuring food security for an estimated **9.7 billion people by 2050** requires crops that can thrive under changing climatic conditions. Climate-resilient crops, integrating both modern science and traditional wisdom, offer a sustainable solution to this challenge.

2. Understanding Climate-Resilient Crops

Climate-resilient crops are those capable of withstanding abiotic stresses such as drought, heat, salinity, and flood, as well as biotic stresses like pests and diseases, without significant yield reduction. These crops exhibit unique adaptive mechanisms, including:

- **Morphological adaptations:** deep or fibrous root systems for better water uptake, waxy leaf coatings to reduce transpiration.
- **Physiological mechanisms:** osmotic adjustment, antioxidant defense systems, and efficient photosynthesis under stress.
- **Molecular mechanisms:** activation of stress-responsive genes and proteins, such as heat shock proteins (HSPs) and dehydrins.

Notable Examples

- **Rice:** *Sahbhagi Dhan* (drought tolerant) and *Swarna Sub-1* (submergence tolerant) developed by IRRI and ICAR.
- **Wheat:** *HD 2967* and *DBW 187* -high-yielding, heat-tolerant varieties adopted widely in North India.
- **Maize:** Drought Tolerant Maize for Africa (DTMA) project hybrids released in India and Sub-Saharan Africa.
- **Pulses:** *Pusa Bold mungbean* and *Pusa Arhar-16* showing enhanced drought tolerance.
- **Millets:** Finger millet, foxtail millet, and pearl millet—naturally adapted to dryland conditions, now rebranded as "climate-smart nutri-cereals."

These examples illustrate that resilience is not limited to genetic modification; it also includes rediscovering underutilized crops adapted to marginal environments.

3. Technologies Driving Climate-Resilient Crop Development

a) Conventional and Molecular Breeding

Traditional plant breeding remains a powerful tool. **Marker-Assisted Selection (MAS)** accelerates breeding by identifying genetic markers linked to stress-tolerance traits. For example, QTLs such as **qDTY1.1** in rice are linked to drought tolerance. Similarly, breeding for early maturity in pulses and millets helps crops escape terminal drought.

b) Genomic and Biotechnological Approaches

Advances in genomics have transformed breeding. **Next-generation sequencing (NGS)** allows precise identification of genes controlling resilience traits.

- **CRISPR/Cas9 genome editing** enables targeted modification of stress-responsive genes such as *DREB, NHX1,* and *HKT1* involved in drought and salinity tolerance.
- **Transgenic approaches** have produced salt-tolerant rice (carrying *BADH* or *mtlD* genes) and insect-resistant cotton, which indirectly reduces climate-related yield losses.
- The **Genome-Wide Association Studies (GWAS)** platform helps identify genes for heat tolerance in wheat and maize.

These innovations are now being complemented by **speed breeding,** allowing multiple crop generations per year to accelerate genetic improvement.

c) Omics and Digital Phenotyping

Omics technologies—genomics, proteomics, metabolomics, and phenomics—help understand stress responses at molecular levels. High-throughput phenotyping platforms, often equipped with **drones and AI,** assess canopy temperature, chlorophyll content, and plant growth under stress. For instance, the **ICAR–Phenome India Network** uses imaging and sensor technologies to screen thousands of genotypes for resilience traits annually.

d) Microbial and Endophytic Associations

Beneficial soil microbes play crucial roles in improving resilience.

- **Plant Growth-Promoting Rhizobacteria (PGPRs)** like *Azospirillum* and *Bacillus* enhance drought tolerance by improving root architecture.
- **Mycorrhizal fungi** increase nutrient and water uptake under saline or arid conditions.
- **Endophytes** from wild plants are now being used to develop microbial bioinoculants that strengthen crop tolerance naturally.

4. Integrating Traditional Knowledge and Indigenous Varieties

Farmers' traditional knowledge and indigenous varieties are vital for climate adaptation. Many local landraces, though lower-yielding, possess unique resilience traits. For example:

- **Pokkal rice** from Kerala's coastal regions tolerates saline and flooded soils.
- **Sahai paddy** from Bihar shows drought tolerance.
- **Rajasthan's bajra (pearl millet)** landraces survive extreme drought and heat.

Community seed banks and participatory breeding programs—where farmers, breeders, and researchers collaborate—help preserve and reintroduce these valuable genetic resources. Integrating such indigenous knowledge systems with modern genomics ensures long-term sustainability and food sovereignty.

5. Policy, Institutional, and Global Efforts

National Initiatives

India has made significant progress in climate-resilient agriculture through several landmark programs:

- **NICRA (National Innovations on Climate Resilient Agriculture)** by ICAR, launched in 2011, focuses on developing climate-resilient varieties, resource-conserving technologies, and contingency plans for vulnerable districts.
- **Mission for Sustainable Agriculture (NMSA)** and **Paramparagat Krishi Vikas Yojana (PKVY)** promote climate-resilient and organic farming.
- The **International Year of Millets 2023** highlighted the importance of traditional resilient crops in ensuring nutrition and income under climate stress.

Global Initiatives

- **CGIAR's Climate Resilience Initiative (2024):** Focuses on integrating genomics, digital tools, and farmer participatory approaches to breed climate-ready crops.
- **FAO's Climate-Smart Agriculture (CSA):** Encourages practices that increase productivity, enhance resilience, and reduce greenhouse gas emissions.
- **The Global Alliance for Climate-Smart Agriculture (GACSA):** Facilitates knowledge sharing among countries on resilient agriculture.

Such programs emphasize that climate resilience is not only a genetic trait but also a system-wide adaptation involving water, soil, and policy management.

6. Socioeconomic Dimensions

Developing resilient crops alone is not enough; their adoption is equally critical.

- **Access and affordability:** Many smallholders cannot afford new seeds or lack awareness of their benefits.
- **Extension services:** Weak linkages between research institutions and farmers slow technology transfer.
- **Gender inclusivity:** Women farmers, often the primary cultivators in small farms, must be included in training and decision-making for climate-resilient agriculture.
- **Market and policy support:** Assured procurement, climate insurance, and credit facilities encourage adoption of resilient varieties.

The intersection of science, social equity, and economics defines the real-world success of climate-resilient agriculture.

7. Challenges and Future Prospects

Despite progress, challenges persist:

- **Multifactor stress interactions:** Most research addresses single stresses, but crops face combined heat–drought or flood–salinity situations.
- **Lack of region-specific models:** Uniform recommendations fail in diverse agro-climatic zones.
- **Data and forecasting limitations:** Climate models and phenotyping data must be integrated for predictive breeding.
- **Regulatory hurdles:** Delays in approving genome-edited crops slow adoption.

Future prospects include:

- **AI-integrated predictive breeding:** Machine learning algorithms can predict resilient genotype performance under simulated climates.
- **Digital twins of crops:** Virtual crop models using real-time weather and genomic data to forecast stress impacts.
- **Carbon-positive crops:** Breeding plants that sequester more carbon in roots and biomass.
- **Gene banks and genomic libraries:** Expanding conservation and accessibility of wild and landrace germplasm.

As technology evolves, combining biological resilience with digital agriculture will redefine food systems for the next generation.

Conclusion

Climate change threatens to undo decades of progress in global food security. Developing and deploying **climate-resilient crops** is not just a scientific goal—it is a moral imperative for humanity. These crops represent a fusion of traditional wisdom and cutting-edge biotechnology, ensuring that agriculture remains productive under adverse conditions. India's initiatives through **NICRA** and global collaborations with **FAO** and **CGIAR** are pioneering examples of adaptation in action. Yet, the path ahead requires stronger farmer participation, better policy incentives, and deeper investment in research and capacity building. Ultimately, resilience in crops translates to resilience in societies. The success of climate-resilient agriculture will determine not only our ability to feed future generations but also the health of the planet itself.

> ***"In a warming world, the seeds of resilience we sow today will determine the harvest of hope we reap tomorrow."***

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CAPTIVE BREEDING AND REINTRODUCTION: SUCCESS STORIES AND CHALLENGES FOR THE RED-CROWNED ROOFED TURTLE

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Introduction

The red crowned Roofed Turtle (*Batagur kachuga*) is a critically endangered freshwater turtle species native to the river systems of northern India, Bangladesh, and parts of Myanmar. Distinguished by the bright red crown of males during the breeding season, the species represents one of the most threatened members of the family Geoemydidae.



Freshwater turtles play an essential role in river ecosystems by controlling aquatic vegetation, maintaining nutrient balance, and contributing to sediment mixing. To combat this decline, conservationists have implemented captive breeding and reintroduction programs to rebuild populations and restore them to their natural habitats.

SPECIES PROFILE

- Taxonomy and classification

- Kingdom: Animalia
- Phylum: Chordata
- Class: Reptilia
- Order: Testidines
- Family: Geoemydidae
- Genus: *Batagur*
- Species: *Batagur kachuga*

PHYSICAL CHARACTERISTICS:

The Red –Crowned Roofed Turtle can grow up to 70-90cm in shell length. Its carapace (shell) is smooth and dark, with a distinctive roof like arch. Males develop a bright red or orange patch on their heads during the breeding season, which serves as a signal to females. Females are larger and duller in colour.

HABITAT AND DISTRIBUTION:

This species inhabits large rivers, floodplains, and wetlands with sandy banks for basking and nesting. Historically, it ranged across the Ganges, Brahmaputra, and Irrawaddy river systems but is now restricted to a few protected river stretches in India and Bangladesh.

BEHAVIOUR AND DIET:

The Turtle is omnivorous, feeding on aquatic vegetation, molluscs, small fish, and organic debris. Females come ashore to lay eggs in sandy areas during the dry season. The species exhibits seasonal migration influenced by water levels and temperature.

THREATS TO SURVIVAL

- Habitat destruction
- Poaching and Illegal Trade
- Climate change
- Low Reproductive success

CAPTIVE BREEDING PROGRAMS

- **OBJECTIVES:**
  - The main goal are to increase population size, preserve genetic diversity, and prepare individuals for reintroduction into the wild.
- **TECHNIQUES USED:**

- Breeding programs use controlled environments with regulated temperature and humidity. Eggs are artificially incubated to ensure higher hatching survival rates. Health assessments, genetic studies, and behavioral monitoring are part of the process.

KEY PROGRAMS:

Major efforts are led by the Madras Crocodile Bank Trust and the Trust survival Alliance (TSA) in India, particularly in the Chambal river region and Odisha. Bangladesh has also initiated small scale breeding projects.

SUCCESSES

Hundreds of hatchings have been successfully reared in captivity and released into rivers, helping and stabilize small populations. Captive breeding has also preserved genetic material that would have otherwise been lost.

CHALLENGES

High maintenance costs, disease outbreaks, and difficulty in maintaining natural behaviours in captivity remain major challenges. Limited funding and inadequate facilities also hinder progress.

REINTRODUCTION INTO THE WILD

PREPARATION FOR RELEASE:

Before release, turtles undergo acclimatization to natural conditions, often through “soft release “programs where they spend time in semi natural enclosures within rivers.

MONITORING POST RELEASE:

Released individuals are tagged and tracked using radio transmitters to study survival, movement, and adaption to the wild environment.

CHALLENGES:

Reintroduced turtles often face threats such as poaching, predation, and degraded river habitats. Human encroachment on riverbanks limits the success of natural nesting.

SUCCESS STORIES:

The National Chambal Sanctuary in India has reported successful reproduction of Reintroduced individuals, making a major step forward in the recovery of species.

LESSONS LEARNED AND RECOMMENDATIONS

The Red Crowned roofed turtle conservation efforts highlight the need for integrated approaches. Community participation has proven crucial, as local awareness programs help

protect nesting sites and discourage illegal hunting. Habitat restoration must accompany breeding and reintroduction, ensuring safe and suitable environments for released turtles. Government must enforce stricter anti-poaching laws and regulate river use to reduce human disturbance.

RECOMMENDATIONS:

1. Expand captive breeding programs and increase cooperation between regional centres.
2. Restore and protect major river habitats from pollution and industrial exploitation.
3. Involve local communities through education and sustainable livelihood initiatives.
4. Enhance long –term research and monitoring of reintroduced populations.
5. Strengthening environmental policies and community based initiatives to reduce threats from human activity.
6. Conducting ongoing research on behavior and ecology and disease management to optimize breeding and reintroduction protocols.

Conclusion

The Red- Crowned Roofed Turtle serves as a flagship species for freshwater conservation in south and Southeast Asia. Captive breeding and Reintroduction programs have shown that it is possible to stabilize and even increase populations of critically endangered turtles when science, policy and community participation work together. However, the persistence of threats such as habitat degradation, poaching and climate change highlights that these programs are only one part of broader conservation effort. Continued commitment, research, and habitat protection are essential to ensure that future generations can witness the recovery of this remarkable species.

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GROWTH AND PERFORMANCE OF CROP INSURANCE SCHEME IN INDIA (2016 – 2024)

Article ID: AG-V05-I10-125

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Abstract

The Pradhan Mantri Fasal Bima Yojana (PMFBY), launched in 2016, aims to protect Indian farmers from crop loss due to natural calamities, pests, and diseases. This paper reviews studies conducted from 2016 to 2024 to understand the level of awareness among farmers regarding PMFBY. The results reveal that awareness levels were initially low but increased steadily through government campaigns, Krishi Vigyan Kendra's (KVKs), and digital initiatives. The overall growth rate in awareness from 2016 to 2024 was found to be 8.25% per annum, showing the impact of outreach and extension efforts.

1. Introduction

Indian agriculture is highly vulnerable to risks such as droughts, floods, and pest infestations that directly impact farmers' income. To address these issues, the Government of India introduced the Pradhan Mantri Fasal Bima Yojana (PMFBY) in 2016, replacing the National Agricultural Insurance Scheme (NAIS) and Modified NAIS (MNAIS). The objectives of PMFBY are to provide financial assistance to farmers in case of crop loss, stabilize their income, and encourage the adoption of improved agricultural practices. Despite its wide coverage, many farmers remain unaware of the scheme's benefits, premium rates, and claim processes. This article reviews studies conducted between 2016 and 2024 to assess changes in awareness levels among Indian farmers.

2. Revised literature review (2016 – 2014)

Rajaram and Chetana (2016) conducted a study in the Karnataka region with 150 farmers,

comprising both insured and uninsured respondents, and found that insured farmers exhibited better awareness about the provisions of the Pradhan Mantri Fasal Bima Yojana (PMFBY). They emphasized that trained and insured farmers could serve as "awareness agents" to educate others in their communities.

Duhan and Singh (2017) carried out research in Haryana and revealed that education and regular extension contact had a significant positive influence on farmers' awareness of crop insurance. The authors suggested that increasing awareness campaigns through Krishi Vigyan Kendra's (KVKs) and field-level training could strengthen farmers' understanding of PMFBY.

Ghanghas (2018) reported from Haryana that although nearly 67 percent of farmers had heard of the PMFBY by name, only 34 percent understood the extent of risk coverage provided under the scheme. The author recommended conducting Gram Sabha-level training sessions to improve understanding of the scheme's benefits and procedures.

WRMS (2018) conducted a multi-state survey across eight Indian states and found that only 28.7 percent of farmers were aware of PMFBY's detailed provisions. The study highlighted that many farmers were automatically enrolled through Kisan Credit Card (KCC) loans without any direct awareness of the insurance terms.

Singh et al. (2018) also studied the situation in Haryana and found that only 38 percent of respondents were aware of the claim process under PMFBY. The study stressed the need for local-level awareness meetings and extension interventions to increase claim literacy among farmers.

In Rajasthan, Meena and Sharma (2019) examined farmer perception and observed that although 70 percent of farmers had heard of PMFBY, only about 25 percent were familiar with the claim timelines. The authors recommended intensive awareness through radio and television to improve the reach of scheme-related information.

Patel and Mehta (2020) analyzed awareness levels in Gujarat and found that 59 percent of farmers had enrolled under PMFBY, yet many lacked clarities on premium rates and claim filing procedures. They concluded that regular training of bank staff and field officers could improve the quality of information passed on to farmers.

A study by Ghosh et al. (2020) in West Bengal revealed that only 42 percent of farmers were aware that they were covered under the scheme, and awareness levels were positively

correlated with education. The authors suggested distributing educational materials in local languages to improve scheme accessibility.

A national-level evaluation conducted by NITI Aayog (2021) showed that although enrollment rates were high, awareness regarding grievance redressal and claim settlement remained weak. The study recommended introducing digital call centers and helplines to improve farmer support and transparency.

Kavitha and Ushanandhini (2022) in their study conducted at Coimbatore district of Tamil Nadu concluded that non-loanee farmers had better awareness than loanee farmers. They also found that among crop-insured farmers, delay in claim settlement ranked first among constraints, while non-insured farmers ranked unawareness about the scheme as the major constraint

Kumar and Jha (2022) studied farmers in Bihar and reported that 52 percent of the sample were enrolled under PMFBY, but less than 30 percent had complete knowledge of the claim process. They suggested setting up Panchayat-level information centers to bridge the information gap between farmers and implementing agencies.

Thomas et al. (2022) conducted research in Kerala after the 2018 floods and found that awareness of PMFBY had improved significantly due to intensive post-disaster campaigns. Farmers expressed satisfaction with the digital claim processing system introduced in the state, which increased their trust in the scheme.

Bhattacharya and Roy (2023) examined PMFBY awareness in Maharashtra and found that 68 percent of farmers were aware of the scheme's features. Smartphone users showed higher levels of awareness compared to those without access to digital tools. The authors recommended developing multilingual mobile applications to enhance understanding and participation.

Mishra and Verma (2024) studied the case of Uttar Pradesh and found that 72 percent of farmers were aware of PMFBY, with awareness being notably higher among educated farmers. The study concluded that the combined effect of social media campaigns, digital outreach, and local government efforts had substantially increased awareness in recent years**.**

3. Methodology

The study is based on secondary data from published journals, reports, and government studies between 2016 and 2024. The tool used for analysis is the Compound Annual Growth Rate (CAGR), to measure the yearly growth in awareness of PMFBY.

Formula,

CAGR (%) = (Ending Value /Beginning Value) power 1n- 1

4. Results and discussion

The awareness level of farmers regarding PMFBY has shown steady improvement from 2016 to 2024. In 2016, only 38 percent of farmers were aware of the scheme. The percentage rose to 40 percent in 2017 and 42 percent in 2018. With enhanced government efforts, awareness reached 50 percent in 2019 and 55 percent in 2020. Further progress was noted in 2021 (60%), 2022 (65%), 2023 (68%), and finally 72 percent in 2024.

Using the CAGR formula:

CAGR = 8.25% per year

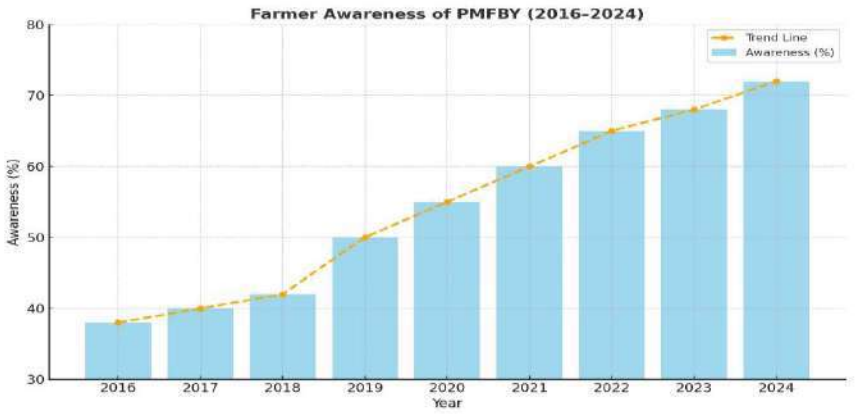
This means awareness of PMFBY among farmers increased by an average of 8.25 percent annually during 2016–2024.

This consistent rise can be attributed to multiple factors such as Fasal Bima Pathshala campaigns, KVK initiatives, digital tools, and social media awareness drives. Southern and western states such as Kerala, Maharashtra, and Gujarat showed better awareness levels compared to northern regions. Education, digital access, and local language communication were key enablers. However, challenges such as delayed claim settlement and lack of awareness among small and tenant farmers persist.

key findings

Awareness improved from **38% in 2016–18** to **70–72% by 2024.** Southern and western states (Kerala, Maharashtra, Gujarat) showed better awareness than northern states.

Figure 1: Trend in PMFBY Awareness Among Farmers (2016–2024)



Education level and access to smartphones were strong predictors of awareness. Women, tenant, and small farmers were less informed than male or large landholder. The graph clearly indicates a steady increase in awareness, highlighting the effectiveness of government campaigns and digital outreach. "Based on the reviewed studies, farmer awareness of PMFBY increased from **38% in 2016** to **72% in 2024**, reflecting a **compound annual growth rate (CAGR) of 8.25%**. This steady growth indicates the effectiveness of government awareness campaigns, digital tools, and extension services over the years."

Conclusion

The **Pradhan Mantri Fasal Bima Yojana (PMFBY**) has become India's most comprehensive crop insurance scheme, protecting millions of farmers from yield losses. Between 2016 and 2024, awareness improved significantly due to consistent government efforts and digital advancements. However, issues like delayed claim settlement and insufficient communication persist. Strengthening local-level campaigns, digital claim tracking systems, and regular training for bank staff can enhance the scheme's effectiveness

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CLIMATE CHANGE'S NEGATIVE IMPACT ON BIODIVERSITY

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Abstract

Climate change is a major and accelerating driuer of biodiversity loss across terrestrial, freshwater, and marine ecosystems. Rising global temperatures, altered precipitation patterns, ocean warming and acidification, and extreme weather events are stressing ecosystems and undermining species' ability to adapt, leading to disruptions in species' life cycles, geographic ranges, and population sizes.

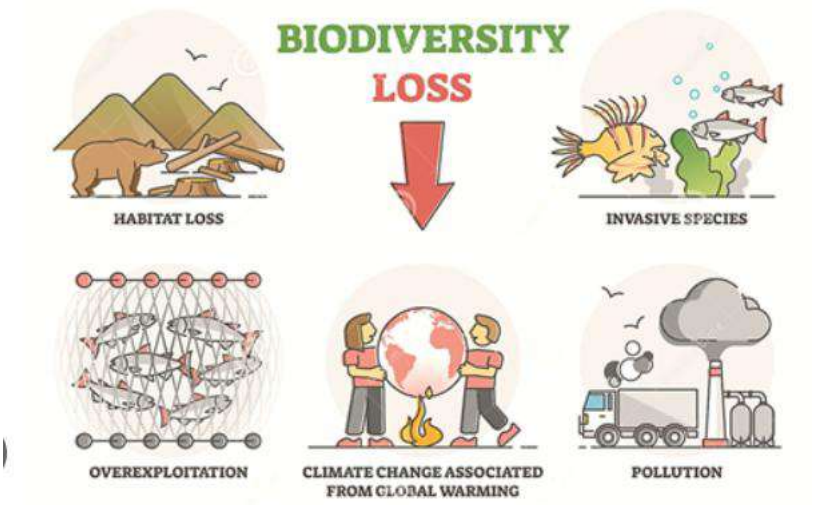
Introduction

Climate change and its impact on biodiuersitg can be traced through the inuestigation of the ongoing transformations in the uarious ecosystems such as marine and forest environmental structures. Climate change affects human society as well, which can be easily demonstrated by the changes in agricultural practices (Moss et al. 750). The topic of the enuironmental transformation and its effects has been examined for decades and all the auailable data is considered in forecasting and designing different scenarios.

The effects of climate change on biodiversity:

Biodiuersity, or the 'diversity of life' on Earth, is essential for the planet's health and surviual. But the effects of climate change are becoming increasingly clear. Extreme weather events are happening more often. The timing of biological euents is changing. Our wildlife is disappearing. Climate change is hauing a greater impact on the poles, tropical rainforests, and coastal areas than anywhere else in the world.

This could haue far-reaching consequences for the planet's health; and our future.



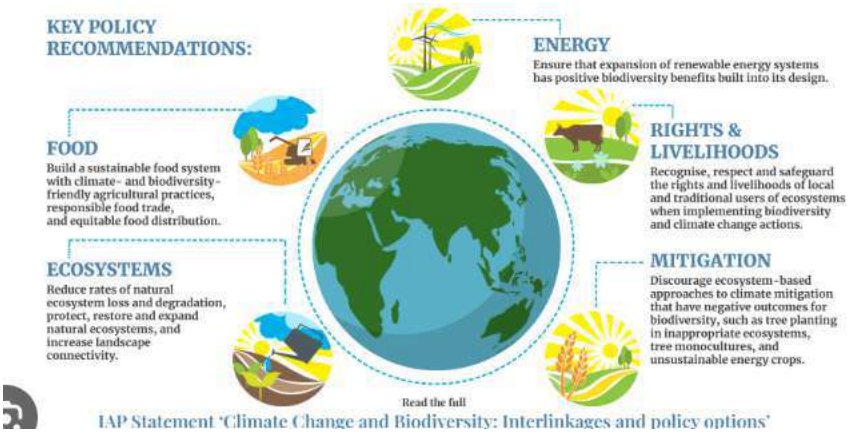
Consequences of Climate Change on Marine Ecosystems:

The increase of carbon dioxide levels triggers the increase of the atmosphere and water temperature that in turn influences the changes in wind, rainfall, and drainage patterns. "Sea-surface pH is estimated to have dropped by 0.1 pH units since the preindustrial era, a 26% increase in acidity over the past 1 50 years. Future projections suggest declines of an additional 0.2-0.3 pH units over this century" (Doney et al. par. 8). This process has extremely negative an impact on the biological life of the oceans such as diminishing of "reef accretion" and forcing "coral reefs into a negative carbonate balance"

The transformation of climate affects the biodiversity of various organisms "we can expect poleward species migrations that could reorganize traditional cold-adapted biomes, change biodiversity, and increase food-web complexity, with direct impact on carbon transfer within the polar ecosystem and enhanced connectivity with the global ocean system" .

Climate change and Biodiversity:

The environment change has a significant influence on biodiversity and, as a result, affects human society. A decrease in the uegetation biodiuersity may "reduce plant production and alter decomposition".Moreouer, changes in the species distinction within uarious ecosystems trigger climate transformations as well. This reciprocal process has been evaluated by CardinaLe and his colleagues and it was concluded that "in areas where local species loss this century falls, negligible effects on biomass production will result, and changes in species richness will rank low relative to the effects projected for other environmental changes".



Conclusion

The transformation of the enuironment contributes to metamorphosis in uarious ecological and biological domains. Changes in the forest and marine ecosystems, as well as in the agricultural patterns, demonstrate a significant impact on biodiversity. The species that moue from one territory to another following the changing weather patterns, along with the animals and plants that adapt to climate transformation, inevitably Lead to enuironmental changes. These reciprocal processes affect human society in various wags such as adaptation to new conditions, mooing to more habitual areas, or changing the patterns of harmful actiuities which minimizes the aduerse effects on the enuironment.

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ARTIFICIAL INTELLIGENCE IN PLANT GENETIC RESOURCES

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Abstract

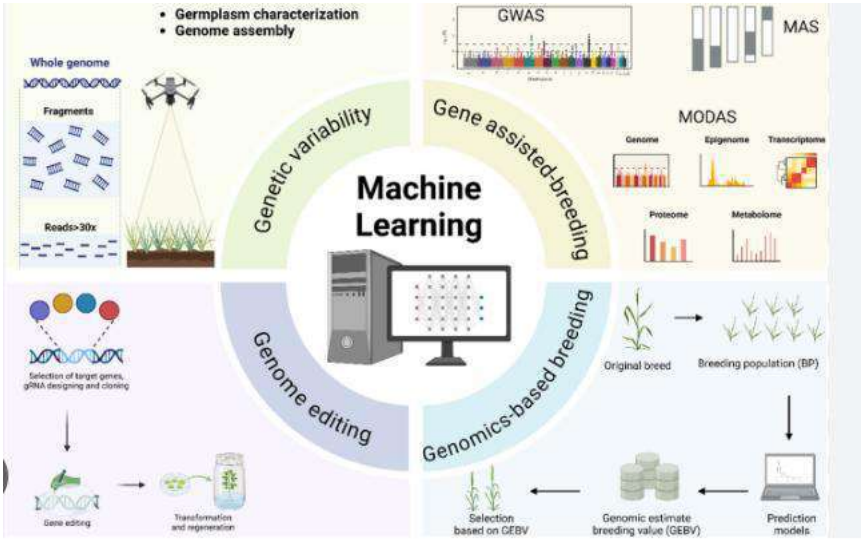
Plant genetic resources (PGR) are the foundation of global food and agricultural security, providing essential raw materials for crop improvement and resilience against climate change. However, the vast amount of genetic diversity stored in genebanks worldwide remains underutilized due to the difficulty of analyzing large, complex datasets. Artificial intelligence (AI) offers transformative tools for managing, characterizing, and utilizing PGR efficiently. Through machine learning, image analysis, and data integration, AI helps identify valuable traits, predict genotype–phenotype relationships, and optimize genebank operations. This article discusses the role, applications, advantages, and challenges of AI in the management and utilization of plant genetic resources.

Introduction

Plant genetic resources encompass the diversity of seeds, tissues, and living plants that serve as the genetic foundation for crop breeding and agricultural development. Global genebanks conserve millions of accessions, but limited phenotypic and genotypic characterization often hinders their effective use.

Recent advancements in artificial intelligence (AI) — including machine learning , deep learning , and data mining — have opened new avenues to analyze vast and complex biological data. AI can learn patterns from genomic, phenotypic, and environmental data, enabling breeders and genebank managers to make faster, more accurate, and data-driven decisions. The

integration of AI in plant genetic resources marks a shift from traditional manual evaluation toward automated, predictive, and precision-based resource management.



Role of AI in Plant Genetic Resources:

AI aids in exploring and managing PGR by:

- Characterizing germplasm collections using automated phenotyping and image recognition.
- Predicting potential traits such as drought tolerance or disease resistance.
- Prioritizing accessions for conservation or breeding programs.
- Streamlining genebank operations and data management.

Applications of AI in PGR:

A.Germplasm Characterization:

AI models analyze high-resolution images, genomic sequences, and sensor data to identify morphological and physiological traits.

Example: Convolutional Neural Networks (Cnns) can classify leaf shapes or detect diseases from images, providing rapid digital characterization of genebank accessions.

B.Genotype–Phenotype Prediction:

AI algorithms integrate genomic and environmental data to predict how genotypes will perform under specific conditions.

This accelerates the selection of accessions with desirable traits without extensive field testing.

C.Mining Hidden Genetic Diversity:

Machine learning helps discover rare alleles or gene combinations linked to stress tolerance, nutrition, or yield.

For instance, AI-assisted data mining in rice and wheat genebanks has uncovered hidden drought- and flood-tolerant varieties.

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D. Genebank Management:

AI optimizes the maintenance of germplasm collections by predicting seed viability, identifying duplicates, and suggesting regeneration schedules.

Image based systems can also monitor seed health and detect contamination.

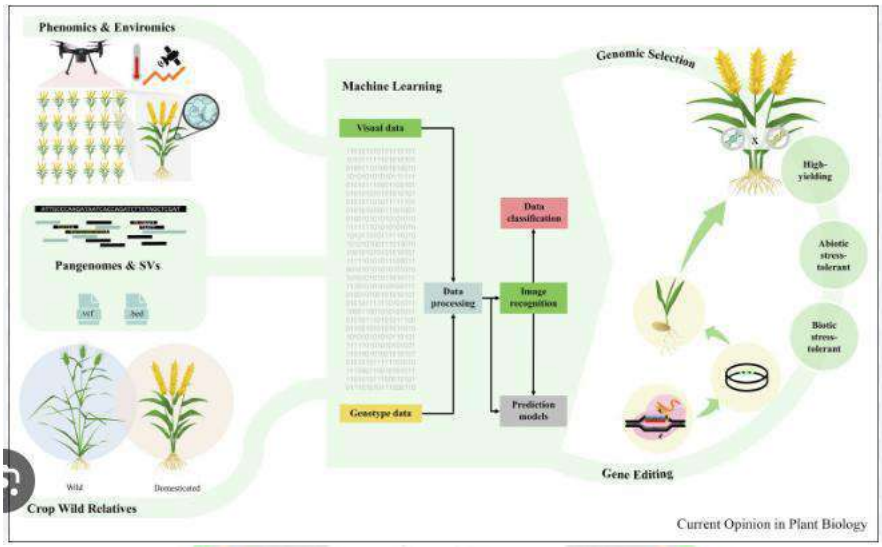
E.Climate-Resilient Breeding Support:

By linking genebank data with climatic and geographic information, AI predicts how genetic resources will perform under changing climate scenarios, aiding the development of climate-resilient crops.

Benefits of AI in Plant Genetic Resources:

- Faster decision-making: reduces time for evaluating large germplasm collections.
- Cost-effective: Minimizes repeated field trials and manual data collection.
- Enhanced diversity use: Identifies underutilized accessions for breeding.

- Improved conservation: Optimizes genebank management and resource allocation.
- Supports global food security: Helps develop crops adapted to future environmental conditions.



CHALLENGES AND LIMITATIONS:

1. Data scarcity and inconsistency: Many accessions lack standardized data.
2. Technical and financial constraints: High initial investment and need for expertise.
3. Model interpretability: AI models may act as "black boxes," making biological validation difficult.
4. Ethical and legal issues: Data ownership, benefit sharing, and access rights must be addressed.

FUTURE PROSPECTS

- AI will continue to revolutionize plant genetic resource management through:
- Development of *explainable AI* for transparent predictions.
- Integration with *CRISPR* and *gene-editing* tools for precise trait improvement.
- Use of *AI-driven digital genebanks* for global data sharing and visualization.
- Broader application in minor crops and wild relatives to enhance agricultural resilience.

Conclusion

Artificial Intelligence has immense potential to transform the conservation and utilization of plant genetic resources. By harnessing big data from genomics, phenomics, and environmental datasets, AI enables smarter decision-making in genebanks and breeding programs. Although

challenges remain — including data quality, cost, and ethical considerations — the integration of AI offers a path toward more efficient, sustainable, and resilient agricultural systems. In the coming decades, AI-driven tools will be crucial in unlocking the hidden potential of global germplasm collections to ensure food security under changing climate conditions. optimizes genebank management and resource allocation.

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INTEGRATING ARTIFICIAL INTELLIGENCE IN PLANT GENETIC RESOURCE MANAGEMENT

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Abstract

Plant Genetic Resources (PGR) form the foundation of crop improvement and global food security. However, managing the vast diversity of germplasm collections remains a challenge due to complex data and limited resources. Artificial intelligence (AI) offers transformative tools for efficient data analysis, characterization and utilization of PGR. This paper explores the integration of AI and machine learning (ML) in genetic resource management, covering applications such as predictive trait analysis, image-based phenotyping, gene bank data management and decision support system. The study emphasizes how AI can enhance conservation strategies, accelerate breeding programs and ensure sustainable use of genetic diversity in the era of climate change.

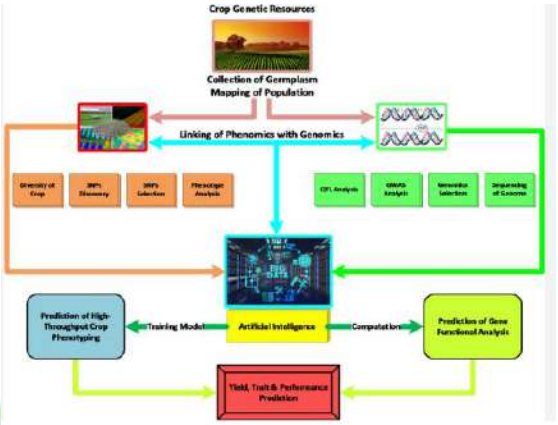
Keywords: Plant Genetic Resources, Artificial Intelligence, Machine Learning, Gene bank Management, Phenotyping, Bioinformatics, Crop breeding.

1. Introduction

Plant Genetic Resources (PGR) are essential raw materials for crop improvement and biodiversity conservation. With the exponential growth of genetic, genomic and phenotypic data, conventional methods of managing PGR are becoming insufficient. Artificial Intelligence (AI) – encompassing machine learning, deep learning and data mining – provides an innovative approach to analyze large, complex datasets efficiently.

AI enables predictive modeling, pattern recognition, automation in PGR management systems. The integration Of AI in PGR can significantly enhance germplasm evaluation, conservation, decision making and utilization in breeding programs.





2. OBJECTIVES

- To understand the role of AI tools in the management and utilization of plant genetic resources.
- To explore application of machine learning in genetic diversity assessment and trait prediction.
- To assess challenges and opportunities for AI – based gene bank management.
- To propose an integrated framework for smart PGR management using AI.

3. REVIEW OF LITERATURE

- **AI in Agriculture:** Early adoption in yield prediction, pest detection and precision farming.
- **AI in Genomics:** Machine learning models used in genome – wide association studies (GWAS) and marker – assisted selection (MAS).
- **AI in PGR:** Recent studies from FAO, Biodiversity International and CGIAR highlighting the use of deep learning for image – based germplasm classification and automated data base curation.

3. METHODOLOGY

1. Data Collection:

Genetic (SNPs, SSRs), Phenotypic (images, yield traits) and environmental data from gene banks.

2. Data Processing:

Standardization and cleaning using bioinformatics pipelines.

3. Modern Development:

Application of ML algorithms (Random forest, SPM, Neural Networks) for diversity analysis and trait prediction.

4. Integration:

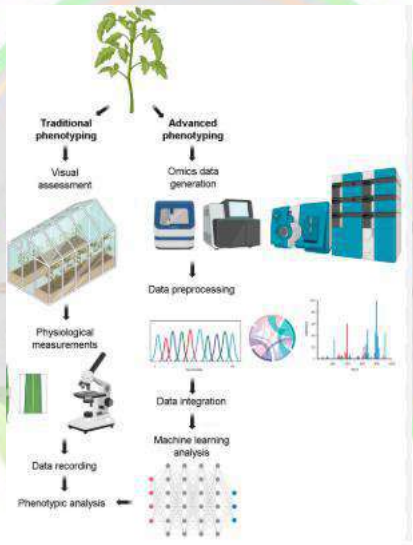
Linking AI models with gene bank databases (e.g., GENESYS, GRIN- Global).

5. Validation:

Cross-validation using field data and expert evaluation.

6. Visualization:

Use of AI dashboards for trait prioritization and diversity maps.



4. APPLICATIONS:

- Automated Germplasm Classification using image recognition.
- AI – based decision support systems for selecting accessions for breeding.
- Predictive trait analysis for stress tolerance and yield potential.
- Smart gene banks using sensors, IoT, and AI for monitoring seed viability.
- Knowledge graphs and AI data bases to link multi-omics data for efficient resource utilization.

5. CHALLENGES AND LIMITATIONS:

- Limited interdisciplinary collaboration between AI experts and geneticists.

- Ethical concerns over data ownership and privacy.
- High cost of AI infrastructure and model training.
- Data scarcity and lack of standardized data sets.

6.FUTURE PROSPECTS:

- Development of AI-driven pangenome databases.
- Integration of AI with blockchain for transparent access and benefit-sharing.
- Use of generative AI for simulating new allelic combinations in silico.
- Expansion of open- access AI tools for PGR research in developing countries.

Conclusion

AI Integration offers unprecedented opportunities for the effective management and utilization of Plant Genetic Resources. By automating data analysis, predicting traits and optimizing conservation, AI acts as a bridge between biodiversity and breeding innovation. Collaboration between computational scientists and plant breeders is essential to fully realize the potential of AI – driven PGR systems for sustainable agriculture.

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IMPACT OF NATIONAL CANCER AWARENESS DAY

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Introduction

On November 7th each year, India observes National Cancer Awareness Day - an initiative that aims to raise awareness about the growing cancer burden in the country and inspire action towards prevention, early detection, and treatment.



India is the first country in the world to officially recognize National Cancer Awareness Day. The day was first introduced in 2014 by **Dr. Harsh Vardhan,** the Union Health Minister of India. The date was chosen to honor the birth of **Nobel Laureate Madame Marie Curie,** who discovered radioactivity and whose work has had a profound impact on cancer treatment but also to reflect India's commitment to addressing cancer as a public health priority.

THERE IS A "CAN" IN CANCER BECAUSE WE CAN BEAT IT !

Cancer was a rare disease before 2000 affecting only about one in 1000 people, but in today's generation it has become alarmingly common, affecting nearly two in 10 people showing a sharp rise in cases over the years.

PREVALANCE

- India covers over 1.4 billion people, is experiencing a rapid rise in cancer cases, largely due to lifestyle changes, tobacco use, poor dietary habits, and inadequate physical activity.
- According to estimates, approximately 800,000 new cancer cases are expected each year, with tobacco-related cancers accounting for as much as 35–50 per cent of all cancers in men and 17 per cent in women. However, various types of cancer are preventable, and through widespread awareness and timely interventions, India is significantly reducing its cancer burden.
- According to data from the National Cancer Registry Programme, cancer cases are expected to increase significantly, with an estimated 800,000 new diagnoses annually. Among these, tobacco-related cancers including oral, lung, and head and neck cancers are particularly prevalent and account for a major proportion of cancer cases.

As per GLOBCAN (Global Cancer) report 2024 India accounts for 13.24 lakh new cases, where

- ❖ Lip/ oral cavity - 16.20 %
- ❖ Lung – 8.00 %
- ❖ Stomach cancer – 6.30 %
- ❖ Breast cancer - 26.30 %
- ❖ Cervix uteri cancer - 18.30 %
- ❖ Ovary cancer - 6.70 %

The mortality rate of cancer is reported as 8,51,678 from the year 2022-24.

Addressing Risk Factors:

Tobacco, Diet, and Lifestyle

India's cancer landscape is shaped by multiple lifestyle-related risk factors. Tobacco consumption, whether through smoking or chewing, is the single most significant contributor to cancer in India. It is responsible for an estimated 40–50 per cent of cancer cases in men and 20.00 per cent in women. Oral cancers, is one particular major concern, with chewing tobacco being more prevalent in Gujarat, Uttar Pradesh and Maharashtra .

Government has taken various measures to address these issues, such as:

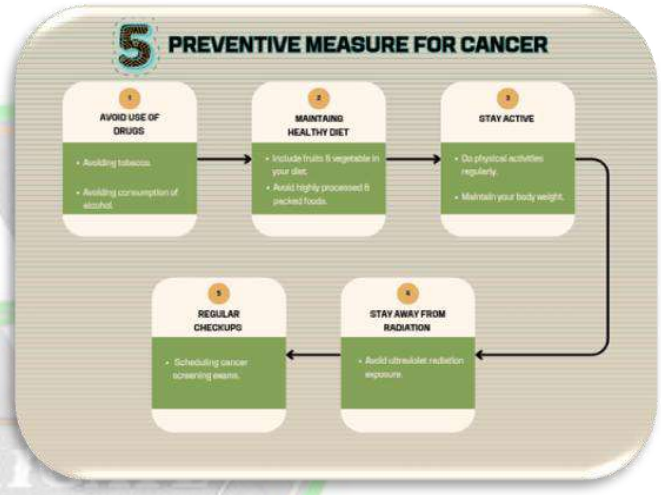
- **Tobacco Control:** As tobacco use is a major risk factor for cancer, measures have been implemented to discourage tobacco consumption through various public health

campaigns.

- **Comprehensive Primary Health Care:** The preventive aspect of cancer is strengthened through the Ayushman Bharat- Health and Wellness Centres (AB-HWC) scheme, which promotes wellness activities and community-level health communication.
- **Nutrition Promotion:** The Food Safety and Standards Authority of India (FSSAI) promote healthy eating habits to reduce cancer risk.

Preventive measures for cancer

Preventive measures for cancer aim to reduce the risk of developing cancer and may vary depending on the type of cancer



Cancer risk can be reduced by:

- Avoiding tobacco.
- Maintaining a healthy body weight.
- Having a healthy diet, including fruits and vegetables.
- Doing physical activity on a regular basis.
- Avoiding or reducing consumption of alcohol.
- Avoiding ultraviolet radiation exposure.
- Scheduling cancer screening exams.
- Avoid using micro plastics.

National Cancer Control Programme

The National Cancer Control Programme (NCCP) was launched in 1975 and later integrated into the National Programme for Prevention and Control of Cancer, Diabetes, Cardiovascular Diseases, and Stroke (NPCDCS), which has been operational since 2010.

Under the National Health Mission (NHM), the NPCDCS supports state and union territories in generating awareness about cancer prevention. Financial support is provided for Information, Education, and Communication (IEC) activities to raise public awareness at the grassroots level.

As part of this initiative, 616 Non-Communicable Disease (NCD) clinics have been established at the district level, along with 3,827 such clinics at the Community Health Centre (CHC) level. Additionally, 214 Day Care Centres for Chemotherapy have been set up to provide specialized care. The programme also includes population-based screening for common NCDs, with individuals aged 30 and above being screened for prevalent conditions, including three major cancers: breast, oral, and cervical cancer.

Budgetary Measures to Improve Cancer Care

The Union Budget for FY 2024-25 has provided a boost to cancer care in India, with an increase of approximately Rs 4,000 crore in funding for the National Health Mission (NHM). This funding is directed toward improving primary and secondary healthcare services, which are vital for preventive cancer care and early detection.

The government is also focusing on enhancing digital public infrastructure (DPI), which drive innovation and productivity across healthcare, including cancer treatment and management.

Prime Minister Narendra Modi stated: A Call to Action for Cancer Prevention, Treatment, and Innovation "**The effort is that the citizens of the whole country can get the benefits of the schemes of the central government, anywhere in the country, there should be no restriction for that. This is the spirit of One Nation, One Health".**

Moreover, in a significant step toward improving access to cancer treatments, the Union Finance Minister, **Smt. Nirmala Sitharaman,** announced the exemption of three critical cancer medicines**— Trastuzumab Deruxtecan, Osimertinib, and Durvalumab**—from customs duty.

These medicines are used to treat breast, lung, and biliary tract cancers, respectively, and their exemption has made it more affordable and accessible to patients. This initiative aims to ease the financial burden on cancer patients, making cutting-edge treatments more accessible to the Indian population.

Cancer Research and Treatment

While prevention is key, progress in cancer treatment is also critical. New approaches to cancer treatment are emerging, such as magnetic hyperthermia-based therapy, which uses magnetic nanoparticles to target and destroy tumor cells with minimal side effects.

This method could revolutionize cancer treatment by reducing the need for traditional chemotherapy, which often comes with severe side effects.

Research conducted by Indian scientists is contributing to the development of nanotherapy and other innovative treatments, making it possible to treat cancers more effectively and with fewer side effects.

Role of Cancer Detection and Prevention Clinics

A key component of India's cancer control strategy is the establishment of Cancer Detection and Prevention Clinics in district hospitals and regional centers. These clinics provide early diagnostic services and basic treatment, helping to identify cancers at an early stage when they are most treatable.

Kerala has been a leader in this initiative, successfully implementing a model where district hospitals provide a range of cancer services, including cytology and palliative care. The goal is to make cancer care more accessible and affordable, particularly in rural areas where access to specialized cancer centers is limited.

Palliative Care: Addressing Late-Stage Cancer With more than 75% of cancer patients in India presenting at advanced stages, palliative care is crucial to improving the quality of life for these individuals.

International Collaboration

- **A Global Fight Against Cancer**

India's efforts to combat cancer are not limited to national initiatives. The World Health Organization (WHO) has been a key partner in India's cancer control strategy, promoting tobacco control, palliative care, and human resource development. Additionally, India's participation in international collaborations such as the Quad Cancer Moonshot further strengthens its role in the global fight against cancer. India is also taking steps to provide cancer care and prevention support to neighboring countries in the Indo-Pacific region. By sharing expertise, providing screening tools, and expanding access to cancer vaccines and treatments, India is



contributing to global cancer control efforts, particularly in the prevention and treatment of cervical cancer, which remains a major health crisis in the region.

Cancer Control Strategy for India

As India observes National Cancer Awareness Day, the importance of prevention, early detection, affordable treatment, and palliative care cannot be overstated. With the increasing burden of cancer, India must continue to expand its efforts in public education, healthcare infrastructure, and research. This will require sustained investment, collaboration between government and private sectors, and a commitment to reducing the inequities in cancer care across the country.

The government's focus on primary healthcare, screening programs, tobacco control, and affordable treatment is a step in the right direction. By prioritizing cancer as a public health issue and implementing strategies to prevent, detect, and treat it effectively, India can significantly reduce the cancer burden and improve outcomes for millions of individuals affected by this disease. National Cancer Awareness Day serves as a reminder of the progress made and the road ahead in the fight against cancer. Together, we can build a future where more lives are saved from cancer, and those affected have access to the care and support they deserve.

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CENTRAL PIVOT IRRIGATION SYSTEM - NEED OF SUSTAINABLE AGRICULTURE

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Introduction

Center-pivot irrigation was invented in 1940 by farmer Frank Zybach who lived in Strasburg, Colorado it was recognized as a method to improve water distribution to fields. Centre Pivot irrigation is a form of overhead sprinkler irrigation consisting of several segments of pipes joined together by trusses to support each other.



The whole assembly is mounted on tires due to which it rotates in circular manner around a central point known as Pivot Point. The space between two tires is known as Span. The arm of the system is connected with number of pipes at fixed intervals of horizontal distance between them are known as sprinklers. The average quantity of water from sprinkler can be controlled by Control Unit. The Centre Pivot irrigation comes under the category of Self Propelled irrigation system and in USA about 29% of the total irrigation is achieved by such self-propelled system of irrigation.

PARTS OF THE CENTER PIVOT SYSTEM

The typical center pivot system consists of a single long irrigating pipeline attached to a central tower that moves slowly over the field in a circular pattern and irrigates the plants with sprayers, or sprinklers placed on it at frequent spacing's. The central tower, which houses the

pivot mechanism and main control panel (electric), is anchored to a small concrete base at a fixed the center of the field. The entire irrigating pipeline is supported above ground by "A"-frame towers that move on wheels, long spans, steel trusses and/or cables. The outside end of the pipe is sometimes overhung with a sprinkler end gun. The whole system is self-propelled and rotates slowly, at a typical speed (for the outermost span) of two to three meters per minute around the fixed pivot. It applies water to the field in the form of overhead spray irrigation and covers the irrigated area in a circular pattern.

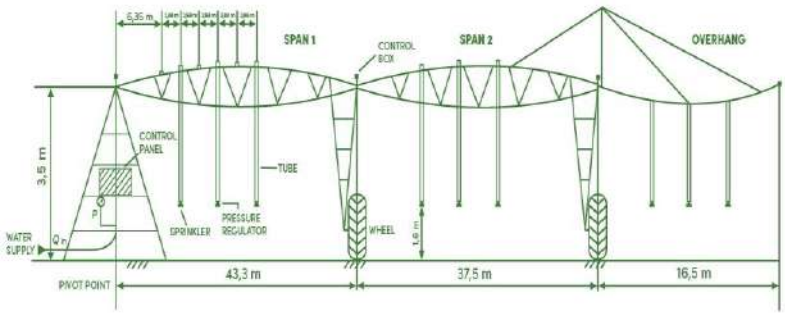
APPLICATION

- All type of crops Ideal for large fields and widely spaced crops like Napier grass, Maize, Cotton, Pulses and Fodder crops
- Spraying the chemical fertilizer on the crops.

ADVANTAGES OF CENTER PIVOT SYSTEMS

- Soil needs not to be in level because water flowing over the ground is not due to gravity effect.
- Rubber tyres with moderate shock absorbing arrangement make the system suitable even for undulating field.
- Indian farmer often suffer from shortage of labour power so this system proves best because almost no labors are involved for operating.
- Herbicides, pesticides and soluble nutrient can be directly fed to each plant.
- Since water washes the leaves of the plant so reduces the chances of diseases
- Irrigation effectiveness by giving suitable quantity of water required to top of the soil wetness to the wanted level.
- Upto 90 % Water use efficiency
- Reduced evaporation losses compared to flood irrigation, Ideal for large fields and widely spaced crops like Napier grass , Maize, Cotton , Pulses and fodder crops
- Energy independence
- Solar PV panels integrated with VFD- Controlled motors.
- Daytime irrigation synced with solar generation
- Eligibility for PM-KUSM Component B& C Subsidies
- Operational ease
- Fully Automated – Minimal Labor requirement

- Integration with IoT, AI and Weather sensors for smart irrigation
- Reduces GHG emissions by eliminating diesel pumps , promotes climate -Resilent Agriculture



DISADVANTAGES OF CENTER PIVOT SYSTEMS

- Very large initial cost in involved.
- If proper service and maintenance is not taken then the system may lead to breakdown.
- Heavy constituent of salt may lead to blockages of sprinkle nozzles which may lead to frequent replacement of them.
- For clayey soil care has to be taken so as wheel does not stuck in the muddy wet soil.

Conclusion

- Centre Pivot Irrigation systems was assembled satisfactory by local experts if the necessary tools are made available.
- High values of coefficient of uniformity, distribution uniformity and water application efficiency are obtainable if the instructions in the operation manual are adhered to particularly the nuzzling chart (nuzzling adjustment).
- Reduce the farmer or operator effort for irrigation.
- The centre pivot has the ability to operate under different rotational speeds and this makes it flexible to apply water according to crop watering requirement (different growth stages or different crops).

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MACADAMIA NUT
THE QUEEN OF NUTS-A BUTTERY TREASURE

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Introduction

Macadamia is a medium size tree and nuts, often referred to as the "queen of nuts," are native to Australia but have gained popularity worldwide due to their rich, buttery flavour and creamy texture, but they also deliver substantial nutritional benefits, including heart-healthy monounsaturated fats, antioxidants, and vital minerals. They support cardiovascular and brain health, contribute to weight management by promoting satiety, and offer bone-strengthening minerals. Their low carb and sugar content also makes them a favoured snack for low-carb and ketogenic diets, and they can be enjoyed raw, roasted, or incorporated into both sweet and savoury dishes. With favourable climatic conditions and increasing demand for these nuts in both domestic and international markets, macadamia cultivation holds significant potential as a lucrative agricultural venture in India.



Nutrients in Macadamia Nuts (100g edible portion)

Macronutrients	Quantity	Vitamins	Quantity	Minerals	Quantity
Calories	718kcal	Thiamine (B1)	1.2 mg	Manganese	4.1 mg
Total fat	75.8 g	Niacin (B3)	2.5 mg	Magnesium	130 mg
Protein	7.9 g	Vitamin B6	0.3 mg	Iron	3.7 mg
Carbohydrates	13.8 g	Riboflavin (B2)	0.16 mg	Phosphorus	188 mg
Fiber	8.6 g	Vitamin C	1.2 mg	Potassium	368 mg
Sugar	4.57 g	Vitamin E	0.54 mg	Calcium	85 mg

There are several species of Macadamia that exist in Australia but only two species, *Macadamia integrifolia* and *Macadamia tetraphylla* and their hybrids are grown commercially. Trees of macadamia are evergreen and grow as high as 10 m. *M. integrifolia* and *M. tetraphylla* are cultivated but M. integrifolia is more common and known as smooth shelled type which has almost spherical, smooth surface kernels while *M. tetraphylla* is known as rough-shelled type and produces slightly elliptical or spindle shaped kernels with pebbled surface. The edible part, a white cream coloured kernel or embryo is enclosed in one piece very tough spherical brown seed coat or shell which is surrounded by a green, fibrous pericarp or husk. The macadamia nut resembles cashew in taste but is more oily and globular in shape.

Area and production:

Global macadamia production is dominated by Australia and South Africa, with significant contributions from Kenya, China, and the United States (particularly Hawaii). Production is growing, with increased investment and land dedicated to macadamia farming driving higher yields. The crop requires specific tropical and subtropical, or temperate, climates with high rainfall, found in regions across Southeast Asia, South America, Australia, and North America. Global production increased significantly by 2024, with over 339,200 metric tons produced, driven by growth in these key countries and the expanding demand in Asia. Macadamia cultivation in India is a promising, though somewhat limited, endeavor, with successful experimental orchards in Kerala, Tamil Nadu, Karnataka, and West Bengal.

Climate and soil:

Macadamia trees thrive in subtropical climates, characterized by moderate rainfall and temperatures ranging from 18°C to 30°C. They require well-drained, slightly acidic to neutral

soils with good organic matter content. Conduct soil tests to ensure your chosen site meets these requirements and, if necessary, amend the soil to improve its quality. Macadamia trees need ample sunlight for optimal growth. Ensure that the selected site receives at least 6-8 hours of direct sunlight daily. Generally, it comes up well where guava and orange thrive well.

Varieties:

Several macadamia varieties have shown promise in global cultivation. The key ones recommended for India include *M. integrifolia*: Kakea, Ikaika, Keaau, Keauhou, Kau, Purvis, Makai and Mauka; *M. tetraphylla*: Greber, Renown, Anamour, Mammoth, Sewell and Probert 2 and Beaumont, Hybrids: Nelmak I and Nelmak II. It is better to plant at least 2 cultivars in an orchard, although self-pollination occurs. Kakea and Keaau grow well under Bangalore climate and good scope exists to test more number of recent standard cultivars. Beaumont is the most widely planted macadamia nut cultivar, followed by A4, 816, 814, Nelmak 2, 695 and 842 in South Africa. Cultivars Nelmak 2, 842, A4, 695 and 814 are favoured for their precocity and subsequent high yields, whereas Beaumont is favoured for its drought tolerance and 816 and A4 for its nut quality.

Beaumont:

A *Macadamia integrifolia / M. tetraphylla*. hybrid cultivar, widely planted in Australia and New Zealand; it was discovered by Dr. J. H. Beaumont. It is high in oil, but is not sweet. New leaves are reddish, and flowers are bright pink, borne on long racemes. It is one of the quickest varieties to come into bearing once planted in the garden, usually carrying a useful crop by the fourth year and improving from then on..



It crops prodigiously when well pollinated. The impressive, grape -like clusters are sometimes so heavy they break the branchlets to which they are attached. Commercial orchards have reached

18 kg per tree by 8 years old. On the downside, the macadamias do not drop from the tree when ripe and the leaves are a bit prickly when one reaches into the interior of the tree during harvest. Its shell is easier to open than that of most commercial varieties.

Maroochy: It is a pure *M. tetraphylla* variety from Australia and this strain is cultivated for its productive crop yield, flavour, and suitability for pollinating 'Beaumont".

Nelmac II: A South African *M. integrifolia / M. tetraphylla* hybrid cultivar, has a sweet seed, which means it has to be cooked carefully so that the sugars do not caramelise. The sweet seed is usually not fully processed, as it generally does not taste as good, but many people enjoy eating it uncooked. It has an open micropyle (hole in the shell), which may let in fungal spores. The crack-out percentage (ratio of nut meat to whole nut by weight) is high. Ten-year-old trees produce an average 22 kg (50 lb) per tree. It is a popular variety because of its pollination of 'Beaumont' and the yields are almost comparable.

Renown: A *M. integrifolia / M. tetraphylla* hybrid, this is a rather spreading tree. On the plus side, it is high yielding commercially with 17 kg (37 lb) from a 9-year-old tree and the nuts drop to the ground. However, they are thick-shelled, with not much flavour.

Propagation: Although macadamia seeds can germinate and produce trees, seed-grown plants lack uniformity in yield and nut quality. Hence, grafted plants are preferred for commercial orchards. Grafting ensures that the plants inherit desirable traits such as disease resistance, high yield, and uniform nut size. The grafted trees produce 34 times more nuts on an average, providing 15% higher kernel yield. Macadamia is propagated by wedge grafting on seedling rootstocks. The well mature husked nuts should be used for raising the rootstocks. In-situ grafting can also be practised, if more attention and care are taken.

Propagation Techniques: The most effective propagation methods include wedge grafting and chip budding. Ideal rootstocks are 9–12 months old with a stem diameter of 1–1.3 cm. *Macadamia tetraphylla* is the recommended rootstock due to its resistance to trunk canker and anthracnose.

Planting Density and Spacing

Planting density depends on the cultivation scale and management system:

- Low density: 10m × 5m (200 trees/ha)
- Medium density: 8m × 4m (312 trees/ha)
- Medium-high density: 7m × 3m (476 trees/ha)

- High density: 5m × 2m (1,000 trees/ha)

Most new orchards in India adopt medium-high density planting to optimize land use while maintaining good yields. Grafted plants should be spaced 9–10 meters apart to allow sufficient canopy growth and air circulation. High-density crops will have a greater blossom density and as such would require a greater amount of bee hives to ensure best possible pollination (AMS,2009). Traditional grafted macadamia trees take 24 months from seedling rootstock to grafting and field planting whereas minigrafted trees take 10-12 months from seed to field planting. The much newer micro -grafting technique can take only 8-12 months to field planting.

Manuring: Macadamia trees require balanced nutrition to maintain vigorous growth and high yields. An annual dose of 450:150:500g of N:P:K per tree per year is recommended. In addition to chemical fertilizers, farmers are encouraged to use **organic manure, compost, and green manures** to improve soil structure and microbial activity. A total of 4050kg of farmyard manure is advisable.

Irrigation: The amount of water to be supplied depends on rainfall, evapo transpiration, soil type and plant vigour. The soil should be kept moist, but not wet, to a depth of at least 1m.

Training and Pruning:

Training macadamia trees during their formative years is essential for shaping a strong framework that supports future yields. When young, macadamia trees are highly flexible, and their branching pattern can be influenced to develop a well-structured canopy. Early training reduces the chances of overcrowded branches, ensures better light penetration, and creates an orchard that is easier to manage during harvesting.



Young trees are usually trained through hand pruning. By simply pinching out unwanted buds with the thumb and forefinger, farmers can prevent undesirable branch development. This allows

the tree's energy to be directed toward the growth of strong, productive branches. Such simple interventions in the first two to three years have long-term benefits for tree health and nut production

Pruning for Productivity and Orchard Management

Pruning in macadamia orchards serves multiple purposes:

1. **Shape management** – Prevents the tree from becoming overly tall or bushy.
2. **Light and air penetration** – Adequate sunlight reduces fungal infections and promotes flowering.
3. **Yield enhancement** – Eliminates weak branches, allowing stronger ones to produce more nuts.
4. **Ease of harvesting** – Well-pruned trees are easier to access during nut collection.

Farmers are advised to avoid excessive pruning, as it may reduce flowering and subsequent nut yields.

Pollination Mechanism:

Macadamia trees are largely insect-pollinated, and most cultivars are at least partially self-incompatible. This means they cannot produce sufficient nuts if planted as a single variety. For a successful nut set, cross-pollination between different varieties is essential. Bees are the most effective pollinators for macadamia orchards. Farmers can significantly improve yields by introducing bee colonies during the flowering season. The buzzing activity of bees transfers pollen grains between flowers, enhancing fertilization and ensuring that a higher proportion of flowers develop into nuts. In Australia, the major pollinators in commercial macadamia plantations are from two genera of social bees: the introduced honey bee, *Apis mellifera*, and native bees of the *genus Trigona*. The studies done at *Chettalli* found that among the different pollinating insects, *Apis cerana indica* was found visiting flowers throughout the day and was the dominant one over other insects. Visit of other insects such as, *A. florea, A. dorsata, Trigona spp*. was either minimum or nil.

Macadamia trees usually flower once a year, producing long, elegant racemes covered with small white or pink flowers. Once pollination occurs, the nuts take about 6–8 months to mature. Grafted varieties may start bearing within 2–3 years, but commercial-scale production generally begins after 7–10 years. With proper care, these trees can continue producing nuts for **over a century**, making them a long-term investment crop.



Harvesting and Postharvest management

Trees do not begin to produce commercial quantities of seeds until it is 710 years old, but once established, may continue bearing for over 100 years. The tree is slow to come to bearing. On an average, 7-year-old trees start bearing. However, 20-year-old ones give full yield and continue to yield for about 4060 years. Nuts typically mature 6–7 months after flowering. In India, harvesting is expected during late autumn to early winter, depending on regional climatic conditions. The fruits are borne in clusters and on maturity; the husk begins to dry and split, exposing the inner brownish nut. Unlike some fruits that must be handpicked from trees, macadamia nuts naturally fall to the ground when mature. Even shaking the trees or branches makes the mature fruits to fall. This makes harvesting easier, although some cultivars retain nuts on the tree and require manual collection. In some countries, harvesting is mechanized or is done by using suspended nets. In Hawaii, a yield of 8090 kg nuts/tree after 18 years of planting has been recorded. After collection, nuts should be processed promptly to prevent spoilage. Immediate dehusking, drying, and storage under controlled conditions ensures longer shelf life and maintains kernel quality.



Pest and disease management Pests :

The major pests likely to cause problems in young trees are macadamia felted coccid, scale insects (mainly latania scale and long soft scale), macadamia twig girdler, macadamia leaf miner, red shouldered leaf beetle. From planting, inspect trees regularly for these pests. Low levels of scale insects, twig-girdler and leaf miner can be tolerated without spraying and will often be effectively controlled by beneficial insects. It is only if infestations become severe, that spraying is necessary. However, felted coccid and red shouldered leaf beetle are much more dangerous and if detected, spraying is generally required immediately. The rats are major problem in most of the orchards. The rats damage mature fruits and eat kernels. Regular monitoring, integrated pest management (IPM) techniques, and the introduction of biological controls such as beneficial insects can help reduce pest infestations.

Diseases :

The only major disease of young trees is trunk canker and Anthracnose. Where cankers are small, pare back the affected bark and wood with a sharp knife, and thoroughly soak trunks with a registered copper fungicide mixed with white, water-based paint. This helps to maintain contact with the fungicide and seals the wound. Where cankers are more extensive, and paring back affected bark and wood is impracticable, spray affected areas with metalaxyl and copper oxychloride. Both diseases can severely damage orchards if left unchecked. Planting resistant rootstocks like *Macadamia tetraphylla,* practicing good orchard sanitation, and applying recommended fungicides are essential preventive measures.

Successful cultivation of macadamia in India starts with the proper site selection and preparation, adopting grafted varieties and integrated orchard management.

Macadamia Nut: Selecting Suitable Varieties

Before embarking on macadamia nut cultivation, it's crucial to select the right varieties that are well-suited to the Indian climate. Some popular macadamia varieties include:

***Macadamia integrifolia*:** Known for its rounder nuts and a sweeter flavour profile. It's well-suited to subtropical regions.

***Macadamia tetraphylla*:** These nuts tend to be elongated and have a slightly tangy taste. They thrive in cooler, subtropical climates.

***Hybrids*:** Many hybrid varieties have been developed, combining the best traits of both *integrifolia and tetraphylla* species.

Comparative Advantage of Macadamia Over Other Nut Crops in India

Cashew and almond are well-established nut crops in India, but macadamia offers certain unique advantages.

- ✓ Macadamia has higher profitability Compared to Cashew and Almond by its higher price realization, longevity (100 years) and low labour requirement for harvesting.
- ✓ Macadamia is suitable for agroforestry system and can be grown in diverse agro-climatic regions of India.
- ✓ Macadamia is still considered a premium luxury nut, giving it an edge in gourmet food markets. It has its own market niche and premium demand.

Future Prospects of Macadamia Cultivation in India

Sustainability and Climate Resilience: Macadamia trees, with their long lifespan and relatively low maintenance once established, offer a sustainable cropping option. They can be integrated into agroforestry systems, providing ecological benefits like soil conservation, carbon sequestration, and biodiversity enhancement.

Integration with Other Crops: Intercropping macadamia with short-duration crops during the initial years can provide farmers with interim income while the trees mature. Suitable intercrops include legumes, vegetables, and medicinal plants.

Global Market Trends: The global demand for macadamia nuts continues to grow, particularly in the snack food, confectionery, and cosmetic sectors. With rising exports from Africa and Australia, India could enter the market as a niche player, especially if it develops organic and high-quality produce.

Potential as a Superfood in Indian Diets: As awareness about heart health, diabetes management, and weight control grows, macadamia could become a mainstream nut in Indian diets, much like almonds and walnuts. The potential for macadamia-based food products is immense, ranging from nut butters to energy bars and protein powders.

Conclusion

The cultivation of macadamia nuts in India holds immense potential as a high-value, long-term cash crop. With rising demand in domestic and global markets, coupled with India's favorable agro-climatic conditions, macadamia could soon join the ranks of cashew and almond as a mainstream nut crop.

However, challenges such as the long gestation period, lack of awareness, and high initial investment must be addressed through government support, research interventions, and farmer training. By adopting best practices in soil management, grafting, irrigation, pollination, and post-harvest handling, Indian farmers can establish thriving orchards that remain productive for generations. As India moves towards diversified, sustainable, and profitable agriculture, macadamia nut cultivation could become a game-changer for both farmers and the economy.

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PROCESSING OF PULSES

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INTRODUCTION

Pulses are an important group of crops in India, which is also responsible for yielding large financial gains by amounting to a large part of the exports. Pulses are the major sources of protein in the diet. Of all categories of people, pulses form an integral part of the Indian diet, providing much-needed protein to the carbohydrate-rich diet.

IMPORTANCE OF PULSES

- Cheapest source of protein′
- Has ability to fix nitrogen and also supports growth of adjacent crops′ by fixing nitrogen.
- Decreased carbon footprint and water footprint.′
- Can be used for animal feed.′
- Emerging substitute to ethanol in fuel.′

NUTRITIONAL ASPECT

- Pulses also have carbohydrate (50-55%) but these are digested at′ slow rate so has low Glycemic Index.
- Pulses are storehouse of dietary fibre. In about half serving of′ pulses, 7g of fibre is present. Consuming pulses (Deficient in tryptophan, methionine and cysteine)′ and cereals (Deficient in lysine) together help consumer to balance their nutrition profile and ingest high quality protein.
- Pulses are abundant source of micronutrients such as selenium,′ zinc, niacin, folate and riboflavin. Pulses are dense in vitamin A and E.′

- Germinated legumes are rich in vitamin C and have enhanced′ absorption of all minerals. Pulses are free from cholesterol, gluten and are not famously known′ as food allergen.
- Exhibits anti-oxidant activity and scavenges free radical.′

POST HARVEST LOSSES

Pulses are non-perishable crop but because of high protein content′ they are susceptible to attack by insects and pests if not stored properly

STAGE After Harvesting- Drying- Threshing- Storage- Milling- Transportation-Packaging

TYPE OF LOSS

- Pest or rodent attacks
- Insufficient drying leads to microbial attacks (mould growth)
- Inappropriate threshing leads to shattered grains and broken pulse grain attracts more insect infestation.
- Increased broken grains and powdered pulses

PROCESSING OF PULSE

Pulses are slow to cook, has low digestibility and possess many anti-nutritional′ factors which hinders the absorption of nutrients. To overcome these cons of pulses, processing is done to improve texture, taste, and flavor, bio-availability of nutrients, decrease anti-nutritional compounds, enhanced anti-oxidant activity and decreased microbial activity. Few processing techniques generally undertaken are splitting, soaking, germination, drying, roasting, fermentation and cooking. Processing affects the physical, chemical and nutritional makeup of pulses and a′ good understanding on the changes brought about through processing can help use processing techniques to their fullest potential.

1. ROASTING :

In roasting, heat from a hot surface is given to food and simultaneously moisture from food is let out into air and then moist air is exhausted out from roaster. After moisture removal, series of browning and caramelization reactions follows.

2. SOAKING : In soaking, simply the pulse grains are soaked in tap water in ratio 1:5 v/v for 12 hours at room temperature. After 12 hours, grains are washed properly and drained.

3. COOKING: cooked using thermal processing techniques to bring in changes in texture, aroma, taste, flavor and nutritional availability.

In this review, main focus would be on steaming, boiling and autoclaving or pressure cooking of pulses.

4. GERMINATION: The germination process is initiated when seed breaks out from its inactive state when it comes in contact of water. When out of dormant stage bioactive compound becomes alive and starts synthesizing more phytochemicals and phenolic which have health promoting benefits.

5. FERMENTATION: Fermented pulses has reduced level of ANFs, improved flavor, texture, taste, aroma, increased synthesis of amino acids and bioactive components thus enhancing digestibility of pulses.

EFFECT OF NON THERMAL PROCESSING OF PULSES

Non thermal processing of pulses using soaking, germination and fermentation are ought to increase digestibility, nutritional availability and decrease ANFs. But the effect of these processes depends on the type of pulses and extent of time devoted to each processing technique. Thermal processing of chickpea decreased saponins level by 59% and it has been′ studied that consumption of diet rich in saponin decreases cardiovascular diseases and obesity. So there are other phytochemicals which are lost during thermal processing so to nullify it food processors are shifting their focus to non -thermal processing. Enhanced soluble phenolic in germinated sprouts and anti-oxidant activity also increased′ in proportion with soluble phenolic . Total Phenolic Content of germinated chickpea increased to 86 and 156 % on second′ and third day of germination. Greater reduction in polyphenol and tannin content.′ Germinated green gram resulted in highest amount of flavonoid and isoflavone.′ . In lactic acid bacteria fermented chickpea total phenolic content increased but′ chymotrypsin and amylase inhibiting enzymes remained active.

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TOMATO GRADING USING ARTIFICIAL INTELLIGENCE – A REVIEW

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Introduction

Tomatoes are one of the most widely consumed and economically important horticultural crops worldwide. The quality and appearance of tomatoes play a crucial role in determining their market value. Traditional tomato grading methods rely on **manual inspection**, which is **time-consuming, subjective, and inconsistent**. To overcome these challenges, **Artificial Intelligence (AI)** has emerged as a promising solution for **automated tomato grading**, offering speed, accuracy, and objectivity.

AI-based tomato grading integrates **computer vision, machine learning, and deep learning techniques** to evaluate quality parameters such as **color, size, shape, texture, and defects**, ensuring consistency and reducing human errors.

2. Importance of Tomato Grading

Grading ensures:

- **Uniformity in quality and appearance** for consumer satisfaction.
- **Fair pricing** for farmers and suppliers.
- **Reduction in post-harvest losses** through early defect detection.
- **Compliance with export standards** and food safety norms.

With the growing demand for high-quality produce, automated grading systems are essential for both **small-scale farmers** and **industrial sorting facilities**.

3. AI Techniques Used in Tomato Grading

a. Computer Vision

Computer vision enables machines to **"see" and analyze tomato images** captured using cameras.

- **RGB imaging:** Used for color and size analysis.
- **Multispectral / Hyperspectral imaging:** Detects internal quality like ripeness, bruising, and contamination.
- **Image segmentation:** Separates the tomato from the background for accurate feature extraction.

b. Machine Learning Algorithms

AI models are trained on labeled tomato datasets to classify and grade samples. Common algorithms:

- **Support Vector Machine (SVM):** Classifies tomatoes based on extracted features such as color histograms or shape descriptors.
- **K-Nearest Neighbors (KNN):** Simple and effective for small datasets.
- **Random Forest:** Handles complex features and reduces overfitting.

These algorithms can achieve **high classification accuracy (above 90%)** with proper training data.

c. Deep Learning (CNN-Based Approaches)

Recent studies use **Convolutional Neural Networks (CNNs)** for **end-to-end grading**, where the system learns automatically from raw images without manual feature extraction.

- CNN models such as **VGG16, ResNet50, and MobileNet** have been successfully applied for grading tomatoes by ripeness level or defect detection.
- These models outperform traditional machine learning approaches due to their ability to learn complex visual patterns.

4. Grading Parameters

AI-based systems evaluate multiple features simultaneously:

Parameter	AI Application
Color / Ripeness	CNNs classify tomatoes into green, pink, light red, and red stages.
Size and Shape	Image analysis measures diameter, circularity, and irregularity for grade classification.

Parameter	AI Application
Surface Defects	Deep learning detects spots, cracks, and bruises.
Texture	Gray Level Co-occurrence Matrix (GLCM) and CNN texture features identify smoothness and firmness.

5. Workflow of AI-Based Tomato Grading System

1. **Image Acquisition:** High-resolution cameras capture tomato images under uniform lighting.
2. **Preprocessing:** Noise reduction, image enhancement, and segmentation.
3. **Feature Extraction:** Extraction of features like color, size, and texture.
4. **Classification:** ML/DL models grade tomatoes into predefined categories (e.g., Grade A, B, C).
5. **Decision and Sorting:** Automated system sorts tomatoes on conveyor belts using robotic arms or pneumatic mechanisms.

6. Research Highlights

- **Kumar et al. (2022):** Used SVM and color-based segmentation for tomato ripeness detection, achieving 94% accuracy.
- **Ponce et al. (2021):** Developed a CNN model for grading defects in tomatoes with 96.2% accuracy.
- **Intello Labs (2023):** Commercial AI system using smartphone cameras and cloud-based AI to grade tomatoes by quality and size in real-time.
- **TOMRA Food (2024):** Implemented AI-powered multispectral cameras for industrial tomato sorting and grading.

Conclusion

The integration of Artificial Intelligence in tomato grading has transformed the traditional methods of assessing fruit quality. By leveraging computer vision, machine learning, and deep learning, AI systems can accurately evaluate parameters such as color, size, ripeness, and surface defects with remarkable speed and precision. These intelligent systems not only minimize human errors and labor costs but also ensure uniform quality standards in both local and global markets.Although challenges like lighting variability, data requirements, and system costs

persist, continuous advancements in deep learning models, edge computing, and smart sensors are steadily addressing these issues. The future of tomato grading lies in fully automated, AI-driven systems integrated with IoT and robotics, capable of real-time grading, sorting, and traceability.In essence, AI-based tomato grading systems mark a significant step toward sustainable and efficient agricultural processing, enhancing productivity, profitability, and global competitiveness in the food industry.

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CRISPR-CAS9: A GENE EDITING TOOL

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Abstract

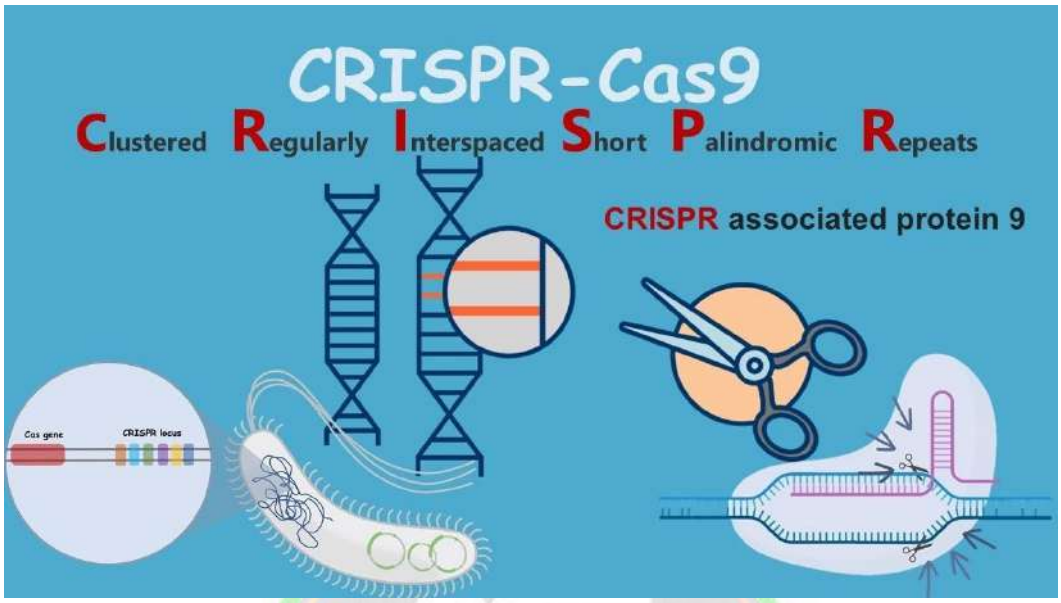
CRISPR–Cas9 is a groundbreaking gene-editing technology derived from the natural defense mechanisms of bacteria. It enables precise, targeted modifications of DNA in living organisms, making it faster, cheaper, and more accurate than previous methods. The system consists of a guide RNA (gRNA) and the Cas9 nuclease, which together can identify and cut specific DNA sequences, allowing scientists to insert, delete, or modify genes. CRISPR–Cas9 has wide-ranging applications in medicine, agriculture, and environmental science, such as correcting genetic disorders, improving crop traits, and controlling disease vectors. However, its rapid advancement raises ethical and safety concerns, particularly regarding germline editing and off-target effects. Continued research and responsible regulation are essential to fully harness the potential of CRISPR–Cas9 for societal benefit.

CRISPR-Cas9 – Gene Editing Tool Overview

CRISPR-Cas9 (Clustered Regularly Interspaced Short Palindromic Repeats–CRISPR-associated protein 9) is a revolutionary **genome editing technology** that allows scientists to **precisely modify DNA** in organisms. Originally discovered as part of the **bacterial immune system**, it has been adapted into a powerful tool for genetic engineering.

- Deoxyribonucleic acid (DNA), which contains the blueprint for constructing a living organism, has been the key to a major breakthrough in the 21 century.

DNA can replicate itself, hold memory and heal itself, as well.

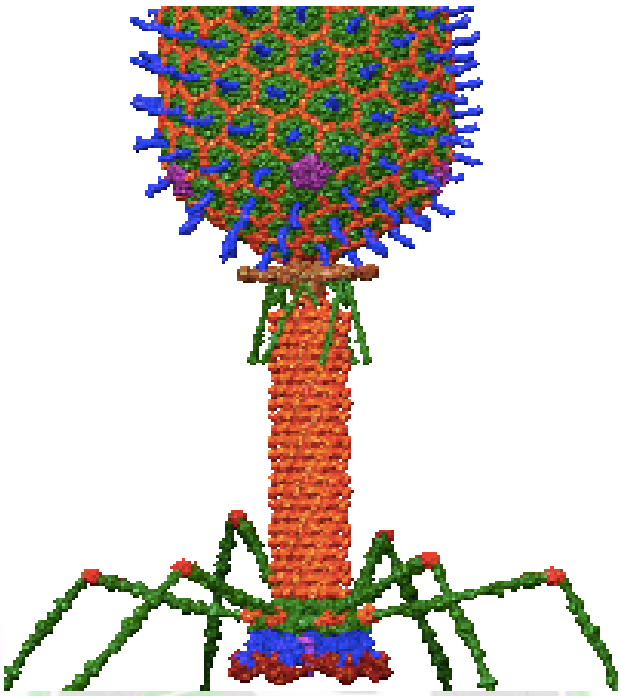


- It is inside that very same DNA that two women discovered a natural reaction that might hold the secret to Cancer treatment through embryo gene manipulation, hereditary disease irradiation and cure famine.
- It is those fundamental natural structure that lead to the discovery of reaction already happening in our day to day environment: CRISPR-Cas system

What Is CRISPR? – Simplest and Most Precise Way to Manipulate DNA in Human History

- The CRISPR-Cas system was discovered by 2 pioneer woman, **Emmanuelle Charpentier** and **Jennifer Doudna**, in the immune system of a bacteria.
- When attacked by a bacteriophage, the natural defense mechanism encrypted in the bacteria's DNA memory jumps into action, recording not only the infection, but its defense mechanism in case of future exposition. Thus naturally creating Clustered Regularly Interspaced Short Palindromic Repeats.
- This acquired immunity is then genetically passed on to every progeny through reproduction. Inside the DNA of a bacteria is where CRISPR-Cas system was then discovered .
- When the target DNA is found, Cas9 – one of the enzymes produced by the CRISPR system – binds to the DNA and cuts it, shutting the targeted gene off.

- Using modified versions of Cas9, researchers can activate gene expression instead of cutting the DNA. These techniques allow researchers to study the gene's function.

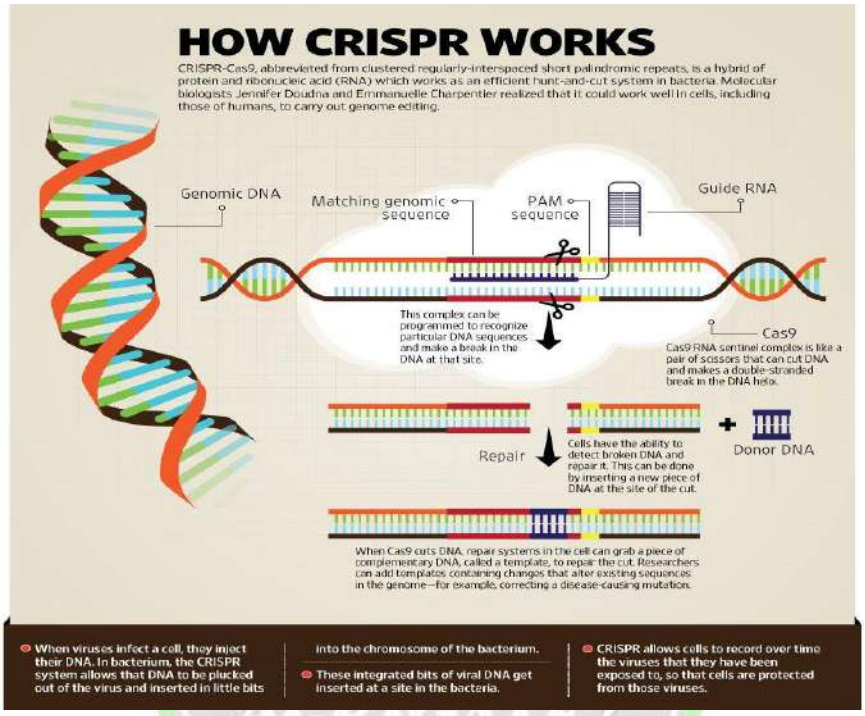


Bacteriophage, highly intelligent viruses small enough to infect a bacterium.

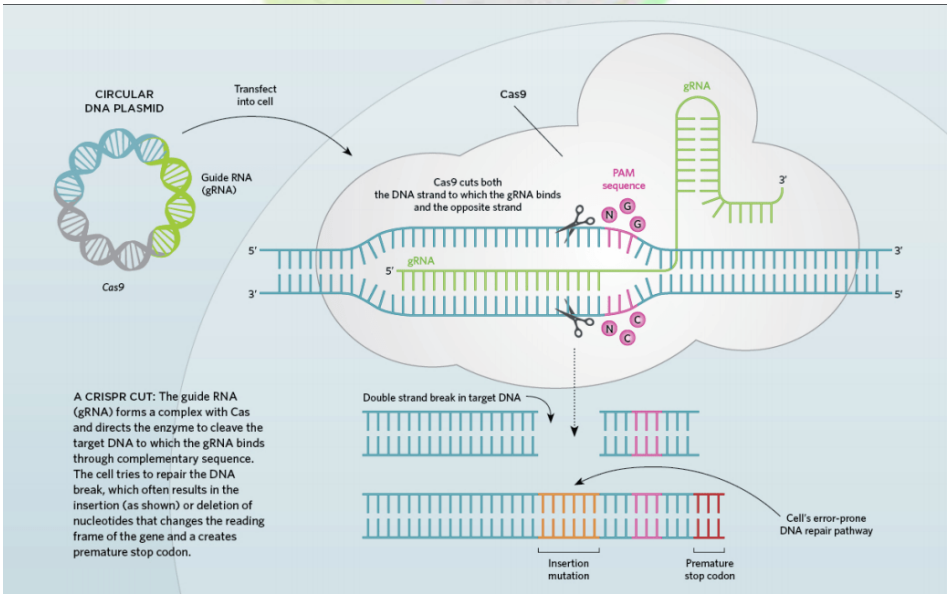
Wait a minute, DNA has a memory ?

- As some of you may know, all living organisms on this planet contain a dna, in fact, we are only a few genetical sequencing away from being a wild bird or a plant.
- DNA codes for absolutely everything that makes us, from the color of our eyes, to the shape of our hearts and the exact cause of our deaths. DNA is in itself a whole living structure.
- It also has something I call "the acquired intelligence". I gave it this name because DNA is able to hold a memory of absolutely everything.
- To keep the bacteria example, when this bacteria gets attacked by a bacteriophage, its DNA will record everything from its infection.
- All this information is stored in Clustered Regularly Interspaced Short Palindromic Repeats, which is where CRISPR-Cas system gets it's name.
- It is the information stored inside the clusters that set in motion a set of event that forever changed not only science, but human history.

- Those clusters contain not only every information that the bacteria encountered during an attack, but it contained the information about its parent since acquired immunity is passed from one parent to the next.
- At a molecular biology level, the CRISPR-Cas system contains.



1-Hyper Acccurate Enzyme to cut DNA (Cas) with sgRNA

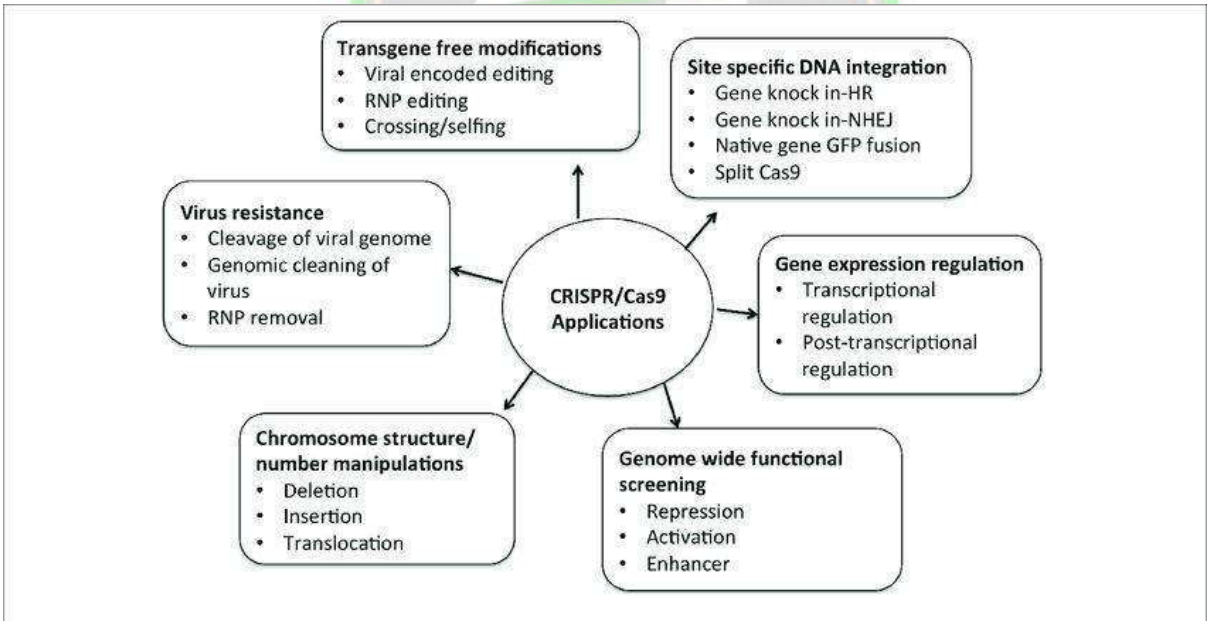


- 3-PAM Sequence

- 2-Protospacer to be inserted after Cas enzyme cut
- (preferencial matching)
- 4-Codon (start & stop Sequencing indicators)
- 5-Self healing properties after DNA strand break: Homology Directed Repairs, Non-homologous End Joining.
- 6-Adaptive Immune System

The applications of CRISPR-Cas system

- The field spectrum to which CRISPR-Cas system can be applied are forever evolving.
- At the moment the technology is widely used in bio-engineering, from the simple expression of phenotype to the most advanced cancer targeting in human genome there is in the 21st century.
- CRISPR can be used in the renewable energy and agriculture field as well.
- An example of its use would be the genetic engineering of a crop (ie: algae) destined to biofuel production. CRISPR can be used to modify both prokaryotic and eukaryotic cells.



The application of CRISPR to edit the genome:

- Genetic vs non genetic modification / embryonic cells
- Reprograming somatic cells
- Cancer treatment
- Hereditary disease

- Blood disease such as sick cell, hemophilia
- Infectious disease
- Famine (genetically engineered food for more nutriment, more abiotic/biotic resistance)
- Learn about natural microbiological process such as T cell cycle, infection pathways ie: malaria infection, Cancer receptor activation.
- HIPSC Increase compatibly due to hemocompatibility (the donor in CRISPR is the host therefore low rejection risk) Gene Drives.

The use of CRISPR-Cas9 for targeted genome editing tool

- Covering CRISPR gene drives, we learned about the ways CRISPR can tackle some humanitarian challenges such has the transmission of infectious disease. One way to tackle this challenge is by using gene drives to eradicate disease vectors. Of all the pathogens, viruses and parasites are the only ones who needs to invade a host in order to reproduce. This is why the eradication of viral disease through the eradication of their vectors is so important.
- Gene drive is highly efficient when tackling large scale situation such as malaria because its application is delivered through sexual reproduction. Meaning direct inoculation of one person at the time is not needed. Instead gene drive guarantees that a specific gene will be inherited.
- Gene drive is used to stabilize the frequency at which a desired gene is expressed. Example, with traditional gene editing, once released into the wild, when a mosquito mates it gives 50% of its own genetic code to the offspring. Meaning there's a 50% chance that the engineered trait will not be pass on.
- In the wild, due to the large variant of gene pool, the engineered gene will eventually become instinct due to low expression rate. With CRISPR-Cas9 gene drive we can "force" a trait to be expressed or repressed in all of the organism's progeny by making the engineered gene a dominant gene.
- CRISPR gene drive technology is used by coding for specific targeting of the genome sequence. Those targeted edit can alter the gene to express or repressed a desired trait and maintain its expression throughout all the generations. By keeping the malaria example, through gene drive, we would be able to release mosquitoes into the wild that contains the gene drive for sterile female mosquitoes. Through sexual reproduction, the gene

would spread at an exponential rate that is stably expressed through all the future generation as long as they keep reproducing.

- Firstly, gene drive is activated when SgRNA (crRNA+tracrRNA) in the gene expression cassette recognizes the targeted DNA region of interest and directs the Cas nuclease (found in the same gene expression cassette) at the site for editing. Once properly identified and targeted the Cas nuclease cuts at the desired site which activates the repair mechanism.
- These cassettes can code for application such as the deletion or insertion of desired genes. (ex: genes that promotes malaria resistance to the host, genes that codes for specific sex drive such as, female sterilization). Once the repair mechanism is activated, it uses the engineered template in the gene expression cassette to repair itself. By binding to the previously cut region, the expression cassette creates a new sequence that expresses the desired trait.
- Once inserted the engineered gene drive is able to copy itself, thus "driving" a specific trait across all of the modified organism progenies.

The impacts of genetic mutations:

- **Gene variation/ off target editing**
- **Accessibility and equity**
- **International laws & Bio-warfare**

- When talking about CRISPR we have to remember that this versatile tool covers an immense spectrum of applications such as the medical field, agricultural field and the renewable energy field.
- Those fields all have their own respective multidimensional set of issues. This is why I would like to say that first and foremost, a single regulation applicable to every type of CRISPR organisms is not ethical.
- To make this tool ethically defensible, we need to all start with the same understanding that regulatory framework needs to be flexible enough to be able to follow the pace of innovation in a very diverse set of applications.
- In addition, it is important to understand the difference between the technology and it's outcome. CRISPR-Cas 9 gene editing becomes unethical when the outcome is not tightly regulated and controlled.

- An example would be the release of genetically modified mosquitoes into the wild without the proper environmental studies and trials beforehand or the approval of local/international organizations such as FDA. In no way shape or form should this technology be rushed to a market.
- Any use of CRISPR for biowarfare is highly unethical as well. As mentioned in a Cambridge online article entitled "Anticipating Emerging-Biotechnology-Threats"
- Rules regarding possible biowarfare applications should be extremely clear and leave no place to interpretation. For public safety, those rules should be internationally applied and heavily sanctioned.
- It is my strong belief that one of the only ways to make CRISPR safe and therefore ethical, is through ongoing monitoring of unintended long-term effects.
- If we keep the same mosquito example, the use of gene drives to sterilize the females needs to be monitored on the long term because the sustained expression of Cas protein+sgRNA molecules can give rise to off-target mutations in future generations.
- This is why the development of fail-safe gene drives that corrects the genetic alterations should be mandatory. A case by case situation should be analyzed and given its own ongoing rules to not only protect the environment, but the whole human race and the integrity of it's diverse genome.
- In conclusion, I believe CRISPR to be ethical only when equitable distribution is possible (accessible to all) with diverse stakeholders mandated with an adaptative system where an independent committee regulates the outcomes and not only the technology.
- Natural gene variations mixed with CRISPR-Cas9 needs to be taken into consideration for all organisms and their progenies by being highly studied and monitored with rules once released into the wild.
- Recent Progress in CRISPR/Cas9 Technology
- **CRISPR/Cas9 in plant biotechnology: applications and challenges**

The application of plant biotechnology to enhance beneficial traits in crops is now indispensable because of food insecurity due to increasing global population and climate change. The recent biotechnological development of the Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR)/CRISPR-associated system 9 (Cas9) allows for a more simple and precise method of gene editing, which is now preferred compared to Zinc Finger Nucleases (ZFNs) and

Transcription Activator-like Effector Nucleases (TALENs). In this review, recent progress in utilizing CRISPR/Cas9-mediated gene editing in plants to enhance certain traits in beneficial crops, including rice, soybean, and oilseed rape, is discussed. In addition, novel methods of applying the CRISPR/Cas9 system in live cell imaging are also extensively reviewed. Despite all the applications, the existing delivery methods of CRISPR/Cas9 fail to provide consistent results and are inefficient for *in planta* transformation. Hence, research should be focused on improving current delivery methods or developing novel ones to facilitate CRISPR/Cas9-based gene editing studies. Strict regulations on the sale and commercial growth of gene-edited crops have restricted more efforts in applying CRISPR/Cas9 technology in plant species. Therefore, a shift in public viewpoint toward gene editing would help to propel scientific progress rapidly.

Applications of CRISPR/Cas9 genome editing in plant species

Table 1.:Examples of successful genome editing of plant species

Plant	**Gene(s) targeted**	**Traits**	**Method**	**References**
Apple	MdDIPM4	disease resistance	gene inactivation	Pompili et al. 2020
Maize	*ZmPHYC1* *ZmPHYC2*	flowering time/plant height	gene knockout & overexpression	Li et al. 2020
Muskmelon	*CmPDS*	albinism (CRISPR trial)	gene knockout	Hooghvorst et al. 2019
Oil palm	*EgIFR* *EgMT*	disease resistance	base editing	Budiani et al. 2018
Oilseed rape	*BnALS1*	herbicide resistance	base editing	Wu et al. 2020
	BnaSDG8.A *BnaSDG8.B*	plant flowering	gene knockout/down	Jiang et al. 2018
Rice	*Os8N3*	disease resistance	gene knockou	Kim et al. 2019

Plant	Gene(s) targeted	Traits	Method	References
	OsProDH *OsGS3* *OsNAC45*	thermotolerance grain length salt tolerance	gene knockout & overexpression site directed mutagenesis gene knockout & overexpression	Guo et al. 2020 Usman et al. 2021 X. Zhang et al. 2020
Soybean	*GmPRR37* *GmFT2a/5a*	flowering time & regional adaptability	site directed mutagenesis	Cai et al., 2018; Cai et al., 2020; Wang et al., 2020
	GmF3H1 *GmF3H2* *GmF3FNSII-1*	disease resistance	multiplex gene knockout	P. Zhang et al., 2020
Tobacco	*NtHL1*	hybrid lethality	frameshift mutation	Ma et al., 2020
Watermelon	*ClPDS*	albinism (CRISPR trial)	gene knockout	Tian et al., 2017

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THE ECOLOGICAL ROLE OF SEA COWS: NATURE'S GENTLE GARDENERS

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Introduction

Marine mammals play diverse and important ecological roles, ranging from consumers to food for other species and sources of nutrient enrichment, which can affect the dynamics of aquatic ecosystems from rivers and lakes to the open ocean The Sirenia, commonly referred to as sea cows or sirenians, are an order of fully aquatic, herbivorous mammals that inhabit swamps, rivers, estuaries, marine wetlands, and coastal marine waters. The extant Sirenia comprise two distinct families: Dugongidae and Trichechidae with a total of four species.



Accordingly, aside from more geographically extensive population monitoring, there is a need for synthesis of what we do know about the roles played by sirenians—and the importance of these roles in maintaining ecosystem structure, function, and resilience—that will help to

predict the ecosystem effects that are likely to accompany future changes to their numbers and distribution and guide research aimed at filling key knowledge gaps. Here, we present the results of a review and synthesis of the roles and importance of sirenians and, based on our findings, an outlook for both the ecological consequences of changes to their abundance and distribution, and future research needs

A sea cow is a common name for large, gentle marine mammals belonging to the order Sirenia. There are two main groups:

1. Manatees (Trichechidae family) - Found in shallow coastal waters, rivers, and estuaries in the Atlantic Ocean, Gulf of Mexico, Caribbean, and parts of Africa.
2. Dugongs (Dugongidae family) - Found mainly in warm coastal waters of the Indian and Pacific Oceans.

Key Features

Herbivorous, feeding primarily on seagrasses and aquatic vegetation.

Large, slow-moving, and gentle in behavior.

Can weigh between 400-1,500 kg and grow up to 3-4 meters long.

Known as "sea cows" because of their grazing habits, similar to cows on land.

An extinct relative, Steller's sea cow (Hydrodamalis gigas), once lived in the North Pacific. It was enormous (up to 9 meters long) but was hunted to extinction within 27 years of its discovery in the 18th century.

Habitats of Sea Cows (Manatees & Dugongs)

Sea cows live in warm, shallow coastal waters where seagrass beds and aquatic vegetation are abundant.

Manatees

West Indian Manatee - Found along the Caribbean Sea, Gulf of Mexico, Florida, Central & South America.

Amazonian Manatee - Restricted to the Amazon River Basin (freshwater).

West African Manatee - Along the west coast of Africa in rivers, estuaries, and coastal lagoons.

Preferred Habitat - Rivers, estuaries, lagoons, and warm shallow seas with seagrass and freshwater inflows.

Dugongs

Found in Indian Ocean & Pacific Ocean regions: India, Sri Lanka, Australia, East Africa, Red Sea, Southeast Asia.

Preferred Habitat - Shallow coastal waters, bays, and lagoons with extensive seagrass meadows.

In India, dugongs are mainly found in:

Gulf of Mannar (Tamil Nadu)

Palk Bay (Tamil Nadu)

Andaman & Nicobar Islands

Gulf of Kutch (Gujarat, rare)

Common Habitat Characteristics

Shallow waters (less than 10 m deep).

Warm tropical/subtropical regions.

Rich in seagrass and aquatic vegetation.

Protected estuaries, lagoons, bays, and sometimes freshwater rivers.

Environmental Benefits of Sea Cows

1. **Seagrass Bed Maintenance**

By grazing on seagrass, they prevent overgrowth and keep meadows healthy.

Their constant feeding encourages new growth, making seagrass beds more productive.

2. **Nutrient Recycling**

Sea cows excrete nutrients like nitrogen and phosphorus back into the water, fertilizing seagrass and algae.

This improves the productivity of coastal ecosystems.

3. **Biodiversity Support**

Healthy seagrass beds provide shelter and breeding grounds for fish, crabs, shrimp, turtles, and sea horses.

By maintaining these habitats, sea cows indirectly support fisheries and marine life diversity.

4. **Carbon Sequestration**

Seagrass beds act as “blue carbon sinks,” trapping large amounts of carbon dioxide.

By keeping seagrass beds healthy, sea cows help reduce climate change impacts.

5. **Ecosystem Balance**

Without sea cows, seagrass beds could grow too dense, die off, and collapse.

Their grazing maintains balance between plants and animals in coastal ecosystems.

In short: Sea cows are essential for the health of seagrass ecosystems, which in turn support marine biodiversity, food chains, and climate regulation.

Ecological Importance

Maintain healthy seagrass ecosystems by grazing.

Support biodiversity (fish, turtles, invertebrates live in seagrass beds).

Aid in carbon storage through seagrass preservation.

Nutrient recycling for marine ecosystems.

Threats & Conservation

Threats: Habitat loss, boat collisions, fishing nets, hunting, pollution, climate change.

Status:

Dugong = Vulnerable (IUCN Red List).

Manatees = Vulnerable to Endangered depending on species.

In India: Dugong is protected under Schedule I of Wildlife (Protection) Act, 1972 (since 1992).

Sea cows (manatees and dugongs) have become threatened species mainly because of human activities and environmental changes. Here are the major reasons:

1. **Habitat Loss and Degradation**

Seagrass beds (their main food) are being destroyed by coastal development, dredging, and pollution.

Mangroves and estuaries are also being cleared, reducing safe breeding and feeding areas.

2. **Boat Collisions**

Sea cows are slow swimmers and often surface for air.

In busy waterways, they frequently get hit by boat propellers, causing severe injuries or death.

3. **Entanglement in Fishing Gear**

Nets, lines, and traps in coastal areas can trap sea cows, leading to drowning or injuries.

4. **Hunting and Poaching**

Historically, sea cows were hunted for meat, oil, hides, and bones.

Although illegal in most places now, occasional poaching still occurs.

5. **Pollution and Climate Change**

Oil spills, plastics, and chemical runoff reduce water quality.

Climate change leads to seagrass die-offs (due to rising sea temperature and algal blooms).

6. Slow Reproduction

Female sea cows give birth only once every 2-5 years.

This slow reproduction makes it hard for populations to recover once numbers decline.

Sea cows are threatened because they are gentle, slow-moving herbivores living in shallow waters-areas most affected by humans. Boat strikes, habitat loss, pollution, and their naturally low reproductive rate all combine to push them toward extinction.

Conclusion

Sea cows (manatees and dugongs) are gentle marine herbivores that play a crucial ecological role in maintaining healthy seagrass ecosystems, recycling nutrients, supporting marine biodiversity, and even contributing to climate regulation through carbon storage. However, they are now threatened species due to habitat destruction, boat collisions, fishing gear entanglement, pollution, and their slow reproduction rate. Protecting sea cows is not just about saving a single species-it is about preserving the balance of coastal ecosystems and ensuring the health of our oceans for future generations.

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ROLE OF GENE BANK IN CROP IMPROVEMENT

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Abstract

Gene banks play a vital role in the conservation and utilization of plant genetic resources (PGRs) essential for sustainable crop improvement. They serve as repositories for genetic materials such as seeds, tissues, pollen, and DNA, which preserve genetic diversity and provide valuable traits for breeding programs. By maintaining access to genes conferring resistance to pests, diseases, and environmental stresses, gene banks ensure the long-term resilience and productivity of crops. This paper discusses the objectives, types, functions, and significance of gene banks in crop improvement, along with major examples, challenges, and future prospects.

Introduction

- A gene bank is a repository where genetic material of plants (and sometimes animals or microorganisms) is conserved for long-term use.
- In the context of agriculture, a gene bank preserves plant genetic resources (PGRs) — seeds, tissues, pollen, or DNA — to maintain genetic diversity and ensure availability of genes for future breeding and crop improvement programs.
- Loss of biodiversity due to modernization, habitat destruction, and climate change makes gene banks essential for safeguarding the genetic foundation of agriculture.

Objectives

- To collect, conserve, and document plant genetic resources (PGRs).
- To preserve genetic diversity of cultivated and wild species.

- To supply germplasm to breeders and researchers for crop improvement.
- To regenerate and multiply accessions for long-term preservation.
- To act as a biological insurance against genetic erosion.

Types

1)Seed banks

- Store viable seeds under controlled conditions (low temperature and humidity).
- **Example**: NBPGR (New Delhi), Svalbard Global Seed Vault (Norway).
- Used for orthodox seeds (those that tolerate drying and freezing).
- Seeds are periodically tested for germination and regenerated as needed.

2)Field Gene Banks

- Living plants are maintained in the field — useful for crops with recalcitrant seeds (which cannot be dried or frozen), such as coconut, cocoa, banana, mango, etc.
- **Example**: National Field Gene Bank for Horticultural Crops at ICAR-NBPGR Regional Station, Thrissur (India).

3)In-vitro Gene Banks

- Plant tissues or organs are maintained under sterile culture conditions (e.g., micropropagation).
- Suitable for vegetatively propagated crops like potato, sugarcane, and banana.
- Ensures rapid multiplication and disease-free material.

4)Cryo-preservation (Cryo-banks)

- Storage of plant materials (seeds, embryos, pollen, or tissue) at ultra-low temperatures (-196°C) in liquid nitrogen.
- Allows very long-term storage without genetic changes.
- **Example**: Cryo-bank at NBPGR, New Delhi.

5)DNA Banks

- Store extracted DNA samples for molecular studies and biotechnology research.
- Used in genomic analysis, marker-assisted selection.

Functions of Gene Bank

1)Collection and Documentation

•Systematic collection of germplasm from farmers' fields, wild habitats, and landraces.

•Proper documentation of origin, traits, and genetic background.

2)Conservation

•Preservation under optimal conditions for short-term or long-term use.

3)Characterization and Evaluation

•Germplasm is evaluated for morphological, biochemical, and molecular traits.

•Useful traits like disease resistance, drought tolerance, and nutritional quality are identified.

4)Regeneration and Multiplication

•Old or deteriorated samples are regenerated under controlled conditions.

•Ensures continuous viability of stored materials

5)Distribution and Utilization

•Gene banks supply germplasm accessions to breeders and researchers globally for developing new improved varieties editing.

Role of Gene Bank in Crop Improvement

1)Source of genetic variability

- Genetic diversity is the raw material for plant breeding.
- Gene banks provide access to diverse germplasm — wild relatives, landraces, and mutants — which possess unique genes for desirable traits.

2)Breeding for Resistance

- Many wild species contain genes for resistance to diseases and environmental stresses.
- **Example**: Wild rice species (Oryza nivara) used for grassy stunt virus resistance.
- **Example**: Wild wheat (Triticum dicoccoides) for rust resistance.

3)Breeding for Quality and Yield

- Genes controlling grain quality, nutrition, and productivity are identified and transferred to cultivated varieties.
- **Example**: High protein content genes in wheat and maize from landraces.

4)Climate Resilience

- Gene banks contain materials adapted to extreme climates (heat, cold, drought, salinity).
- These are used to develop climate-smart crops to ensure future food security.

5)Restoration of Lost Varieties

- If a local landrace becomes extinct, it can be reintroduced using gene bank materials.

- **Example**: Traditional rice varieties revived in India using NBPGR collections.

6)Support for Biotechnology and Genomics

- Marker-assisted selection (MAS)
- Genomic selection
- Genetic transformation
- Gene editing (CRISPR/Cas9)
- This accelerates the precision breeding process

7)Safeguarding Biodiversity

- Prevents genetic erosion due to modernization, monocropping, or natural disasters.
- Acts as a backup system for agricultural biodiversity.

Major Gene Banks(Examples)

- National Bureau of Plant Genetic Resources (NBPGR) New Delhi,India's main plant gene bank,holds >4.5 lakh accessions.
- IRRI (International Rice Research Institute) Philippines Global rice gene bank.
- CIMMYT Mexico Wheat and maize improvement.
- ICARDA Lebanon/Morocco Dryland crops.
- Svalbard Global Seed Vault Norway,Global backup of seed diversity.
- FAO Global System on PGRFA,Rome, Italy ,Coordination of international genetic resource conservation.

Challenges in Gene Bank Management

•Loss of viability during storage.

•Limited regeneration capacity of some species.

•High maintenance cost and need for continuous funding.

•Intellectual property and access restrictions (legal and ethical issues).

•Integration of traditional knowledge and modern technology.

Conclusion

Gene banks are the backbone of sustainable crop improvement. They preserve the genetic heritage of the world's crops, ensuring that valuable traits remain available to develop new varieties that are productive, resilient, and adapted to changing climates. Without gene banks, future breeding efforts would be severely limited, threatening global food security.

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MAIZE FALL ARMYWORM, *SPODOPTERA FRUGIPERDA* (J.E.SMITH) THREATENING TO MAIZE FARMERS

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Introduction

The Fall armyworm *(Spodoptera frugiperda)* Family Noctuidae, posess a significant threat to maize farmers in Tamil Nadu by causing severe yield reductions and increasing cultivation costs. The term "armyworm" can refer to several species, often describing the large-scale invasive behaviour of the species in larval stage. It is regarded as a pest which can damage and destroy a wide variety of crops, leading to large economic damage. Its scientific name derives from '*frugiperda',* which is Latin word mean a '*lost fruit'*, named because of the species' ability to destroy crops. The larva are voracious feeders and attack all parts of the maize crop (Stem, leaves, cobs, tassels) at all stages of the crop development (Shylesha *et al.,* 2018). The adult moths are strong fliers and can travel up to 100 km per night, aiding their rapid spread.

HISTORY

The Fall armyworm is originally from the tropical and subtropical regions of the Americas. It was recorded as a polyphagous invasive pest in Africa during 2016. In the Indian subcontinent, the pest was first reported in UAHS, Bengaluru, Karnataka during May 2018. In Tamil Nadu, Fall armyworm was first noticed in Karur district in August, 2018 and was simultaneously recorded in Coimbatore. FAW gradually spread to various states (Rakshit *et al.*, 2019) including Karnataka, Telangana, Andhra Pradesh, Maharastra, Gujarat and Tamil Nadu. In January 2019, a heavy infestation of fall armyworm was recorded in corn plantations in India (Bidisha *et al.*, 2024).

BIOLOGY AND IDENTIFICATION

Eggs: Laid in masses (120-150 eggs/ egg mass), white coloured, dome shaped (measures around 0.4 mm) covered with scales.

Larvae: Vary in colour from light green to brown or black as they mature. An inverted "Y" shape marking is found on the head with four black spots (arranged in square shape) on 8th and 9th abdominal segment.

Moths: Adults are nocturnal having a wingspan of 3 to 4 cm. Males have white triangular spot on their forewings and white hindwings, while females have greyish brown forewing with white hind wings.

LIFE CYCLE

- The fall armyworm's life cycle is completed within 30 days during summer, and 60 days during the spring and autumn seasons; during the winter, these caterpillars' life cycle lasts about 80 to 90 days.
- The number of generations a moth will have in a year varies based on climate, but in her life span a female will typically lay about 1,500 eggs. Because larvae cannot enter into diapause they cannot survive cold temperatures. In warm weather, the eggs will hatch into larvae within a few days.
- The larvae go through six different instars, each varying slightly in physical appearance and pattern. The larva process lasts from 14 to 30 days, again depending on temperatures. The larvae then pupate underground for 7 to 37 days in a cocoon they form of soil and silk.
- Once emerged, the adults live for about 10 days, and sometimes up to 21 days, with the female laying most of her eggs early in life.

SURVIVAL IN OTHER CROPS

- Over 350 species of plants are attacked by fall armyworm including serious infestation in commercial crops like maize, cotton, rice.
- It is being considered as a threat to an array of field crops because of continuous presence of maize and other hosts. Due to continuous availability of host throughout the period, the FAW poses a serious threat to maize ecosystems.
- Host utilization by fall armyworm will provide an indirect measure of the host's relative susceptibility for growth and infestation.

- Studies on the FAW survival on different hosts under laboratory conditions revealed that the pest showed a much high propensity only on three hosts viz., maize, sorghum and pearl millet though it is able to complete the life cycle.

SYMPTOMS

- Young caterpillars (1-3 instars) feed inside the whorls of young plants by scrapping the leaves, resulting in formation of white semi-transparent patches on the leaves.
- The grownup larvae (4-6 instars) causes maximum damage to the crop that is characterized by torn appearance (or) ragged holes on the leaves.
- Large amount of frass (excreta) is seen in the whorls which when dries, resemble sawdust.
- Deep feeding on the whorls may destroy developing tassels.
- On the older plants, caterpillar bores into the cobs and feeds on developing kernels.

Symptoms of Fall armyworm in maize crop



Stage 1 White semi-transparent patches on leaves



Stage 2 Appearance of window like damage symptoms on leaves



Stage 3 Large amount of frass (excreta) seen in the whorls



Stage 4 Damaging the tassel



Stage 5 Damaging the cobb

INTEGRATED PEST MANAGEMENT FOR FAW

Cultural Measures

- Deep ploughing will expose FAW pupae to predators.
- Timely and uniform sowing

- Avoid staggered sowings.
- Intercropping of maize with suitable pulse crops (e.g. Maize + pigeon pea/black gram /green gram).
- Erection of bird perches @ 10/acre during early stage of the crop (up to 30 days).
- Sowing of 3-4 rows of trap crops (e.g. Napier) around maize field and spray with 5% NSKE or Azadirachtin 1500 ppm as soon as the trap crop shows symptom of FAW damage.
- Cultivation of maize hybrids with tight husk cover will reduce ear damage by FAW.

Mechanical control

- Hand picking and destruction of egg masses and larvae in mass by crushing or immersing in kerosene.
- Application of dry sand in to the whorl of affected maize plants soon after observation of FAW incidence in the field.
- Application of Sand + lime in 9:1 ratio in whorls in first thirty days of sowing.
- Mass trapping of male moths using FAW specific pheromone traps @ 5/acre.

Biological Control

- Increase the plant diversity by intercropping with pulses, oil seeds and ornamental flowering plants which help in build-up of natural enemies.
- Augmentative release of egg parasitoid *Trichogramma pretiosum* or *Telenomus remus* @ 50,000 per acre at weekly intervals or based on trap catch of 3 moths/trap.
- If infestation level is at 5% damage in seedling to early whorl stage and 10% ear damage, then use following entomopathogenic fungi and bacteria

Metarhizium anisopliae *Metarhizium rileyi* *Beauveria bassiana* *Verticilium lecani*	1×10^8 cfu/g @ 5g/litre whorl application.

Chemical Control

- Seed treatment: Cyantraniliprole 19.8% + Thiamethoxam 19.8% FS @ 6 ml/kg of seed will be effective for 15-20 days.

- First Window (seedling to early whorl stage): To control FAW larvae at 5% damage to reduce hatchability of freshly laid eggs, spray 5% NSKE / Azadirachtin 1500ppm @ 5ml/l of water.
- Second window (mid whorl to late whorl stage): To manage 2nd and 3 rd instars larvae having more than 10% foliar damage the following chemicals may be used upto early tasselling stage: Spinetoram 11.7% SC or Chlorantraniliprole 18.5% SC or Thiamethoxam 12.6% + Lambda cyhalothrin 9.5% ZC.
- Poison baiting: Poison baiting is recommended for late instar larvae of second window. Keep the mixture of 10 kg rice bran + 2 kg jaggery with 2-3 litres of water for 24 hours to ferment. Add 100g Thiodicarb just half an hour before application in the field. The bait should be applied into the whorl of the plants.
- Third Window (8 weeks after emergence to tasseling and post tasseling): Insecticide management is not cost effective at this stage.

All the sprays should be directed towards whorl and either in the early hours of the day or in the evening time.

Conclusion

The fall armyworm spread all over India. It caused Both Yield and Economic losses. Due to high reproductive rate feeds on many different crops, strong flyer, disperses long distances, continuous generation throughout the year. To use IPM modules against fall army worm reduce the infestation throughout the year.

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IMPROVED WHEAT VARIETIES FOR FARMERS OF MAHARASHTRA: USEFUL FOR UPCOMING *RABI* SEASON

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Abstract

Wheat is one of the major *Rabi* crops in Maharashtra, cultivated under diverse sowing windows and varying climatic conditions. To meet the needs of farmers across these production environments, improved wheat varieties have been developed for specific sowing conditions and agro-climatic zones of the state. The Indian Council of Agricultural Research–Indian Institute of Wheat and Barley Research (ICAR-IIWBR), in collaboration with State Agricultural Universities and All India Coordinated Wheat and Barley Improvement (AICRP) Centres, has played a pivotal role in this process. These improved varieties not only enhance adaptability and resilience but also ensure higher productivity, making them particularly useful for adoption in the upcoming *Rabi* season by farmers of Maharashtra.

Introduction

Wheat is one of the most important staple food crops of India, contributing significantly to national food security and rural livelihoods. The crop is cultivated across diverse agro-climatic regions of the country, and to cater to this diversity, India has been divided into five major wheat-growing zones: Northern Hills Zone (NHZ), North Western Plain Zone (NWPZ), North Eastern Plain Zone (NEPZ), Central Zone (CZ) and Peninsular Zone (PZ). Each zone has distinct climatic conditions, soil types, and growing environments, which necessitate the development and adoption of suitable wheat varieties for sustainable production.

Maharashtra falls under the Peninsular Zone, where wheat is mainly cultivated during the Rabi season under both irrigated and restricted irrigation conditions. The state's wheat cultivation is unique because of the presence of three important species *viz.*, bread wheat (*Triticum aestivum*), durum wheat (*Triticum durum*), and *khapli* wheat (*Triticum dicoccum*). Among these, bread wheat is the most widely grown due to its higher adaptability and yield potential, while durum and *khapli* wheat are valued for their nutritional quality and specialty uses.

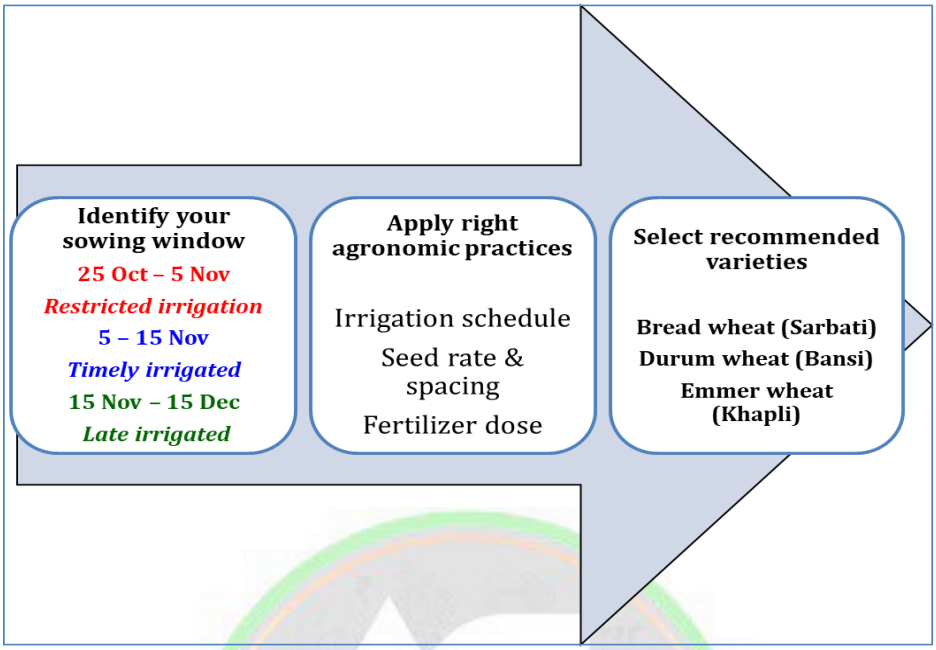
Over the years, coordinated efforts of the Indian Council of Agricultural Research – Indian Institute of Wheat and Barley Research (ICAR-IIWBR), State Agricultural Universities, and the All India Coordinated Research Project on Wheat & Barley (AICRP) centers have led to the release of high-yielding, disease-resistant, and climate-resilient wheat varieties suitable for the Peninsular Zone. These varieties not only ensure higher productivity but also provide stability across varied growing conditions. For farmers of Maharashtra, adopting such improved wheat varieties is particularly important for maximizing returns from the upcoming Rabi season while reducing production risks under changing climatic scenarios.

Proper selection of Varieties

Depending on the sowing environment and water availability, wheat cultivation in Maharashtra is classified into three categories: (a) restricted irrigation timely sown, (b) timely sown irrigated and (c) late sown irrigated conditions. Each category demands varieties that are tailored to specific challenges such as terminal heat stress, limited water availability, and disease pressures like rusts. In this context, the role of improved varieties becomes crucial. The selection of recommended varieties as per requirement is key to get higher grain yield



Info graphic-Style Flow



Recommended Wheat varieties are given in table No1.

Table 1 Recommended wheat varieties for Maharashtra as per sowing conditions

Sowing Condition	Time of Sowing	Irrigation	Seed Rate	Spacing	Fertilizer Dose	Recommended Varieties
Restricted Irrigation Timely Sown	25 Oct – 5 Nov	1–2 irrigations	100 kg/ha	20 cm	120:60:40 (N:P:K)	**Bread wheat:** Netravati, Phule Satwik, Phule Anupam, Phule Anurag, Pusa Ujala, DBW 93, Pusa Bahar, PBW 596 **Durum wheat:** GW 1346, HI 8802, HI 8805, MACS 4058, NIDW 1149
Timely Sown Irrigated	5 – 15 Nov	4–5 irrigations	100 kg/ha	20 cm	120:60:40 (N:P:K)	**Bread wheat:** Phule Samadhan, Trimbak, Tapovan, UAS 304, MACS 6222, MACS 6478

Sowing Condition	Time of Sowing	Irrigation	Seed Rate	Spacing	Fertilizer Dose	Recommended Varieties
						Durum wheat: Godavari, Poshan, MACS 3949, UAS 415, UAS 428, DDW 48 **Emmer wheat:** DDK 1025, DDK 1029, MACS 2971
Late Sown Irrigated	15 Nov – 15 Dec	4–5 irrigations	125–150 kg/ha	18 cm	80:40:40 (N:P:K)	**Bread wheat:** Phule Samadhan, NIAW 34, Phule Shashwat, AKAW 4627, PDKV Sardar, MACS 6222, Pusa Wheat (HD 2932), Pusa Amulya, Pusa Wani, RAJ 4083

Conclusion

The development of improved wheat varieties tailored for Maharashtra plays a crucial role in enhancing productivity and resilience. These varieties are specifically bred for restricted irrigation, timely sown, and late sown conditions, ensuring adaptability across diverse environments. ICAR-IIWBR, State Agricultural Universities, and AICRP centers have significantly contributed to varietal development for the Peninsular Zone. The recommended varieties offer resistance to major diseases, tolerance to heat stress, and stability in yield performance. Their adoption can help farmers mitigate risks posed by climate variability and resource limitations. By selecting varieties as per sowing condition and irrigation availability, farmers can maximize returns.

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SUNFLOWER – WHERE PROSPERITY BLOOMS

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Introduction

"The sunflower is not just a flower that turns towards the sun, it can also turn the fortunes of farmers and brighten economy of a nation."

When we think of the sunflower, the golden fields that brighten our mornings often fade behind the simple bottle of oil in our kitchen. But this bright and versatile crop has so much more to offer. Sunflowers play an important role not just in agriculture, but also in biofuel production, natural dye industries and even tourism. In India, nearly 51% of land is under rainfed agriculture, which contributes about 40% of the country's total production. Sunflower, being naturally drought-tolerant, grows well under these conditions. With its wide range of uses, it can provide farmers with valuable products while also helping strengthen the country's economy.

An essential source of edible oil :

Oil in India is far more than just a cooking ingredient – it is woven into the very fabric of daily life and culture. From traditional oil baths to lighting lamps during pooja, it holds a sacred place. In Indian cuisine, it is indispensable – from crisp dosas in the South to fluffy chole bhature in the North. Beyond the plate, oil is treasured for its beauty-enhancing properties and, in Ayurveda, revered as a healer for ailments from skin care to bone restoration. India's diversity extends far beyond its culture, languages, and cuisine–it is equally reflected in its oilseed consumption. Different regions have distinct preferences for edible oils, often influenced by local production and traditions. In the South, coconut oil dominates kitchens; in the North, mustard oil brings its pungent flavour to countless dishes; while in the West, groundnut oil is the go-to choice for everyday cooking. India is the world's fourth-largest producer of oilseeds,

contributing about 5–6% to the total global production in 2024. However, due to rising demand, nearly 57% of the country's edible oil requirement is met through imports, with palm oil being the major import, followed by soybean and sunflower oils. The Government of India has launched several initiatives to boost oilseed production, the latest being the National Mission on Edible Oils–Oilseeds (NMEO–Oilseeds), approved by the Union Cabinet for a seven-year period from 2024–25 to 2030–31, with the aim of making the country self-reliant in oilseed production.

Sunflower, typically grown under rainfed conditions, holds significant potential as an oilseed crop in our country, contributing to reduced imports and greater self-sufficiency. Containing 38–50% oil, sunflower seeds yield an oil valued for its richness in unsaturated fatty acids and natural antioxidants, making it a healthy dietary choice. However, its cultivation area and production have sharply declined from 2012–13 to 2021–22 due to erratic monsoons coupled with various biotic and abiotic stresses and unremunerative prices. Just as big problems can have simple solutions, mulching can help alleviate moisture stress and suppress stress-induced pathogens such as *Macrophomina phaseolina*, which causes charcoal rot in sunflower and is particularly severe in semi-arid and arid regions. Despite years of scientific effort to develop improved varieties, many farmers persist with traditional cultivars, unaware of the superior benefits and support available through schemes like the National Food Security Mission – Oilseeds and Oil Palm and the National Mission on Edible Oils – Oilseeds. Under these schemes, farmers receive incentives and subsidies for purchasing seeds, biofertilizers, seed storage bins, plant protection chemicals, farm implements, and other inputs. Government has also sanctioned a special project worth ₹43.53 crore to the ICAR–Indian Institute of Oilseeds Research, Hyderabad, aimed at expanding the area and production of sunflower cultivation through hybrid seed production and demonstrations over a three-year period (2022–23 to 2024–25). Additionally, under the Pradhan Mantri Fasal Bima Yojana (PMFBY), crop insurance is provided to safeguard farmers against losses due to crop failure. Farmers can boost sunflower yields and profitability by integrating modern practices, cultivating high-yielding varieties and hybrids, and utilizing available government initiatives.

A shinning component of Integrated Farming System :

Sunflower seeds serve multiple purposes beyond oil extraction. Seeds of sunflower are consumed by humans as snack and used as bird feeds which broadens their utility and market demand. The sunflower meal, obtained as a by-product of oil extraction, is particularly valuable

in animal nutrition as it is rich in protein and fat, making it an efficient feed supplement for cattle, poultry, and other livestock. Sunflower meal is the fourth largest oilseed meal produced and consumed in the world. It can be effectively utilized as a feed ingredient for both ruminants and non-ruminants and serves as a valuable protein source for dairy cattle, beef cattle, swine, sheep, poultry, and even rabbits. Incorporating sunflower meal into the diet of dairy cattle has been reported to enhance milk yield by approximately 15%, thereby demonstrating its significance as a nutritionally beneficial feed component.

In addition, sunflower pollen and nectar are highly attractive to honeybees, making the crop highly suitable for apiculture and honey production. Alongside honeybees, sunflowers also attract a diverse array of pollinators, thereby enhancing pollination services and promoting ecological diversity. Increased pollinator activity has been positively associated with higher seed set, improved grain filling, and enhanced oil content in sunflower, which ultimately contributes to greater productivity and profitability of the crop.

Sunflower possesses strong allelopathic properties, and its incorporation into crop rotation or intercropping systems has been shown to effectively suppress weed proliferation. The release of allelochemicals such as phenolic acids, terpenes, and other secondary metabolites from sunflower roots, residues, and decomposed plant parts inhibits seed germination and growth of several weed species. Research findings indicate that sunflower cultivation can delay weed emergence for up to 75 days in subsequent crops. Furthermore, the substitution of one crop in the rice–wheat cropping system with sunflower significantly reduces weed infestation, thereby enhancing system productivity and sustainability.

The multipurpose utilization of sunflower clearly demonstrates its significance as a vital component of integrated farming systems (IFS), contributing substantially to enhanced farm profitability.

A green approach

Fossil fuels have long served as primary energy sources; however, their escalating costs, associated environmental pollution, and unsustainable exploitation have prompted researchers to investigate alternative energy pathways. Among these, biodiesel has emerged as a promising substitute owing to its renewable, non-toxic, biodegradable, and environmentally benign characteristics. Unlike fossil fuels, biodiesel is free from sulphur and aromatic compounds, making it a cleaner-burning fuel. It is typically produced from triglyceride-rich feedstock, such

as vegetable oils, through the transesterification process. In this context, sunflower oil is considered a potential feedstock for biodiesel production, as the crop can be cultivated extensively under rainfed conditions, thereby offering both economic and ecological advantages.

Growing awareness of the adverse impacts of synthetic products and industrial pollution has led to an increased preference for eco-friendly alternatives derived from natural materials. In this regard, sunflower seeds, particularly the Hopi Black variety, have been employed in the dyeing industry to produce shades ranging from purple to black. Furthermore, research has also focused on extracting natural dyes from sunflower petals. Considering the substantial environmental burden posed by synthetic dyes and the textile dyeing sector, natural dyes are anticipated to emerge as a sustainable and widely adopted alternative in the future.

Sunflower Agrotourism

The sunflower is more than just a crop–it is a flower of joy, light, and beauty. Beyond its value in oil and seed production, it graces gardens as an ornamental plant, cherished for cut flowers, potted displays, and vibrant landscaping. Pollen-free varieties are specially grown for this purpose: tall, single-headed blooms perfect for bouquets, and cheerful, multi-headed types that brighten pots and terraces. Today, ornamental sunflowers appear in dazzling forms–different sizes, vivid colours, and unique petal patterns—each variety carrying its own charm.

Scrolling through social media, one often comes across endless reels showcasing the breath-taking sight of golden sunflower fields stretching toward the horizon. These clips draw millions of views, countless likes, and streams of comments from curious admirers longing to visit. This fascination reveals a glowing opportunity–Agrotourism in sunflower fields. In states like Karnataka, where vast acres are already devoted to sunflower cultivation, opening these fields to visitors during the flowering season could transform farming into both livelihood and experience. Agrotourism is more than strolling through fields—it is about connection. Tourists can join in simple farm tasks, from sowing to harvesting, finding joy in the soil beneath their hands. For people weary of city life, a farm stay amid endless yellow blooms offers peace and renewal. Sunflowers, with their radiant golden petals, not only draw honeybees but also beckon hearts seeking beauty, simplicity, and belonging.

And tell me–who could ever resist basking in the first light of sunrise or the last glow of sunset, lost in a boundless ocean of golden petals, where the earth itself seems to bloom with the sun?

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FLAVR SAVR TOMATO: A MILESTONE IN PLANT GENETIC ENGINEERING

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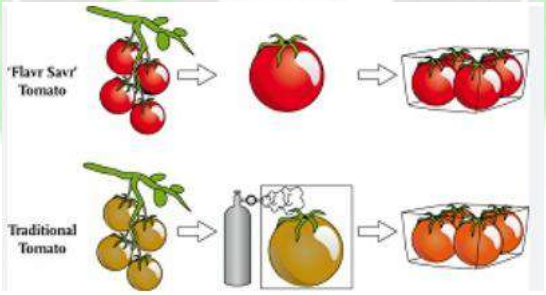
Abstract

The document discusses the development of the flavr Saur tomato, the first commercially available genetically engineered food. Scientists at Calgene introduced a gene that produces mRNA to inhibit the enzyme polygalacturonase (PG), which is responsible for fruit softening. This delayed the ripening process, allowing the tomatoes to huge a longer shelf life without compromising flavor. Specifically, the antisense RNA technique was used, where cDNA complementary to the PG gene was introduced, preventing the sense mRNA from producing the PG enzyme and thus slowing ripening. The resulting Flaur Saur tomato had a slower ripening rate, ripened longer on the Vine, and had an increased shelf life while fully developing flavors. Introduction: flavr Saur, a genetically modified tomato, was the first commercially grown genetically engineered food to be granted a license for human consumption. It was developed by the Californian com any Calgene in the 1980s. The tomato has an improued shelf- ife, increased fungal resistance, and a slightly increased Uiscosity. The flavr Saur contains two genes added by Calgene; a reversed antisense polygalacturonase gene, which inhibits the production of arotting enzyme, and a gene responsible for the creation of APH(3')II, which confers resistance to certain aminoglycoside antibiotics, including kanamgcin and neomycin On Mag 18, 1994, the FDA completed its evaluation of the Flaur Saur tomato and the use of APH(3')II concluding that the tomato "is as safe as tomatoes bred by conventional means" and "that the use ofaminoglgcoside

3'-phosphotransferase II is safe for use as a processing aid in the development of new varieties of tomato, rapeseed oil, and cotton intended for ood use.



" It was first sold in 1994, and was only available ore production ceased in 1997. Calgene made history, but mounting costs prevented the company m becoming profitable, and it was euentuallg acquired g Monsanto Company.



characteristics :

Genetic modification

The Flaur Saur tomato was genetically engineered by Calgene to extend shelf life and allow tomatoes to ripen naturall on the Uine without becoming too soft for transport. Norma ly, tomatoes spoil quickly after ripening, so they are picked green and ripened with ethylene gas, which reduces flavor. Calgene used the bacterium Agrobacterium tumefaciens to insert an antisense gene that suppressed the beta-polygalacturonase (PG) enzyme, responsible for fruit softening. This slowed rotting but did not make the fruit firm enough for machine handling. A kanamgcin-resistance gene was also added as a marker to identify successfully modified plants.

Parent variety:

The Flaur Saur tomato was developed from an old, low-yield variety to avoid patent Issues, but this caused poor productivity. It produced only 25-50% of the normal yield, with many fruits too small for premium sale. Since it couldn't be machine-harvested, production costs rose to $10 per pound, while it sold for only $1.99 per pound, making it economically unviable.



Genetic Modification Process:

- Scientists isolated the polygalacturonase (PG) gene from tomato plants.
- They then created an antisense copy of this gene a reversed sequence that binds to the normal (sense) mRNA and prevents its translation.
- The antisense gene was inserted into tomato plants using tumefaciens (a natural bacterium). Agrobacterium gene-transfer

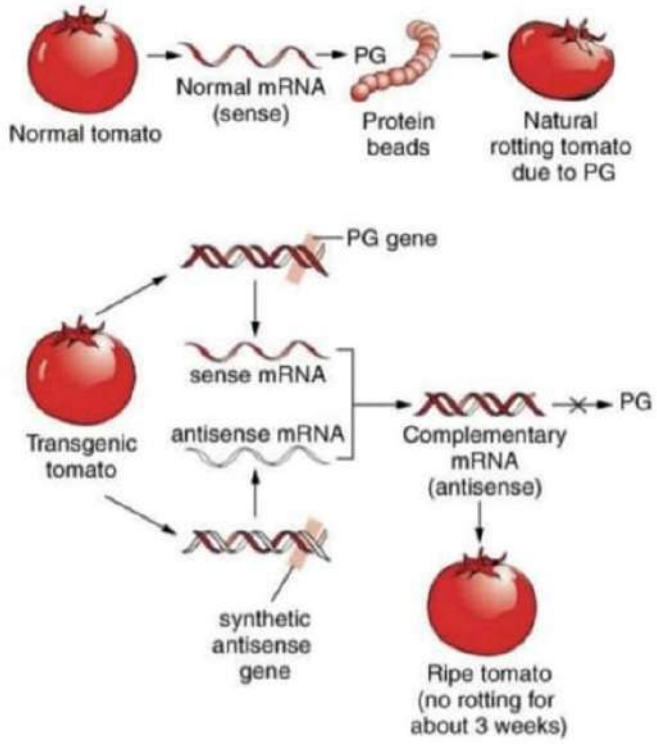
Steps involved:

- Gene Identification: Identification of PG gene responsible for fruit softening.
- Antisense Gene Construction: Creation of complementary (antisense) DNA to block PG mRNA.
- Transformation: Insertion of antisense gene into tomato DNA Uia Agrobacterium tumefaciens.
- Selection: Plants with successful gene incorporation were selected using antibiotic resistance markers
- Regeneration: These transformed cells were regenerated into full plants via tissue culture.
- Screening: Plants were tested for reduced PG activity an improved shelf life.

Mechanism ofPG antisense RNA

Approach:

In normal plants, PG gene encodes a normal or sense mRNA that produce the enzyme PG and it is actively involved in fruit ripening.



PARENTAL

1. The cDNA of PG encodes for antisense mRNA, which is complementary to sense mRNA.
2. The hybridization between sense and antisense mRNA render the sense mRNA ineffective.
3. Consequently, polygalacturonase produced hence ripening is delayed. No is fruit Commercialization
4. Released under the brand name Flaur Saur.
5. Produced by Calgene and marketed in collaboration with Campbell Soup Company.
6. Sold in U.S. supermarkets starting in 1994.

Regulatory Approval

*The U.S. Food and Drug Administration (FDA) declared in 1994 that the flavr Saur tomato was safe for human consumption.

It was the first genetically engineered crop to receive FDA approvals for sale.

Significance

*First commercial genetically modified food crop.

*Demonstrated that antisense RNA technology could modify plant traits.

*Opened the path for future GMO development in crops like soybean, maize, and cotton. Advantages: Delayed Ripening

The flavr Saur tomato was genetically engineered to slow down the softening process, allowing the tomato to stag firm and fresh for a longer time after harvest.

Improved Shelf Life

Because ripening ts delayed, the tomatoes could be stored and transported over long distances without spoiling quickly.

***Better flavr**

Unlike traditional shipping tomatoes @hich are picked green and ripened artificially), Flaur Saur Tomatoes could be vine-ripened and still transported, giving them a more natural taste and aroma.

***Reduced Post-Haruest Losses –**

The firmer texture made them less prone to bruising and damage during handling, packaging, and transportation.

Consumer Appeal

*They looked and tasted like

Garden-fresh tomatoes while lasting longer – appealing to both consumers and retailers.

Limitations and Issues

*The parent tomato variety used had low yield and poor agronomic performance.

*Production and handling costs were high.

*The antisense technology worked scientifically, but the product was not commercially successful.

*Calgene was later acquired by Monsanto.

Conclusion

The development of the Flaur Saur tomato marked a revolutionary milestone in agricultural biotechnology as the first genetically modified (GM) food crop to be approved for human consumption. Developed by Calgene Inc.,It successfully demonstrated the use of antisense RNA technology to suppress the polygalacturonase enzyme responsible for fruit softening.

This innovation allowed tomatoes to remain rm longer, enabling them to be vine-ripened for improved uor while extending their shelf life. Although the flavr Saur tomato was not a long-term commercial success due to low yield, high production costs.

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THE EMERGENCE OF WINGED TERMITES AFTER RAIN: OVERVIEW

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Introduction

The sudden appearance of thousands of winged termites following a rain shower is a fascinating natural phenomenon that many people observe, particularly in tropical and subtropical regions. These winged reproductive termites, known as alates, seem to materialize out of nowhere, swarming around lights and creating quite a spectacle. This synchronized mass emergence is not coincidental but rather the result of millions of years of evolutionary adaptation and complex biological mechanisms that ensure the survival and propagation of termite colonies.

Understanding Termite Colony Structure

To comprehend why winged termites emerge after rain, we must first understand the social structure of a termite colony. Termites are eusocial insects, meaning they live in highly organized colonies with distinct castes, each serving specific functions. A typical mature colony contains:

Workers: The most numerous caste, responsible for foraging, nest construction, and caring for young termites. These are wingless and blind.

Soldiers: Specialized defenders with enlarged heads and mandibles, protecting the colony from predators, particularly ants.

Reproductives: This includes the king and queen (primary reproductives) who founded the colony, and the alates (secondary reproductives) - the winged termites that emerge after rain.

The alates develop from larvae that have been specially groomed and fed within the colony. Their development is carefully regulated by pheromones produced by the queen, which suppress

reproductive development in most colony members. However, when a colony reaches maturity - typically after 3-5 years depending on the species - it begins producing these winged reproductives in large numbers.

The Role of Rain and Environmental Triggers

Rain serves as the primary environmental trigger for termite nuptial flights, but the mechanism is more complex than simply "rain equals termites." Several interconnected factors work together:

Humidity and Moisture: Rain dramatically increases atmospheric humidity, which is crucial for the survival of alates. Termites have soft, permeable exoskeletons that lose moisture rapidly in dry conditions. High humidity following rain creates ideal conditions where alates can survive outside the protected colony environment long enough to mate and establish new colonies. Without this moisture, they would quickly dehydrate and die.

Barometric Pressure Changes: Before and during rainfall, atmospheric pressure drops significantly. Termites are highly sensitive to these pressure changes, which they can detect through specialized sensory organs. This barometric sensitivity acts as an early warning system, allowing colonies to prepare for the upcoming favorable conditions.

Temperature Moderation: Rain typically cools the air temperature to more moderate levels, creating comfortable conditions for flight. Extreme heat would stress the delicate alates and reduce their survival chances.

Soil Softening: Perhaps most importantly, rain softens the soil, making it easier for newly mated pairs (the king and queen) to burrow and establish their new underground colonies. Hard, dry soil would be nearly impossible for these small insects to penetrate.

The Synchronization Phenomenon: One of the most remarkable aspects of termite emergence is the synchronization across multiple colonies in an area. On the same evening after a significant rain, dozens or even hundreds of nearby colonies will release their alates simultaneously. This synchronization serves several critical evolutionary purposes:

Predator Satiation: By emerging in massive numbers all at once, termites overwhelm their predators. Birds, lizards, frogs, spiders, and other insectivores can only consume so many termites, meaning that despite heavy predation, a significant percentage will survive. If colonies released alates sporadically, predators could efficiently consume nearly all of them.

Genetic Diversity: Synchronized swarming from multiple colonies ensures that alates from different colonies intermingle, promoting outbreeding and genetic diversity.

This is crucial for maintaining healthy, robust populations.

Environmental Optimization: All colonies responding to the same environmental cues ensures that alates emerge under optimal conditions, maximizing survival rates.

Scientists believe this synchronization is achieved through the combination of environmental triggers mentioned earlier, which affect all colonies in a region simultaneously, and possibly through chemical signals or vibrations that colonies might detect from neighboring colonies.

The Emergence Process: The actual emergence of alates is a carefully orchestrated event within the colony. Hours or even days before the flight, worker termites begin preparing exit holes, clearing debris and soil from specific locations in the nest. These exit points are strategically chosen and may have been prepared during previous seasons.

As conditions become favorable, alates gather near these exit points. The colony becomes visibly agitated, with increased activity throughout. When the moment arrives - typically during late afternoon or early evening when light levels are decreasing but sufficient for flight - workers break through the final barriers, and alates begin pouring out. The emergence can be dramatic, with thousands of winged termites streaming from a single colony within minutes. They crawl up vegetation, walls, or any vertical surface to gain height before launching into flight. Their flight is relatively weak and fluttering compared to other flying insects, making them vulnerable during this crucial dispersal phase.

The Nuptial Flight and Pair Formation

Once airborne, alates engage in their nuptial flight - a dispersal flight that can carry them anywhere from a few meters to several hundred meters from their parent colony, depending on wind conditions and species. During this flight, males and females identify each other through pheromones, though mating does not occur in the air. After landing, which often happens near light sources (explaining why we see them swarming around lamps and lit windows), alates shed their wings. This is a remarkable process - the wings are designed to break off easily at a predetermined breaking point near the base. The termites accomplish this by twisting their bodies or rubbing against surfaces. The shed wings create a distinctive pattern on the ground, often the first sign people notice after a termite swarm.

Now wingless, the males and females begin their courtship ritual. A female will raise her abdomen and release sex pheromones, calling to potential mates. Males respond to these chemical signals, and when they find a receptive female, a pair is formed. The female leads, and

the male follows in a behavior called "tandem running," where the pair searches for a suitable nesting site.

Establishing New Colonies:

Once the newly paired king and queen find suitable soil - preferably softened by the recent rain - they excavate a small chamber called the copularium or royal cell. This is exhausting work for these small insects, and many pairs die during this vulnerable phase due to predation, desiccation, or inability to find suitable nesting sites.

Successfully paired termites that complete their nuptial chamber seal themselves inside and mate. Unlike many insects where males die after mating, termite kings remain with their queens for life, mating periodically as the colony grows. The queen begins laying eggs within days, starting with just a few. She and the king care for these first offspring themselves until they mature into workers. These first-generation workers then take over nest construction, foraging, and care of subsequent broods, allowing the queen to focus exclusively on egg production. If the colony survives these critical early months - and most do not - it will gradually grow over years into a mature colony capable of producing its own alates, completing the cycle.

Ecological Significance: The post-rain termite emergence plays a crucial role in ecosystem functioning. Despite being considered pests when they interact with human structures, termites are essential ecosystem engineers. Their swarming events provide:

Nutrient Cycling: Termites that don't successfully establish colonies become food for countless predators, transferring nutrients through food webs. The protein-rich alates represent an important seasonal food source for many species.

Soil Aeration: Colony establishment activities contribute to soil mixing and aeration, improving soil structure.

Decomposition: Successful colonies break down dead plant material, returning nutrients to the soil and preventing accumulation of organic debris.

The timing of these flights after rain ensures that new colonies form when conditions favor both establishment and the availability of moist wood and plant material for consumption.

Conclusion

The emergence of winged termites after rain is a masterpiece of evolutionary adaptation, representing the culmination of complex environmental sensing, social coordination, and reproductive strategy. Rain provides the combination of high humidity, soft soil, and other

favorable conditions that maximize the chances of successful colony establishment. The synchronized mass emergence reflects millions of years of selection pressure, balancing the need for dispersal and genetic mixing against the ever-present threat of predation. Understanding this phenomenon not only satisfies scientific curiosity but also helps us appreciate the intricate connections between seemingly simple environmental events and the complex life cycles of the creatures sharing our world.

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ROTARY DISC SPRAYER

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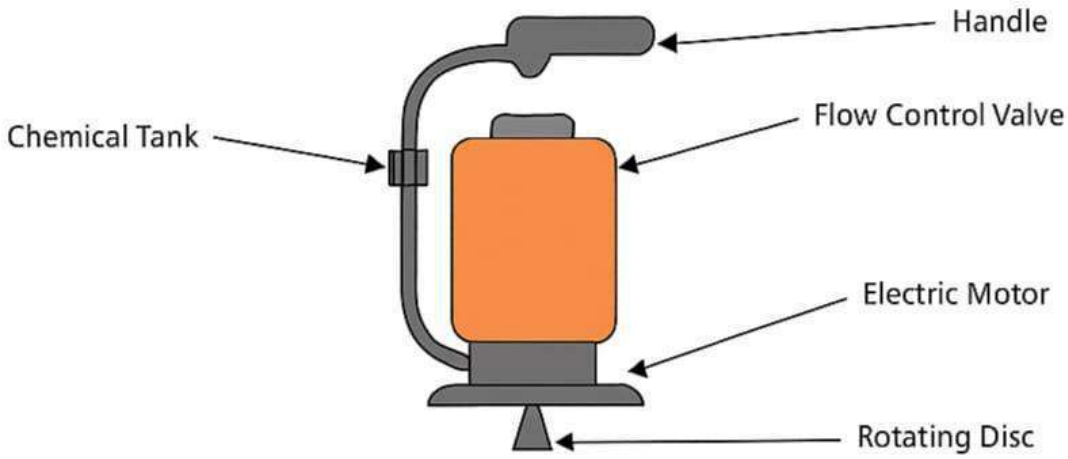
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Abstract

The Rotary Disc Sprayer is an advanced agricultural device designed to atomize liquid pesticides, herbicides, and fertilizers into uniformly fine droplets using a high-speed rotating disc. This technique enhances droplet distribution, reduces chemical wastage, and significantly improves coverage efficiency. Compared to conventional hydraulic nozzles, rotary disc sprayers utilize centrifugal atomization, which ensures precise control of droplet size and spray volume. This makes the system ideal for low-volume (LV) and ultra-low-volume (ULV) applications. With recent developments, such as battery-powered and drone-mounted systems, this technology represents a major step toward sustainable, precision-based crop management and environmental conservation.

Introduction

The Rotary Disc Sprayer is an innovative agricultural spraying tool that operates based on centrifugal atomization. It replaces traditional hydraulic nozzles with a rotating disc mechanism that uniformly disperses liquid chemicals into fine droplets. This mechanism ensures efficient pesticide and fertilizer application with minimal loss and drift. The sprayer is particularly suitable for small-scale farms, greenhouses, and drone-based aerial spraying. Its design allows for precise control of the spray rate, making it invaluable for precision farming applications. Ultimately, this device reduces environmental impact while maintaining effective pest and disease control, thereby promoting modern and sustainable agricultural practices.



Rotary Dise Sprayer Aconsnter

CONSTRUCTION OF ROTARY DISC SPRAYER

- The rotary disc sprayer consists of the following major components:
- Chemical Tank: Stores the pesticide or fertilizer solution. It is typically made of corrosion-resistant material like HDPE or stainless steel.
- Flow Control Valve: Regulates the flow rate of the liquid to ensure uniform delivery to the disc.
- Rotary Disc (Atomizer): A circular metal or plastic plate mounted on a motor shaft that spins between 3,000–10,000 RPM, generating fine droplets by centrifugal force.
- Electric / DC Motor: Provides the necessary rotational speed for the disc. It is often battery-powered or solar-assisted.
- Handle / Mounting Frame: Offers a user grip for handheld use or enables attachment to drones or boom sprayers.
- Power Source: Usually a rechargeable battery (12V/24V) or connected via external power for field use.
- The overall structure is compact, lightweight, and ergonomically designed for easy operation and maintenance. Modern versions often include speed control circuits and flow sensors for real-time droplet size regulation.

WORKING PRINCIPLE

The Rotary Disc Sprayer works on the principle of centrifugal atomization. The liquid pesticide flows from the tank through the control valve and reaches the center of the rotating disc. Due to the high rotational speed, the liquid spreads radially outward and forms a thin film. At the disc's edge, this film disintegrates into fine, uniform droplets because the centrifugal force overcomes the liquid's surface tension. The resulting droplet size is influenced by the disc speed, liquid viscosity, and flow rate. A higher disc speed produces smaller droplets, which are suitable for ULV applications. The ambient air current or wind then assists in carrying these droplets to the crop canopy, ensuring uniform coverage and efficient use of chemical

ADVANTAGES

- Produces uniform and fine droplets, ensuring precise coverage and better pest control.
- Reduces pesticide usage by up to 80%, minimizing environmental impact.
- Lightweight, portable, and energy-efficient; suitable for handheld and drone-mounted systems.
- Reduces drift losses due to the controlled and consistent droplet size.
- Compatible with various chemical types—insecticides, fungicides, and liquid fertilizers.
- Ideal for both low-volume (LV) and ultra-low-volume (ULV) spraying applications.

LIMITATIONS

- Not suitable for thick or highly viscous liquids that resist effective atomization.
- Droplet drift can still occur under strong wind conditions.
- Requires regular maintenance and cleaning to prevent clogging of the disc and filter.
- The initial investment is slightly higher than for traditional knapsack sprayers.
- Limited area coverage for large-scale farms without a mechanized mounting system.

APPLICATIONS

- Rotary Disc Sprayers are widely used in agriculture, horticulture, and public health programs.
- Agriculture: Effective for pest and disease control in major crops such as paddy, cotton, maize, and various vegetables.
- Horticulture: Used for the precise application of micronutrients and growth regulators.
- Forestry: Employed for localized pest management.

- Urban Health: Utilized for mosquito and vector control programs.
- Research: Employed in laboratories for droplet size analysis and pesticide formulation testing.

Conclusion

The Rotary Disc Sprayer represents a significant innovation in modern agricultural engineering. It combines precision, efficiency, and sustainability by minimizing chemical wastage and ensuring uniform droplet application. The technology supports both manual and automated systems, such as drones, aligning perfectly with the future of precision agriculture. Continued research and material improvements will further enhance its performance, reliability, and adaptability across diverse agricultural operations.

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INTEGRATED PEST MANAGEMENT OF RICE INSECT PESTS

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Introduction

Rice (*Oryza sativa* L.) is the principal staple food crop for more than half of the world's population, a vital component of global food security and supporting the livelihoods of millions of farmers. In India, rice occupies a prominent position, being cultivated over about 47.6 million hectares with an annual production of around 137 million tonnes. However, the productivity of rice is severely constrained by several biotic and abiotic stresses, among which insect pests constitute one of the most serious threats. More than 800 species of insects have been reported to infest rice worldwide, of which about 20–25 species regularly attain pest status. In India, key pests such as the yellow stem borer (*Scirpophaga incertulas*), gall midge (*Orseolia oryzae*), leaf folder (*Cnaphalocrocis medinalis*), brown planthopper (*Nilaparvata lugens*), green leafhopper (*Nephotettix virescens*), and rice hispa (*Dicladispa armigera*) cause significant economic damage during various crop growth stages. Yield losses due to insect pests in rice have been estimated at up to 25–30% annually in India.

Integrated Pest Management (IPM) is a holistic, ecological approach to insect pest management that emphasizes monitoring, threshold-based decision making, use of biological and cultural controls, and judicious, minimal use of chemical pesticides. The significance of IPM for rice is heightened because rice is cultivated across diverse agro-ecological zones in India from irrigated lowlands to rainfed uplands, deep-water and flood-prone systems and the intensification of rice cultivation along with high inputs and pesticide misuse has often exacerbated insect pest incidence. IPM in rice offers a sustainable pathway to enhance productivity, reduce pest-driven

losses, lower environmental and health risks from pesticide overuse, and improve profitability for farmers.

Insect pests of Rice

Yellow stem borer

Five species of stem borers reported to attack rice crop, of which the yellow stem borer (YSB), *Scirpophaga incertulas* is dominant. The female moth is straw coloured with a single dark spot at the centre and abdomen is covered with tuft of yellowish silken hairs. The male is smaller than female and is light brown with numerous small dark spots. Caterpillar is yellowish white with orange coloured head. The larvae initially boring and feeding in the leaf sheath cause broad longitudinal whitish discolouration at feeding sites. Later it enters the stem mostly at nodal region, feeding within the stem. Larval feeding causes death of the central shoot at vegetative stage, a condition known as "dead hearts" and at panicle bearing stage results in drying of the panicles and such panicles are called as white ear heads. Damaged tillers/panicles can be pulled out easily. It is a pest of both the seasons.



Adult



Egg mass



Larva



Dead heart



White ear

Management

- Summer ploughing and stubble destruction to kill the larvae/pupae in the stubbles.
- Harvesting close to the ground to eliminate majority of the larvae.
- Nursery protection through application of granules like carbofuran 3 G @ 160 g or phorate 10 G @ 50 g/cent nursery seven days before pulling up of the seedlings.
- Clipping up of seedling leaf tips while transplanting to remove the egg masses.
- Application of optimum rates of nitrogenous fertilizers in splits.
- Synchronized early planting.
- Monitoring the stem borer population through setting the light trap or through pheromone traps @ 8 per/ha.

- Mass trapping of male moths through pheromone traps @ 20/ha.
- Release of *Trichogramma* egg parasitoids 3-4 times @ 50,000/ha starting from 35 DAT at 10-15 days interval.
- Need based application of insecticides based on economic threshold (ETL) i.e. one egg mass or one female adult moth/ sq. m or 5% dead hearts. During vegetative stage spray application of monocrotophos 36 WSC @ 1.6 ml or chloripriphos 20 EC @ 2.5 ml or phosphamidon 40 SL @ 2.0 ml/L of water. At reproductive stage, apply granular insecticides like carbofuran 3G @ 10 Kg or fipronil 0.3 G @ 5 Kg or chlorantraniliprole 0.4% G @ 4 Kg or cartap hydrochloride 4G @ 8 Kg/ac within 7-10 days after panicle initiation or spraying of cartap hydrochloride 50 SP @ 2.0 g or acephate75 SP @ 1.5 g or fipronil 5 SC @ 2.0 ml or chlorantraniliprole 18.5% SC @ 0.3 ml/L of water. The application of insecticides should be coinciding with the peak emergence of moths.

Gall midge: *Orseolia oryzae*

It is a serious pest of rice in tillering stage only. The adult is a small fly like a mosquito with yellow brown body and long dark brown hairy legs. The adult female is bright red with a reddish-brown abdomen. The maggots are apodous, acephalous and remain inside the basal part of the stem. Feeding of the maggot on primordial and injecting a toxin 'cecidogen' cause's transformation of leaf sheath in to a tubular gall-like structure called onion/silver shoot Affected tillers do not bear panicles. Early infestation encourages profuse tillering and stunted growth of the plants. It normally infests *Kharif* season but in recent years it becomes a pest of *Rabi* season also.



Adult



Eggs



Silver shoots

Management

- Growing of resistant varieties like Kakatiya, Surekha, Erramallelu, Kavya, Divya, Pothana, Srikalulam Sannalu etc. in endemic areas.
- Adopt early and synchronous planting with short duration varieties.
- Judicious use of nitrogenous fertilizers.
- Conservation of larval parasitoid like *Platygaster oryzae* through avoidance of insecticides at their peak occurrence.
- Nursery protection through application of granules like carbofuran 3g @ 160 g or phorate 10 G @ 50 g/cent nursery seven days before pulling up of the seedlings.
- Need based application of insecticides based on ETL i.e. 5% silver shoots with carbofuran 3 G @ 10 Kg or phorate 10 G @ 5 Kg/acre at 15 days after transplanting or spraying of chloripyriphos 20 EC @ 2.5 ml/L of water.

Brown planthopper (BPH): *Nilaparvata lugens*

The brown planthopper is common in irrigated wetland ecosystem especially during the reproductive stage of the rice plant in both the seasons. The adult hoppers are yellowish brown to dark brown. The wings are sub hyaline with a dull yellowish tint. Adult BPH has two characteristic wing morphs, macropterous (long winged) and brachypterous (short winged). They are found in clusters at the base of the plants. Both nymphs and adults of BPH damage the rice plants by sucking the sap from the base of the plant and plugging the phloem vessels with their feeding sheaths and pierces tissues during their exploratory feeding. It results in yellowing and drying up of plants. At early infestation round yellow patches appears which soon turn to brownish due to drying up of the plants. The patches of infestation spread in concentric circles within the field, known as 'hopper burn'.



Brown planthopper adult



Hopper burn

Management

- Growing of tolerant/resistant varieties like Chaitanya, Krishnaveni, Vijetha, Indra, Cottondora Sannalu etc.
- Avoid close planting (33 hills/sq. m in *Kharif* and 44 hills/ sq. m in *Rabi*).
- Formation of alley ways of 20 cm for every two meters of planting.
- Alternate wetting and drying of rice field.
- Use of balanced fertilizer dose and avoid use of excessive nitrogenous fertilizers.
- Conservation and encouraging the buildup of natural enemies like spiders and mirid bugs by avoiding early season sprays.
- Do not apply resurgence causing insecticides like quinalphos, chloripyriphos, profenophos, methyl parathion, triazophos, deltamethrin, cypermethrin like synthetic pyrethroids, application of phorate granules etc.
- When BPH crosses ETL (10-15 insects/hill during tillering stage and 20-25 insects/hill at reproductive stage) apply any of the following insecticides as foliar spray
    - ✓ Buprofezin 25 SC @ 1.6 ml/L
    - ✓ Imidacloprid+ethiprole 80 WG @ 0.25 g/L
    - ✓ Dinotefuran 20 SG @ 0.4 g/L
    - ✓ Pymetrozine 50 WG @ 0.6 g/L
    - ✓ Triflumezopyrim 10 SC @ 0.47 ml/L
    - ✓ Monocrotophos 36 WSC @ 2.2 ml/L
    - ✓ Fenobucarb 50 EC @ 2.0 ml/L of water
- A spray fluid of 200 litres per acre is a must and spray should be directed towards the base of the plant.

White-backed planthopper (WBPH): *Sogatella furcifera*

It causes serious loss in the vegetative stage of the crop particularly in *Kharif* season. The adult hopper has a distinct long narrow face. The forewings are uniformly hyaline with dark veins. There is a conspicuous black dot about the middle of the posterior edge of each forewing which meets when forewings are come together. The body is black dorsally and creamy white elsewhere. There is a prominent white band between the juncture of the wings. Adults and nymphs suck the sap remaining at the basal part of the plants. As a result of which the leaves turn yellow and later on rust red. High population gives a burning appearance to

plants looking orange-yellow which later dry up and turn brown.



WBPH adult



Hopper burn

Management: Same as BPH

Leaf-folder: *Cnaphalocrocis medinalis*

It has assumed the major status of a pest in all types of rice cultivation during both the seasons. Adult moths are golden yellow in colour with black wing margins in the apical region. Males are brighter than females. They have three dark brown wavy oblique lines on each forewing. In the hind wing, there are two brown lines. It looks like a triangle when rest on leaves. Larva when full grown found inside folded leaves, light green in colour with reddish-dark head and one inch in length. The caterpillars fold the leaves longitudinally into tubular structures by fastening the margins with silken thread and they feed on the green leaf tissue within the leaf fold. Larval feeding results in white transparent streaks which run parallel to the mid rib. The discoloration and folding of the leaves affect the general vigor of the plants and reduces the photosynthetic ability. Severe infestation can cause complete drying of the leaves; the field presents a scorched appearance. The damage will be more when it affects the flag leaf.



Adult



Larva



Damaged Leaves

Management

- Removal and destruction of alternate weed hosts.

- Nursery protection through application of granules like carbofuran 3 G @ 160 g or phorate 10 G @ 50 g/cent nursery seven days before pulling up of the seedlings.
- Use of optimum fertilizer dose and avoid using of excessive nitrogen fertilizers.
- Avoid early season broad-spectrum insecticide sprays.
- Do not apply resurgence causing insecticides like quinalphos, application of phorate and carbofuran granules etc.
- Release of egg parasitoids *Trichogramma chilonis* 3-4 times @ 50,000/ha starting from 35 DAT at 15 days interval.
- Dragging of a rope across the field to dislodge the larvae of leaf folder in to the water in field.
- When the pest crosses ETL i.e. two damaged leaves/hill apply insecticides mentioned for yellow stem borer.

HISPA: *Dicladispa armigera*

This is a sporadic and occasional leaf feeding pest and in certain years ranked as major pest. The adult beetle is small, blue black with a spiny body. The eggs are laid singly near the tip of the leaf blade, generally on the ventral surface and are partially inserted beneath the epidermis and covered with a small amount of dark substance secreted by female beetle. The grubs after hatching mine in to the leaf blade between the two epidermal membranes. Both adults and grubs cause damage. The grubs' tunnels in between the two epidermal layers and feeding on green chlorophyll tissue results in irregular translucent white patches. The adults scrape the upper surface of the leaf blade often leaving only lower epidermis. The damaged areas appear as white streaks parallel to the mid rib. Under severe infestation, the crop turns brownish and withers away.

Management

- Removal and destruction of alternate weed hosts.
- Clipping of seedling leaf tips while planting.
- When pest crosses ETL i.e. two damaged leaves or one adult hispa/hill, spray insecticides like monocrotophos 36 WSC @ 1.6 ml or chloripyriphos 20 EC @ 2.5 ml or profenophos 50 EC @ 2.0 ml/L of water.



Adult



Damage

Green leafhopper (GLH): *Nephotettix virescens* and *N. nigropictus*

The adults are pale green with black markings on the head and wings. Males have a dark brown/black band in the middle of the forewings and is absent in females. The adult has two black spots at the centre of the fore wings. They are active during day and night and walk side wise; when disturbed they quickly jump from the leaf blade. The leafhoppers attack all the stages of the plant. Both adults and nymphs cause direct damage by sucking plant sap leading to stunted growth and reduced tillering. Heavy infestation causes withering and complete drying of plants. Besides direct damage GLH also transmits number of viral diseases such as rice dwarf, transitory yellowing, tungro, yellow dwarf etc. Tungro infected plants show severe stunting and orange yellowing of leaves. It is a serious pest in *Kharif* season.



GLH adults



Damage

Management

- Removal and destruction of alternate weed hosts.
- Judicious use of nitrogen fertilizers.
- The insecticide management is same as recommended for BPH.

Conclusion

Integrated Pest Management in rice offers a sustainable, eco-friendly, and economically viable approach to manage insect pests. By combining cultural, biological, mechanical, and need-based chemical control measures, IPM minimizes pest damage while preserving beneficial organisms and environmental health. Implementing IPM not only reduces the overreliance on chemical pesticides but also delays pest resistance, lowers production costs, and ensures safe grain production. Widespread farmer awareness, training, and community-based implementation are essential to achieve long-term success of IPM in rice ecosystems, contributing to sustainable rice productivity and food security.

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BIOFORTIFICATION OF FOOD CROPS AND ARTIFICIAL INTELLIGENCE IN AGRICULTURE IS FUTURE INDIA FOOD SECURITY

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Abstract

Biofortification of staple food crops is crucial for addressing micronutrient deficiencies and improving global nutrition security. Biofortification piggybacks on the agronomically superior varieties being developed at agricultural research centers. Central plant breeding research discoveries can be spread globally. Farmers have every motivation to adopt the latest high-yielding, high profit crops. High productivity leads to lower food prices. Recent advancements in Artificial Intelligence (AI) and machine learning have revolutionized plant breeding, enabling the development of biofortified crops with enhanced yields, disease resistance, and nutritional profiles. This article explores the integration of AI-driven smart breeding techniques, including genomic selection, multi-omics integration, and predictive modeling, to accelerate the development of biofortified crops. We'll also dive into the applications of AI in agriculture, including precision farming and crop monitoring, and discuss how these innovations are transforming the agricultural landscape. By harnessing the power of AI, we can develop climate-resilient crops, improve nutrition security, and contribute to sustainable agriculture practices.

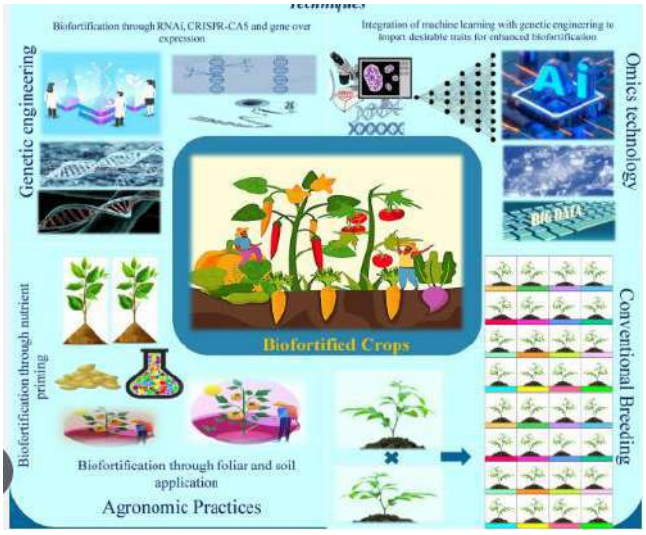
Introduction

Biofortification was coined as a term to define a plant breeding strategy to increase the micronutrient content of staple food crops to reduce the burden of micronutrient deficiencies

in low- and middle-income countries. Many people around the world don't get enough nutrients from their food, which can lead to health problems. One way to address this issue is by making staple foods more nutritious through a process called biofortification. In 2003, the HarvestPlus program, based in the centers comprising the Consultative Group on International Agricultural Research, was initiated to implement the biofortification strategy. However, traditional methods of biofortification can be slow and difficult. Recently, scientists have started using Artificial Intelligence (AI) to make biofortification faster and more effective.

Biofortification is the process by which the nutrient density of food crops is increased through conventional plant breeding, and/or improved agronomic practices and/or modern biotechnology without sacrificing any characteristic that is preferred by consumers or most importantly to farmers . It is recognized as a nutrition-sensitive-agriculture intervention that can reduce vitamin and mineral deficiency . Iron-biofortification of beans, cowpea and pearl millet, zinc-biofortification of maize, rice, and wheat, and pro-vitamin A carotenoid-biofortification of cassava, maize, rice, and sweet potato are currently underway and at different stages of development

The biological mechanism for biofortified crops improving nutritional status is simple: biofortified crops are more nutrient-dense than non-biofortified varieties. Therefore, assuming similar micronutrient bioavailability and retention after cooking or processing and storage, persons will consume and absorb more micronutrients from eating biofortified crops than from the same amount of non-biofortified crops. In populations with a diet limited in these micronutrients, the consumption of biofortified staple crops can improve micronutrient intake.



Until recently, using the words AI and agriculture in the same sentence may have seemed like a strange combination. After all, agriculture has been the backbone of human civilization for millennia, providing sustenance as well as contributing to economic development, while even the most primitive AI only emerged several decades ago. Nevertheless, innovative ideas are being introduced in every industry, and agriculture is no exception. In recent years the world has witnessed rapid advancements in agricultural technology, revolutionizing farming practices. These innovations are becoming increasingly essential as global challenges such as climate change, population growth together with resource scarcity threaten the sustainability of our food system. Introducing AI solves many challenges and helps to diminish many disadvantages of traditional farming.



In this article, we'll explore how AI is being used to improve the nutritional content of staple foods and help people around the world.

Biofortification in Food Crops

Biofortification is the process of increasing the nutrient content of crops through breeding, agronomic practices, or biotechnology. Unlike conventional fortification (adding nutrients during food processing), biofortification enhances nutrient levels within the plant itself.

Objectives

Combat hidden hunger (micronutrient deficiencies).

Improve human health through nutrient-rich staples.

Enhance sustainability by reducing the need for external supplements.

Methods of Biofortification

1. Conventional Breeding: Crossing high-yielding varieties with nutrient-rich lines (e.g., iron-rich beans, zinc rice).

2. Genetic Engineering: Introducing genes responsible for nutrient biosynthesis (e.g., Golden Rice with β-carotene).

3. Agronomic Practices: Application of micronutrient fertilizers (like zinc or selenium).

Examples

• Golden Rice – Enriched with Vitamin A.

• Iron and Zinc Wheat – Developed by HarvestPlus initiative.

• Orange-fleshed Sweet Potato – Rich in β-carotene.

Key benefits

- **Sustainable and cost-effective:** Once biofortified seeds are developed, the benefits are delivered through the food system with no recurrent costs, unlike supplements.
- **Addresses hidden hunger:** It helps combat micronutrient deficiencies, also known as "hidden hunger," which is particularly prevalent in populations relying heavily on a few staple crops.
- **Reaches remote areas:** It provides a way to deliver essential nutrients to rural and low-income populations who may not have access to commercially fortified foods or diverse diets.
- **Supports immunity:** Micronutrients like zinc, iron, and vitamin A are crucial for a healthy immune system, making biofortification important for improving resistance to infections.

Use of Artificial Intelligence in Agriculture

There are many approaches to leveraging AI to enhance efficiency and productivity in agriculture. We've gathered a few examples to illustrate some of them.



Monitoring soil health

AI systems can conduct chemical soil analyses and estimate missing nutrients accurately. One example is AI-powered hardware and software built by Agrocares, a Dutch agritech company.

One of their products, Nutrient Scanner, collects data from soil samples and provides farmers with accurate estimates of missing nutrients and overall soil status. This allows farmers to adjust their fertilizer application and irrigation practices to ensure optimal crop growth and reduce environmental impact.

In addition to this, AgroCares provides farmers with customized recommendations for soil management, helping them to maintain the health of their soil in the long term.

Breeding seeds

By collecting data on plant growth, AI can help produce crops that are less prone to disease and better adapted to weather conditions. With the help of AI, scientists can identify the best-performing plant varieties and crossbreed them to create even better hybrids.

Yes, the process of creating hybrids has been used in the agricultural industry for many years. However, gathering genomic information of seeds through AI technologies like that of Seed-X can help to speed up the process and increase the likelihood of success.

Protecting crops

AI can monitor the state of plants to spot and predict diseases, identify and remove weeds, and recommend effective treatment of pests. For example, a precision agriculture startup called Taranis uses computer vision and machine learning to analyze high-resolution images of crops, providing plant insights to identify signs of stress or disease. Their AI-powered technologies can detect and classify diseases and pests with high accuracy. It can also suggest the most effective treatment for pests, reducing the need for broad-spectrum insecticides that can harm beneficial insects and lead to pesticide resistance.

Observing crop maturity

Estimating crop growth and maturity is a tedious and challenging task for farmers, but AI can handle the job quickly and precisely. Through AI-powered hardware such as sensors and image recognition tools, farmers can detect and track crop changes to obtain accurate predictions on when crops will reach optimal maturity. Studies have found that using AI to predict the maturity of crops resulted in a higher accuracy rate than the accuracy rate achieved by human

observers. This increased accuracy can bring significant cost savings and higher profits for farmers.

Soil monitoring

Integrating sensors and AI systems enables farmers to accurately monitor how much water and nutrients are available in the soil. Using sensors in soil monitoring could involve deploying devices that measure various parameters like soil moisture, temperature, pH levels, and nutrient content. These sensors send information back to AI systems which then analyze it and provide instructions to farmers on how best to manage their crops based on what they find out about the soil conditions.

For example, the AI system might identify areas of the field where the soil is too dry or too moist and provide recommendations on when and how much water to apply to optimize crop growth. Similarly, the system might detect nutrient deficiencies in the soil and provide advice on the suitable types and amounts of fertilizer to use to improve yields**.**



Insect and plant disease detection

Farmers can use AI-powered systems to detect insects and plant diseases more quickly than humans. For example, an AI-powered system could detect an infestation of aphids on a crop of strawberries, send the data back to the farmer's mobile phone, and then suggest what action should be taken next. If a pesticide application is needed, the system could even automate it through a connected sprayer.

Intelligent spraying

Weed or pest control can be automated with AI technologies. With the help of computer vision, weeding robotics is said to be remarkably precise, resulting in a 90% reduction in

pesticide usage. Based on data analytics, these tools can calculate how much pesticide is needed for each field based on data about its history, soil status, or crop type.

Blue River Technology has disrupted traditional weed control methods with its flagship product, the "See and Spray" machine. Using computer vision and machine learning, the device can distinguish between crops and weeds and then apply herbicide only where needed. This can be cost-effective.

Analyzing market demand

Analyzing market demand is a crucial aspect of modern agriculture. AI can help farmers select the best crop to grow or sell. Descartes Labs is a New Mexico-based company that offers an AI-powered platform to help farmers evaluate market demand. The company develops machine learning algorithms to analyze satellite imagery and weather data, providing valuable insights on optimal planting times and the best crops to grow. By analyzing data patterns, Descartes Labs can predict the market demand for specific crops and help farmers maximize their profits.

The Future of AI in Agriculture

Artificial Intelligence (AI) in agriculture is poised to grow significantly in the coming years, as it has the potential to revolutionize the sector by improving crop yields, reducing waste, and increasing efficiency. Collecting and analyzing large amounts of data is among the most notable advantages of AI in agriculture for farmers. This will lead to more informed decision-making and improved crop yields, essential for addressing the global food security challenge.

Farmers can also use AI to monitor soil conditions, crop growth, and climate changes. As a result, they will be able to detect diseases early and take the necessary preventive measures before a crop is destroyed. AI will also continue to aid in forecasting weather changes, allowing farmers to plan their activities better and to take advantage of the optimal planting season.

Furthermore, AI can also help to reduce waste and resource usage. For example, farmers can use AI to optimize the amount of fertilizer and water used on their crops, leading to a more sustainable and environmentally friendly practice. This optimization will reduce the risk of soil and water contamination, which is an increasing concern today.

While the benefits of AI in agriculture are numerous, the reality is that most farmers worldwide, particularly smallholder farmers, lack the necessary resources to implement these technologies. Smallholder farmers typically have limited access to technical training, which makes it difficult

for them to operate AI systems effectively. Many also lack the financial resources needed to purchase the equipment and software required for AI-based farming. The adoption of AI in agriculture must be inclusive, considering the needs and limitations of smallholder farmers, who make up a significant portion of the global agricultural workforce.

Conclusion

Biofortification and AI-driven smart breeding represent a new era of agricultural innovation. Together, they ensure food crops are not only high-yielding but also nutritionally rich and climate-resilient. Efforts are underway around the world to create demand for high yielding biofortified crops and to develop healthy food products from biofortified crops so that non-farmers and urban consumers can also benefit. These technologies support global food security, sustainable farming, and better nutrition for future generations. Initiatives that provide access to training and funding for smallholder farmers to implement AI-based farming practices can help bridge the divide. With this, farmers at all levels can benefit from emerging technologies that the world needs to secure our food system's future.

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IPR RELATED TO PLANT GENETIC RESOURCES AND TRADITIONAL KNOWLEDGE

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Abstract

Intellectual Property Rights (IPR) related to plant genetic resources (PGR) and traditional knowledge (TK) involves a complex field of law that seeks to balance the rights of innovators, communities, and nations. The primary challenges include preventing the misappropriation of TK and ensuring the equitable sharing of benefits when PGR and associated TK are used commercially. The development of international treaties and national laws attempts to formalize this process, moving away from the historical assumption that this knowledge is part of the public domain.

Introduction

Intellectual property is the property to the intellect or brain which is an idea, a design, an invention, a manuscript etc. and can ultimately give rise to a useful product. World Intellectual property organization treaty on intellectual property, Genetic resources & Associated Traditional knowledge (ATK) is a significant win for countries of the global south including India. The treaty was adopted more than 150 countries, including the majority of the developed economies.

AIM

To balance the rights of countries rich in biodiversity & Traditional wisdom with the global IPR system

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Copyright

SUI GENERIS RIGHTS

Plant breeders rights

Indigenous intellectual property



PATENTS

Patents (Amendment) Act – 2005

Patent is an exclusive right granted for an invention.

It aims to protect the rights of indigenous communities by obligating patent applicants to disclose the origin of biological resources in their inventions

TRADEMARKS

Trademark Act- 1997

Trademark are used to claim exclusive properties of products or services.

It is typically name ,word, phrase, logo, symbol, design, image or a combination of these elements.

COPYRIGHT

Copyright act – 1957

A form of intellectual property that gives creators exclusive rights over their original works, protecting them from unauthorised use .

Ex: literary, dramatic, musical & artistic work

- duration of copyright 60 years.

SUI GENERIS RIGHTS

Sui generis rights are a form of intellectual property (IP) protection created for subject matter that doesn't fit within traditional IP categories like patents or copyrights.

The term, from Latin, means "of its own kind" or "in a class by itself".

PLANT BREEDERS RIGHTS

Also known as " plant variety Rights" are a form of intellectual property tha gives a breeder exclusive control over new plant varieties for a specific duration.



PBR schemes are regulated internationally by the International Union for the Protection of New Varieties of Plants (UPOV) Convention and are implemented through national or regional legislation.

INDIGENOUS INTELLECTUAL PROPERTY

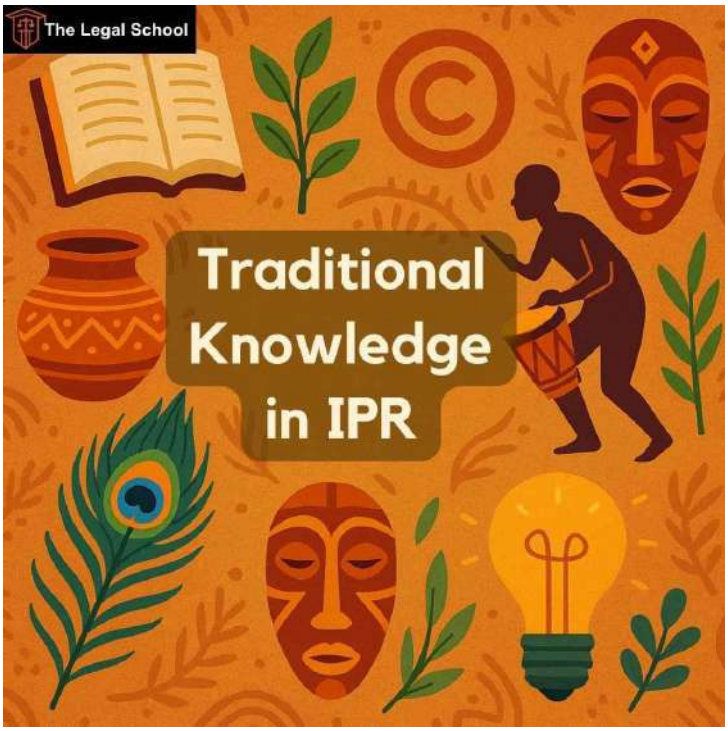
Indigenous intellectual property (IP) refers to the collective rights of Indigenous peoples to protect their traditional knowledge and cultural heritage

COMPONENTS:

Traditional knowledge (TK)

Traditional cultural Expression (TCE)

Genetic Resources (GRs)



TRADITIONAL KNOWLEDGE

The body of knowledge, know-how, skills, and practices that are developed, sustained, and passed down from generation to generation within a community.

This encompasses fields such as,

Traditional medicine & healing practices

Agricultural technique & biodiversity management

THREATS

Bio piracy

Erosion of culture

BIO PIRACY

This is the unauthorised commercial use of patenting of biological resource & associated traditional knowledge without a free, prior & informed consent of the communities who developed it.

EROSION OF CULTURE:

Globalization , external pressure & the decline of indigenous language can disrupt the oral transmission of TK to younger generations, causing invaluable knowledge to be lost forever.

PROTECTION

DEFENSIVE PROTECTION

Involves using existing IP laws & creating database, such as India ‘s (TKDL) Traditional knowledge Digital Library to prevent third parties from obtaining unjustified patents.

POSITIVE PROTECTION

This involves creating special legal systems, known as sui generis systems, to give TK holders more direct control & exclusive rights over their knowledge.

LANDMARK JUDGEMENTS SURROUNDING TRADITIONAL KNOWLEDGE IN IPR:

Neem case

Turmeric case

. Basmati rice case

Turmeric Case (1997):

Issue: The U.S. Patent and Trademark Office (USPTO) had granted a patent on the wound-healing properties of turmeric, which was based on Indian traditional knowledge



Neem Case (1999/2000):

Issue: The European Patent Office (EPO) granted a patent to the US firm W.R. Grace and the US Department of Agriculture for a method of controlling fungi using neem oil extract.



Basmati Rice Case (2001):

Issue: The company RiceTec claimed a patent on Basmati rice cultivation methods



INTERNATIONAL AGREEMENTS

WIPO Treaty on Intellectual Property, GeneticResources and Associated Traditional Knowledge - 2024

Convention on Biological Diversity (CBD) – 1992

Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits - 2010

International Treaty on Plant Genetic Resources for Food and Agriculture – 2001

Conclusion

The relationship between IPR, PGR, and TK is fraught with ethical and legal challenges. It requires a delicate balance between promoting innovation through the existing IP system and protecting the rights of indigenous and local communities who have preserved and developed

this knowledge over centuries. International agreements and national laws are gradually evolving to address these issues, with new frameworks being established to combat misappropriation and formalize the principles of access and benefit-sharing.

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Volume: 05 Issue No: 10

ROLE OF ARTIFICIAL INTELLIGENCE AND DIGITALIZATION IN DISASTER MANAGEMENT IN AGRICULTURE

Article ID: AG-V05-I10-146

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Abstract

Artificial intelligence (AI) and digitalization are revolutionizing disaster management in agriculture by enabling predictive analytics, efficient resource allocation, and rapid response to natural hazards. Recent advancements include AI-driven crop monitoring, early warning systems, and intelligent decision-support platforms, offering resilience against increasing environmental threats.

Keywords: artificial intelligence, digitalization, disaster management, agriculture, predictive analytics, resilience, early warning systems

Introduction

Rising global population and climate change have intensified the frequency and severity of agricultural disasters, including droughts, floods, pest outbreaks, and wildfires. Traditional methods of disaster management often struggle to meet the increasing complexity of these challenges. The integration of AI and digitalization in agriculture provides smart solutions for risk assessment, disaster prediction, and operational efficiency, supporting sustainable food production

Content

Role of AI in Disaster Prediction and ManagementAI-powered weather modeling and

satellite sensor networks enable early detection of crop-threatening hazards such as hail, fire, and drought, facilitating timely intervention and mitigating yield losses. Machine learning models, including Random Forests (RF), Support Vector Machines (SVM), and Artificial Neural Networks (ANN), now accurately predict drought stress, disease outbreaks, and pest invasions across diverse crop types and region.



Digitalization and Smart Farming System

Decision Support Systems

Decision support systems, fueled by big data and deep learning, empower farmers and authorities to prioritize resources, plan responses, and optimize recovery actions during and after disasters

AI-based decision support tools help farmers and policymakers choose the best response strategies before, during, and after disasters.

They integrate data from multiple sources to recommend:

- When to sow or harvest
- Which crops to plant under risk conditions
- Where to allocate emergency resources

Risk Mapping and Vulnerability Analysis

- Geographic Information Systems (GIS) combined with AI create risk maps for drought- or flood-prone regions.
- Helps governments plan disaster-resilient agricultural zones and insurance coverage.

Digital Communication and Advisory Services

- Mobile apps, SMS alerts, and AI chatbots provide farmers with localized weather forecasts and disaster alerts.
- Digital extension platforms ensure timely dissemination of recovery practices (e.g., re-sowing tips, input subsidies).
- Example: FAO's "Digital Village Initiative" and India's "Kisan Suvidha" app.

Real-Time Monitoring and Assessment

- Digital platforms and IoT (Internet of Things) sensors continuously monitor field conditions (temperature, rainfall, humidity, pest activity).
- AI-assisted image analysis from drones and satellites detects crop damage after disasters.
- Example: Use of drones for rapid flood damage assessment in paddy fields.

Early Warning and Prediction Systems

- AI-powered models analyze weather data, soil moisture, and satellite images to predict natural disasters such as droughts, floods, cyclones, or pest outbreaks.
- Machine learning algorithms help forecast extreme weather events more accurately and at local scales.
- Example: AI-based drought prediction using remote sensing and rainfall data.

CYBERSECURITY

Cybersecurity and digital infrastructure are essential for protecting smart farming systems from disruptions due to cyberattacks or system failures that could compromise critical agricultural operations.

Case Studies and Application

Examples: Studies in wheat farming demonstrate the fusion of multisource sensor data and machine learning for drought monitoring and moisture-status prediction, improving crop productivity and resilience.

Hail protection and fire detection

AI models have been implemented for large-scale crop monitoring, offering area-wide risk assessments and automated protective responses for farmers.

Region-specific disaster management platforms employ satellite data and intelligent algorithms to guide insurance decisions and policy response.

Discussion

The rapid expansion of AI research in agriculture disaster management has led to a diverse landscape of applications and collaborative networks worldwide. Trends suggest increasing emphasis on interdisciplinary approaches, global data sharing, and integration with policymaking and emergency planning. Key challenges remain in ensuring data security, bridging infrastructure gaps, and developing universal models adaptable to local contexts.

Conclusions

Artificial intelligence and digitalization offer transformative potential in disaster management for agriculture, driving predictive accuracy, operational efficiency, and adaptive capacity.

Future directions include real-time, universal risk assessment systems, enhanced cyber resilience, and large-scale collaborative networks between stakeholders. Integrating these technologies will be essential to protect food security and livelihoods in the face of mounting environmental uncertainties.

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DEVELOPMENT OF IOT AND DATA DRIVEN MODELS FOR ESTIMATION OF CROP EVAPOTRANSPIRATION A CASE STUDY OF OKRA (LADIES FINGER)

Article ID: AG-V05-I10-147

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Abstract

Efficient water management is vital for sustainable agriculture, especially for water-sensitive crops like Okra (*Abelmoschus esculentus*). This study presents a hybrid approach combining Internet of Things (IoT) technologies and data-driven models to estimate crop evapotranspiration (ET) in real time. A smart agricultural system was deployed using soil moisture, temperature, humidity, solar radiation, and wind speed sensors, all integrated into a cloud-based platform for continuous monitoring. Reference ET (ET_o) was calculated using the FAO-56 Penman-Monteith method, while crop ET (ET_c) was derived using Okra-specific crop coefficients and variable canopy resistance models. Traditional methods of ET estimation, including lysimeters and empirical models, are often costly, labor-intensive, and fail to capture the spatial and temporal variability of field conditions. To address these limitations, the present study focuses on the development of an IoT-based monitoring system integrated with data-driven models for real-time estimation of crop evapotranspiration in okra fields. This scalable solution demonstrates the potential of smart farming in semi-arid regions and offers a blueprint for optimizing water resources across diverse cropping systems.

Keywords: Reference evapotranspiration (ET_o), FAO-56 Penman-Monteith method, Internet of Things (IoT), Artificial Neural Networks (ANNs), Water use efficiency.

Introduction

Agriculture is rapidly evolving through the adoption of smart technologies and data analytics, with evapotranspiration (ET) estimation emerging as a critical factor in irrigation planning and sustainable crop production. ET, the combined loss of water via soil evaporation and plant transpiration, directly influences crop water requirements (CWR), which are essential for irrigation scheduling and maximizing yield. Water scarcity remains a major challenge in regions like Sub-Saharan Africa and arid parts of India, where rainfed agriculture and erratic rainfall patterns hinder year-round cultivation. Studies show that up to 60% of rainfall is lost to ET, severe dry-season water shortages and threatening food security. Efficient irrigation especially through drip systems and fertigation has proven effective in enhancing water and nutrient use efficiency, particularly in vegetable crops. Traditional ET estimation methods, such as the FAO Penman-Monteith equation, rely heavily on meteorological data and may not adapt well to microclimatic variations.

Moreover, crop coefficient (K_c) values are location and season-specific, requiring local calibration for accurate ET_c (crop evapotranspiration) determination. Okra (*Abelmoschus esculentus*), a commonly cultivated vegetable in tropical and subtropical regions, is highly sensitive to water availability during its growth stages. With its economic and nutritional significance, optimizing water use in okra cultivation is very important. This study explores the use of IoT-enabled sensors to monitor environmental parameters such as temperature, humidity, and soil moisture and applies machine learning models to estimate ET_c with greater precision. By integrating real-time data and predictive analytics, this research study aims to develop a scalable framework for ET estimation in okra, contributing to precision agriculture and sustainable water resource management.

2. MATERIALS AND METHODS:

2.1. Study Area and Crop Selection:

The present study was carried out in a open agricultural field located in Kumulur, Trichy, District , Tamil Nadu. It is a region known for its tropical climate, fertile soils, and suitability for year-round vegetable cultivation. The area experiences warm temperatures, moderate humidity, and seasonal rainfall, creating an ideal environment for growing Okra (variety viz., *Arka Anamika).* Okra was selected as the focus crop due to its agronomic relevance and economic potential. It is one of the most widely cultivated vegetables in tropical and subtropical regions,

valued for its nutritional content and dietary fiber. In India, okra contributes significantly to both domestic consumption and export earnings, accounting for a major share of fresh vegetable exports (Rs. 10 billions by Daniel, W (2024) excluding staples like potato, onion, and garlic.

From a cultivation standpoint, okra is highly sensitive to water stress, particularly during its flowering and pod development stages. Inadequate moisture during these critical at stages can lead to reduced yield and poor fruit quality. This sensitivity makes okra an ideal candidate for studies focused on evapotranspiration (ET) and precision irrigation. The choice of Kumulur as the study site was strategic, given its representative climate and soil conditions typical of many okra-growing regions in India. The field environment allowed for consistent monitoring of crop growth, soil moisture dynamics, and environmental variables, thereby enabling accurate data collection for model development. By focusing on okra in this setting, the present study aims to generate insights that are both locally relevant and scalable to other regions with similar agricultural profiles. The Fig. 1 shows the layout of the research field trial of okra with drip irrigation with plot area of 200 m^2.(20 m x 10 m) or (5 cents) of the farm field was ploughed thoroughly to bring the soil into fine tilth for effective seed bed preparation. The okra crop hybrid chosen was *Arka Anamika* which is resistant to yellow vein mosaic virus, (YVMV) and sown at 60 cm (lateral spacing) x 30 cm (dripper spacing). Various cultural practices such as thinning, weeding and insect pests and diseases control were carried out timely. In this research work, the drip fertigation (irrigation water along with water soluble fertilizers such as 19:19:19) system was followed.



Fig. 1: Layout of the research field trial of okra with drip irrigation

2.2. DRIP IRRIGATION:

Drip irrigation is a water-saving irrigation method that delivers water slowly and directly to plant roots through a network of tubes and emitters, minimizing evaporation and runoff. This low-pressure system applies water precisely where it's needed, reducing water wastage, inhibiting weed growth, preventing fungal diseases by keeping foliage dry, and delivering a consistent water supply for healthier plant growth. By targeting the root zone, drip irrigation can also improve nutrient uptake and allow for the direct application of fertilizers along with irrigation water (i.e., Fertigation).

2.3. YIELD AND WATER USE EFFICIENCY:

2.3.1. Water use Efficiency:

Water use efficiency is the yield of marketable crop produced per unit water used in evapo-transpiration (ET). It is usually expressed in kg ha^{-1} mm^{-1}.

Water use efficiency is of two types:

1. Crop water use efficiency and
2. Field water use efficiency

a) Crop water use efficiency:

It is the ratio of yield of crop (Y) to the amount of water depleted by crop in the process of evapo-transpiration (ET). It is also expressed in kg ha^{-1} cm^{-1}.

Mathematically, **CWUE** = $\frac{Y}{ET}$ ---------- (1)

Where, CWUE = Crop water use efficiency;

Y = Crop Yield;

ET = Evapo-transpiration.

b) Field water use efficiency:

It is the ratio of yield of crop (Y) to the total amount of water used in the field (WR).

Mathematically, **FWUE** = $\frac{Y}{WR}$ ---------- (2)

FWUE = Field water use efficiency;

Y = Crop Yield;

WR = Water Requirement.

2.3.2. Crop Water Requirement (ET_c): Crop water requirement is the total volume of water a crop needs for survival, growth, and economic yield, primarily to meet its evapotranspiration

(ET) losses from planting to harvest. This amount varies significantly based on the crop type, its growth stage, local weather conditions (temperature, rainfall, etc.,), soil type, and management practices. Effective irrigation management aims to supply this water, often through rainfall or irrigation, to prevent water stress and ensure healthy growth and maximum yield.

Mathematically, $\mathbf{ET_c = K_c \times ET_o,}$ ---------- (3)

where, ET_c = Crop evapotranspiration (or crop water requirement),

K_c = Crop coefficient (specific to the crop),

ET_o = Reference evapotranspiration (the water loss from a standardized grass surface such as Alfalfa).

2.3.3. Crop Coefficient: A crop coefficient (K_c) is a unitless ratio that represents how much water a specific crop uses (crop evapotranspiration, ET_c) compared to a reference crop (reference evapotranspiration, ET_O) under the same conditions. This factor that adjusts the ET_o to the specific ET_c of the crop being studied.

2.3.4. Crop Evapotranspiration (ET_c): The total amount of water lost through evaporation from the soil and transpiration from the crop.

2.3.5. Reference Evapotranspiration (ET_o): The amount of water that would be lost by a reference crop (often well-watered, clipped grass or alfalfa) under the same climatic conditions. It represents the atmospheric water demand and is determined by climatic factors like solar radiation, air temperature, humidity, and wind speed, not the specific crop or soil conditions. The FAO Penman-Monteith equation is the globally recognized standard equation for calculating ET_o, which is crucial for irrigation planning and scheduling. The Fig. 2 show the crop establishment 5 days after sowing (DAS). To measure the soil moisture tension, the instrument namely tensiometer was installed as shown in Fig. 3



Fig.2



Fig.3

2.4. Soil Vegetation Atmosphere Transfer Models:

The Soil Vegetation Atmosphere Transfer (SVAT) model is defined as a standard framework used to estimate the transfer of ammonia and other trace gases, incorporating a canopy compensation point approach to resolve the competition between leaf surface deposition and bi-directional fluxes. The Fig. 4 and 5 represents the okra crop under flowering stage (36 DAS) and fruiting stage (45 DAS) respectively



Fig.4



Fig.5

2.5. Meterological data collection:

The necessary data such as Maximum and Minimum Temperature (°C), Relative Humidity (%), Sunshine hours, Wind speed (ms^{-1}) were collected from the Kumulur weather station for finding reference evapotranspiration (ET_o) of okra crop.

3. RESULTS AND DISCUSSION:

The SVAT model integrated soil moisture, canopy resistance, and aerodynamic resistance parameters, driven by IoT-based meteorological data. Simulated ET from the SVAT model closely matched observed values from the Penman–Monteith method and lysimeter data. The R^2 between SVAT and reference ET was 0.94, indicating strong predictive performance. The results showed that average yields per plant were maximum recorded by *Arka Anamika* (76.25 g). The model effectively represented the physical processes of water transfer through soil and vegetation layers and provided a dynamic understanding of crop-water interactions. The SVAT-based estimation was particularly effective in accounting for soil evaporation and canopy transpiration components separately, unlike empirical models.

Conclusion

As per our experimental findings, we recommend Arka Anamika as a suitable variety to the farmers for effective yield and productivity. Commercial farmers must select location specific, high performing variety namely Arka Anamika for high yielding from nearer their

agrovet. The study is limited due to the changing weather and climatic conditions. The findings may not represent the large area due to the lack of time to conduct research and limited access to leveled land which found difficulty in maintaining homogenous field conditions. A single field trial may not be enough to provide the conclusion. Thus, to get valid results several varietal trials in different locations must be conducted with diverse climatic conditions.

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GRAVITY FED MICRO IRRIGATION A WATER SAVING SOLUTION

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Introduction

Gravity-fed micro irrigation is a low-pressure, energy-efficient, and long-lasting method of water distribution that makes use of gravitational potential energy. A network of mainlines, sub-mains, laterals, and emitters transports water to the crop root zone from a raised tank or reservoir in this system. Since gravity alone controls the flow of water, there is no need for mechanical pumping. At low discharge rates, this method applies water precisely and uniformly, maximizing plant growth, reducing evaporation and deep percolation losses, and improving water use efficiency. Gravity-fed micro irrigation works best in remote areas where power is scarce or nonexistent, undulating terrain, and smallholder farms.

COMPONENTS

A gravity-fed micro irrigation system consists of several essential components that work together to deliver water efficiently to the plant root zone by utilizing gravitational force. The major components are as follows:

1. Tank and the Source of Water

The primary source of water is an elevated tank or reservoir in which water is collected and stored. The gravitational head necessary to generate pressure for water flow through the system is provided by the tank's height.

2. Mainline

The mainline Is the primary conduit that carries water from the storage tank to the sub-main lines. It is usually made of PVC or HDPE pipes and designed to withstand low-pressure flow conditions.

3. Sub-main Line

Water is evenly distributed from the mainline to the lateral lines by the sub-main line. It helps to break up the total flow into smaller chunks, ensuring that the pressure in the system is evenly distributed.

4. Lateral Lines

Lateral lines are smaller-diameter pipes connected to the sub-mains. They run along the crop rows and deliver water to individual plants through emitters. Maintaining an even discharge necessitates a uniform spacing of laterals and the field's slope.

5. Emitters / Drippers

Emitters are the most critical components that control the discharge rate and ensure precise water delivery to the plant root zone. Low-pressure emitters are used in gravity-fed systems to keep uniformity under minimal head conditions.

6. Filters

To get rid of organic matter, silt, and suspended particles that could clog the emitters, filters are installed close to the tank outlet. Screen filters and sand media filters are two common types.

7. Control Valves

Control valves are used to regulate, isolate, or shut off the flow in different sections of the system. They help manage irrigation scheduling and water distribution efficiency.

8. Pressure Regulator (Optional)

In cases where elevation difference is high, a pressure regulator may be installed to maintain uniform pressure and prevent emitter damage.

WORKING CONSTRUCTION

Principle of Gravity-Fed Micro Irrigation's Operation Utilizing the energy of gravitational potential to evenly distribute water to the crop's root zone at a controlled discharge rate and low pressure is the fundamental operation of gravity-fed micro irrigation. Mechanical pumps are no longer required by the system, resulting in lower energy consumption and lower upkeep costs.

1. Head Formation and Storage of Water A reservoir, elevated tank, or overhead structure stores water. The elevation height provides the gravitational head (pressure) necessary to move water through the pipeline network. The pressure at which water can flow is greater the higher the height difference between the tank and the field.

2. Flow through the Sub-main and Mainline Water begins to flow through the mainline and sub-main pipes by gravity as soon as the outlet valve is opened. The purpose of these pipes is to ensure consistent flow while minimizing friction losses. The typical operating pressure for the system is between 0.5 and 2.0 meters of head.

3. Distribution along Lines of Laterality Water enters the crop rows along lateral lines that are laid out from the sub-mains. Most of the time, the laterals are made of polyethylene pipes with a small diameter that evenly distribute water along their length. In order to maintain a steady flow, the field's slope and water source's height are carefully designed.

4. Discharge Controlled Through Emitters Each lateral is equipped with emitters or drippers that release water directly to the root zone of each plant at a controlled rate. Even when the system operates solely on gravity, these emitters are made specifically for low-pressure operation to ensure uniform water application.

5. Filtration and Flow Regulation Water is filtered through screens or sand filters to remove suspended particles and prevent clogging before entering the mainline. Adjusting flow and ensuring consistent discharge at all outlets can be accomplished with the help of pressure regulators and control valves.

TYPES

- Gravity-Fed Drip Irrigation System Delivers water slowly to the base of each plant through drippers using gravity.
- Gravity-Fed Micro Sprinkler System Sprays water like light rain over crops using micro sprinklers without a pump.
- Gravity-Fed Inline Drip System Uses pipes with built-in drip emitters to water plants evenly.
- Gravity-Fed Bubbler Irrigation System Provides deep watering by releasing small streams of water around the plant's base.
- Gravity -Fed Porous Pipe (Soaker Hose) System Lets water seep slowly through a porous pipe along its length.
- A gravity-fed subsurface drip irrigation system delivers water to plant roots close to the surface of the soil.
- Gravity-Fed Surface Drip Tape System Uses thin, flexible tapes with holes to water crops on the soil surface.

SPECIFICATION

1. Head and Source of Water A water source that is fed by gravity, like an elevated tank or reservoir, is what the system uses. Required Head: 1–3 meters is typically sufficient for small-scale systems.
2. Rate of Flow The type of crop and the needs of the soil determine the flow rate. Drip Emitters: 1–8 liters per hour (lph) per plant.
3. Micro Sprinklers: 20–200 liters per hour (lph) depending on spacing. To avoid either over- or under-irrigation, uniformity is required across all outlets.
4. Main and Lateral Pipes Water is transported to plants by pipes from the source. PVC, PE, or flexible tubing can be the material. Diameter: Main line (25–50 mm), laterals (12–25 mm). Length: Limited to maintain pressure uniformity.
5. Emitters/Drippers at the plant root zone, emitters regulate the distribution of water. Types: Pressure-compensating, non-pressure-compensating, or inline emitters. Flow Rate: It must meet crop water needs. Spacing: Depends on plant spacing and soil type.
6. System of Filtration prevents sprinkler or dripper clogging. Common Filters: Screen filters, disc filters, or sand filters. Drip systems typically use mesh sizes between 120 and 200 microns.
7. Layout and Slope Since the system uses gravity: Slope: Gentle slop(0.5–2%) ensures uniform water flow. Layout: Main and lateral lines should follow the topography.
8. System Capacity The area and crop water requirements determine capacity. Small-scale systems: 500–2000 liters per day. Orchard or plantation systems: 5,000–20,000 liters per day.

ADVANTAGE

- Water Conservation – Delivers water directly to plant roots, reducing wastage.
- Utilizes no electricity or pumps to save energy.
- Improves crop yield and quality by ensuring that the soil is adequately moist for improved growth.
- Low Maintenance and Easy Operation – Simple design, easy to repair and clean.
- Reduced Soil Erosion and Nutrient Loss: Leaching and runoff are prevented by applying water slowly.
- Flexibility and Adaptability – Suitable for slopes, orchards, vegetables, and nurseries.

- Environmentally friendly because it reduces chemical runoff and conserves water.

DISADVANTAGES

- Elevation Dependence on the Water Source Requires a Tank or Reservoir That Is Elevated for Enough Pressure.
- Lack of Pressure and Flow Control: Unable to easily adjust pressure, which results in uneven distribution of water.
- Risk of Clogging: If filtration is inadequate, sediments could clog emitters and pipes.
- Not Suitable for Large-Scale Farming – Gravity alone may not provide uniform irrigation over large areas.
- Limited Fertigation Capability: Uneven fertilizer distribution can be hindered by low pressure.
- Initial Setup Constraints – Requires careful planning of slope, pipe layout, and tank placement.

APPLICATION

- Vegetable and Fruit Crops – Used to water vegetables and fruits directly at the root for better yield and quality.
- Orchards and plantation crops: Provides trees and plantation crops with deep root watering.
- Seedlings and potted plants receive uniform water from nursery and greenhouse crops.
- Hilly and Remote Areas – Suitable where pumps or electricity are unavailable.
- Low-Cost and Smallholder Farms: Affordable irrigation for kitchen gardens and small farms.
- Fertigation – Delivers water along with soluble fertilizers directly to plant roots.

FUTER SCOPE

- Water conservation: Can be utilized extensively in semi-arid and water-poor regions.
- Energy-Effective: Suitable for remote areas, it operates without electricity or pumps.
- Support for Smallholder Farmers: Affordable and simple to keep up for backyard gardens and small farms.
- Agriculture that is climate-resilient minimizes crop stress, soil erosion, and waterlogging.

- Crop diversification makes it possible to grow high-value fruits, vegetables, and medicinal plants.
- Integration of Technology: Compatible with sensors, fertigation, and intelligent irrigation systems.
- Research and Development Opportunities – Potential for improving emitters, using local materials, and adapting to hilly or uneven terrains.

Conclusion

Gravity-fed micro irrigation, or GFMI, uses gravitational force to deliver water directly to the plant root zone and is a sustainable, low-cost, and water-efficient method of irrigation. It is ideal for smallholder farms, orchards, nurseries, and hilly terrain due to its numerous benefits, including reduced upkeep, energy savings, increased crop yield, and water conservation. Despite certain limitations such as dependence on water source elevation and potential clogging, careful design, proper filtration, and slope management can overcome these challenges. With increasing water scarcity, energy constraints, and the need for climate-resilient agriculture, GFMI has significant potential for expansion. Its integration with cutting-edge technology, crop diversification, and fertigation have the potential to further boost productivity and sustainability. In conclusion, gravity-fed micro irrigation is a practical, eco-friendly, and cost-effective option for modern agriculture, particularly in locations where conventional irrigation methods are unaffordable or impossible to implement.

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SWOT ANALYSIS: VERTICAL FARMING

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Introduction

Dr William Gericke and colleagues perfected an alternative strategy to soil-based farming in 1930, where crops are grown in the absence of soil which is called hydroponic. Instead of normal soil Dr Gericke and colleagues created an aqueous solution, a solution where the solvent is water, which is used to provide the crops with the right amount of nutrients to grow.

In 2007, Despommier finalized his concept of the vertical farm. He combined the strategy of Dr Gericke (1930), the innovative technology with growing crops on vertical stacked racks to create a vertical farm. In these vertical farms Led lights and computer assisted control systems are used to create the perfect crop. The computer assisted control systems assure that the crops get the right amount of nutrients and light. This strategy of farming is now used all over the world in greenhouses. Indoor farming is also referred to as CEA, Controlled Environmental Agriculture. “CEA has rapidly evolved into a commercially viable approach for the large-scale production of a wide variety of crops in close proximity to, or even within, urban centres.



Strength:

- ✓ **Higher Yield from lesser space and cost -** Vertical farming utilizes vertical space efficiently, allowing for higher crop yields per square metre compared to traditional farming methods. Any land can be used for cultivation inspite of fertile or non-fertile of the land.
- ✓ **Water Conservation -** Vertical farming typically uses hydroponic or aeroponic systems, which require less water compared to conventional soil-based agriculture, making it more water-efficient.
- ✓ **Customization and Control -** Precise regulation of environmental variables such as light intensity, temperature and humidity enables optimization of growth conditions for diverse crops, yielding high-quality produce with consistent outputs.
- ✓ **Year-Round Production -** Maintenance of regulated environments in vertical farms facilitates continuous production, independent of external weather conditions, thereby mitigating seasonal constraints.
- ✓ **Reduced Carbon Footprint -** Vertical farms can substantially decrease carbon emissions associated with food transportation by decreasing distances from farm to consumer.
- ✓ **Market availability -** Most products are available in the market needed for hydroponics such as nutrient solutions, plant growing kit, etc
- ✓ **Research and extension -** Availability of agricultural university and research institutes for technical support.
- ✓ **Other benefits -** Producers can start their own business without owning agricultural land. The crops can be produced in a healthier manner with fewer pesticides. Minimal human activity.

Weakness

- ✓ **High Initial Investment -** The establishment expenses for vertical farming are substantial, encompassing infrastructure, technology and specialized equipment, rendering it financially unfeasible for many farmers. Precision monitoring and expensive start-up costs limit this technology to low-profile crops.
- ✓ **Energy Consumption -** Vertical farms necessitate substantial energy consumption for artificial illumination, heating, cooling and other environmental regulation systems, resulting in elevated operational expenses and ecological issues.

- ✓ **Technological Dependency -** Dependence on intricate technology and automation systems implies that any malfunction or breakdown could interrupt operations and impact agricultural harvests.
- ✓ **Lack of knowledge -** Most farmers lack basic entrepreneurship knowledge and skills related to smart farming. Availability of many subsistence farmers. Wrong assumptions made by people that plants grown in soilless environment are unnatural.
- ✓ **Lack of research -** Extremely low use of research findings from agriculture universities and research institutes by private companies and government organizations.
- ✓ **Limited Crop Variety -** Some crops may not be suitable for vertical farming due to their size, growth requirements, or economic feasibility, limiting the range of produce that can be cultivated. Further, pollination rate is very low.
- ✓ **Perception and Consumer Acceptance -** Despite its potential benefits, vertical farming is still relatively new and may face skepticism or resistance from consumers accustomed to traditional farming methods.

Opportunities:

- ✓ **Urban Agriculture -** Vertical farming offers the chance to cultivate fresh produce within urban areas, lessening dependence on far-off rural farms and bolstering food security in densely populated regions. Chemical usage is reduced to a great extent which encourages the people to use the vegetables produced in this method. There are no seasonal restrictions.
- ✓ **Local Food Movements -** Rising consumer interest in locally sourced and sustainably produced food creates a market opportunity for vertical farms to provide fresh, high-quality produce to nearby communities. Can be used for growing different crops available in all over the world despite of the environmental issue.
- ✓ **Technological Advancements -** Ongoing advancements in automation, LED lighting and environmental control systems have the potential to enhance efficiency, lower costs and broaden the variety of crops suitable for vertical farming.
- ✓ **Research and Development -** Ongoing research into plant genetics, cultivation techniques and nutrient formulations can drive innovations that can improve the crop yields and nutritional content of the plant species.

- ✓ **Collaboration and Partnerships -** VF companies can collaborate with urban planners, architects and food distributors to integrate vertical farms into urban infrastructure and create more resilient and sustainable food systems.

Threats:

- ✓ **Competition with traditional agriculture -** Conventional farming methods dominates the agricultural practices unless VF has clear economic and environmental advantages.
- ✓ **Regulatory Challenges -** Regulatory barriers like zone restrictions, food safety regulations and certification requirements, could impede the growth of vertical farming.
- ✓ **Environmental Concerns -** Despite its potential to reduce land use and pesticide usage, vertical farming still faces scrutiny over environmental impacts like waste generation and pollution effects.
- ✓ **Management risks -** Disease management is a huge risk in vertical farming and availability of human resources is needed. When a component of the vertical irrigation system fails, may cause death of plants.
- ✓ **Market Volatility -** Variations in the costs of energy, land and agricultural commodities could impact profits of vertical farming ventures.

Conclusion

Food sustainable development in urban areas could benefit greatly from the use of vertical farms. As we design into the long term, whenever the urban population is expected to grow considerably, this is critical. In terms of environmental, social and economic sustainability, vertical farming has a myriad of benefits over rural farming. The need for soil-based farming is being largely challenged by new high-tech cultivation techniques such as hydroponics, aeroponics and aquaponics.

When it comes to growing crop production, vertical farming is becoming increasingly popular. Soil- and water-constrained areas and the poorest and landless can benefit greatly from vertical farming, which allows crops prefer fodder maize, potatoes and short-lived crops like vegetables to be grown year-round in very small spaces with lower labour requirements. Future growth of the vertical farm industries in India is predicted to be tremendous. Low-cost hydroponics and other low-cost vertical farming technologies must be developed in effort to enhance commercial vertical farming as well as lesser startup and operating cost. Affordability for low-income families is a major concern when implementing a vertical farm. Slums, food

deserts and other modern-day dislocations are all factors contributing to the poverty of these people. There are many variables that can affect the success of vertical farming, such as the supply and amount of food, population size, technological advancement, cultural and dietary patterns and energy and water supply.

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SMART FERTIGATION TECHNOLOGY FOR EFFICIENT NUTRIENT AND WATER MANAGEMENT

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Introduction

Precision irrigation and intelligent nutrient delivery systems are combined in smart fertigation technology to maximize the utilization of fertilizer and water in agriculture. Smart fertigation enables real-time monitoring and control of soil moisture, nutrient concentration, and environmental conditions by combining sensors, automation, and Internet of Things (IoT) technology. This reduces waste and pollution of the environment by ensuring that crops receive the right amount of water and nutrients at the right time. While maintaining or increasing crop yield and quality, studies have demonstrated that smart fertigation significantly improves water-use efficiency (WUE) and nutrient use efficiency (NUE). The system typically includes soil and weather sensors, electronic control units, and automated injection systems that adjust fertigation schedules based on data- driven decisions. Smart fertigation can save up to 30–60% of water and 20–40% of fertilizer inputs when compared to manual fertilization and traditional irrigation. By reducing greenhouse gas emissions, improving soil health, and reducing nutrient leaching, this technology also supports sustainable agriculture.

Keywords:

Management of nutrients, precision agriculture, drip irrigation, water-soluble fertilizers, fertilization, micro irrigation, efficiency, and sustainable farming.

Introduction

One of the most significant difficulties in contemporary agriculture is the effective management of nutrients and water. With the growing demand for food and limited availability of freshwater resources, farmers are under pressure to adopt advanced technologies that ensure higher productivity with minimal environmental impact. Smart fertigation technology has emerged as a contemporary and long-lasting solution to these problems. Smart fertigation is the process of applying fertilizers through an irrigation system with the help of sensors, automation, and digital control technologies. It integrates precision irrigation with data-driven nutrient management, allowing real-time monitoring of soil moisture, electrical conductivity (EC), pH, temperature, and weather conditions.

The system uses platforms from the Internet of Things (IoT), microcontrollers, and decision-support algorithms to automatically adjust the timing and dosage of fertilizer and water based on the needs of the crop. Crops' nutrient- and water-use efficiency (NUE) is enhanced as a result of this technology, which ensures that they receive the appropriate quantities of nutrients and water at the appropriate times and locations. Smart fertigation systems outperform conventional methods in terms of yield, quality, and resource conservation, according to studies. In addition, smart fertigation reduces nutrient losses, minimizes leaching and runoff, and contributes to sustainable soil health.

DEFINITION

Smart fertigation technology is an advanced agricultural system that combines fertilizer application with irrigation using automated control, sensors, and data- driven technologies to deliver the right amount of water and nutrients directly to the root zone of crops at the right time and in precise quantities. This technology enhances nutrient use efficiency, water conservation, and crop productivity through real-time monitoring and intelligent decision-making systems.

COMPONENTS

A fertigation system consists of several key components that work together to mix, control, and deliver nutrients through irrigation water. The main components are:

1. Water Source :Provides the water used for both irrigation and fertilizer application.
2. Tank for fertilizer (injection unit): holds the fertilizer, which will be injected into the irrigation line and be either soluble or liquid.
3. Fertilizer Injector or Pump: Controls the rate at which fertilizer is mixed with

irrigation water. Common types include venturi injectors, piston pumps, and diaphragm pumps.

4. The Mixing Room: Ensures uniform mixing of fertilizers with irrigation water before distribution.
5. Filters: To avoid clogging the irrigation system, get rid of impurities and undissolved particles.
6. Irrigation Network (Pipes and Drip Lines): dispenses the water enriched with fertilizer to the crop's root zone.
7. Control Valves and Pressure Regulators: For precise fertigation, the system must maintain the appropriate pressure and flow rate.

WORKING AND CONSTRUCTION

Working Principle:

Fertilization is based on injecting soluble fertilizers into irrigation water, allowing crops to receive both nutrients and moisture simultaneously.

Enhancing crop yield and resource utilization efficiency, the procedure ensures precise and effective nutrient management.

Step 1: Making the Fertilizer Solution To make a uniform nutrient solution suitable for injection into the irrigation system, soluble fertilizers are dissolved in water.

SPECIFICATION

1. The kind of system: Drip or sprinkler irrigation-based fertigation system.
1. Water Source: Clean water supply with adequate pressure(1.0–2.5 kg/cm²).
2. Capacity of the Fertilizer Tank: 50 to 200 liters typically (depending on the size of the field and the amount of fertilizer used).
3. Type of fertilizer injector: Venturi Injector: Operates on a pressure difference (often in sizes of 12", ¾," or 1") Pump Injector: Piston or diaphragm type for larger systems.
4. Injection Rate: Adjustable — generally 1% to 10% of irrigation flow rate.
5. Filter Unit: Screen or Disc Filter: 120–150 mesh to prevent clogging of emitters. When there are suspended particles in the water, a sand filter is used.
6. Laterals and Main Line: PVC or HDPE pipes, whose diameters range from 16 millimeters for laterals to 63 millimeters for mainlines, depending on system size.

7. Pressure Control: For drip systems, pressure regulators maintain a constant operating pressure of approximately 1.5–2 kg/cm2.
8. Valves for Control: Manual or automatic valves to control flow and isolate sections of the system.
9. Optional monitoring device: EC (Electrical Conductivity) and pH meters for monitoring nutrient concentrations in real time.
10. Requirement for Power: Usually 0.5 to 2 HP pump for fertilizer injection (in powered systems).

ADVANTAGE

- Efficient use of fertilizers — nutrients reach directly to the root zone.
- Saves both water and fertilizer through combined application.
- Improves nutrient uptake and overall plant growth.
- Ensures uniform distribution of water and nutrients.
- Reduces labor and operational cost.
- Allows flexible and precise control of nutrient supply.
- Increases crop yield and quality.
- Minimizes environmental pollution and nutrient loss.

DISADVANTAGE

- High initial installation and setup cost.
- Requires skilled operation and maintenance.
- Clogging of drip emitters may occur due to impurities.
- Some fertilizers may not be compatible with irrigation water.
- Needs regular monitoring of fertilizer concentration.
- Dependence on continuous power supply and proper equipment.
- Over-application can damage plants or pollute soil and water.

FUTURE SCOPE OF FERTIGATION

- Precision Agriculture Integration Fertigation will increasingly integrate with precision farming technologies such as IoT sensors, drones, and GIS mapping. This enables real-time monitoring of soil moisture, nutrient levels, and crop needs, ensuring precise nutrient delivery.

- Automation and Smart Control Systems The future will see fully automated fertigation units that adjust fertilizer dosage automatically based on data from sensors. AI and machine learning algorithms can optimize fertilizer use, minimizing human error and waste.
- Utilization of Nano- and Organic Fertilizers Bio- and nano-fertilizers, organic nutrients, and fertigation will all contribute to environmentally friendly and sustainable farming. This approach enhances nutrient uptake efficiency and reduces environmental pollution.
- Water and Nutrient Conservation Fermentation systems will evolve to maximize water use efficiency and minimize nutrient leaching as water scarcity grows. Climate-resilient agriculture will rely heavily on fertigation systems that are based on drip and sprinklers.
- Integration with Renewable Energy It is anticipated that solar-powered fertigation units will become more common, particularly in rural or remote farming areas. This reduces operational costs and supports sustainable agricultural practices.

Conclusion

Fertigation is a sophisticated and effective method that delivers nutrients directly to the plant's root zone b Singh y combining fertilization and irrigation. It improves crop growth and yield, reduces nutrient losses, and ensures optimal use of fertilizers and water. Farmers can increase productivity while reducing input costs and impact on the environment by implementing fertigation. Fermentation has a lot of potential for future smart and sustainable farming if modern technologies like automation, sensors, and precision agriculture are integrated.

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ADVANCEMENTS IN AGRICULTURAL SPRAYER TECHNOLOGY FOR PRECISION PESTICIDE APPLICATION

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Abstract

The effective application of agrochemicals (pesticides, herbicides, fertilizers) is paramount for sustainable agriculture, ensuring crop protection, optimal yields, and minimized environmental impact. This paper reviews the evolution of **sprayer technology**, from conventional hydraulic sprayers to modern **Precision Spraying** systems. The core challenge addressed is achieving uniform target coverage while mitigating issues like drift, runoff, and excessive chemical use. Modern innovations, particularly **Smart Spraying** integrating sensors and AI, represent a paradigm shift, enabling highly targeted, **variable-rate application** and significantly boosting the efficiency and environmental responsibility of crop management. The findings underscore the critical role of advanced application technology in meeting global food security and sustainability goals.

Introduction

Agricultural sprayers are delivery systems that ensure the uniform and timely distribution of liquid agrochemicals onto crops or soil. The primary goal of application technology is to maximize the amount of active ingredient that reaches the biological target (e.g., a pest or weed) while minimizing off-target losses (drift, runoff, volatilization).

Importance of Proper Application

- **Efficacy:** Uniform coverage ensures the chemical is effective against the target pest or disease, preventing under dosing and the risk of resistance.
- **Economics:** Efficient application reduces chemical wastage, lowering input costs for

farmers.

- **Environment:** Minimizing off-target movement (drift and runoff) protects non-target organisms, soil health, and water quality.

Application Challenges

- **Non-uniformity:** Spray quality (droplet size) and deposition often vary across the target, especially in dense canopies.
- **Drift:** Small droplets are easily carried away by wind, leading to chemical loss and contamination of neighboring areas.
- **Blanket Application:** Traditional systems treat the entire field uniformly (**broadcast application**), leading to over-application in areas with low or no infestation.

Advancements in Sprayer Technology

Modern technology focuses on increasing precision, reducing chemical volume, and improving safety.

Main Functions of a Sprayer

1. **Atomization:** To **break the bulk liquid** solution into fine droplets of the correct size. The droplet size must be appropriate for the target (e.g., fine for flying insects, coarse for herbicides to reduce drift).
2. **Uniform Distribution:** To **distribute the droplets evenly** across the treated area, ensuring consistent coverage of the target plants or soil to maximize chemical effectiveness.
3. **Penetration and Coverage:** To apply the spray with sufficient force (pressure or air assistance) to **penetrate dense crop canopy** and cover all parts of the plant, including the underside of leaves.
4. **Flow Regulation:** To **control the rate of liquid application** (volume per unit area) accurately, preventing both under-dosing (poor control) and over-dosing (chemical waste and potential crop damage).
5. **Safe Containment and Transport:** To securely **store and transport the chemical mixture** in a corrosion-resistant tank, minimizing leaks, spills, and operator exposure.
6. **Agitation:** To **keep solid chemical particles suspended** and uniformly mixed within the liquid solution in the tank, ensuring a consistent concentration is sprayed throughout the operation.

Desirable Qualities of a Good Sprayer

1. **Durability and Chemical Resistance:** Should be constructed from **strong, corrosion-resistant materials** (like high-quality plastic or stainless steel) that can withstand harsh agrochemicals and continuous use.
2. **Ease of Calibration:** Must have components (nozzles, pressure gauge) that allow for **accurate and simple calibration** to ensure the correct application rate is maintained
1. **Adjustable and Consistent Pressure:** The pump and regulator system must be capable of generating the **required pressure** and maintaining it consistently to ensure the desired droplet size and spray pattern.
2. **Ergonomics and Comfort (for portable units):** Should be **lightweight and comfortable** to carry (e.g., padded straps, good weight distribution) to reduce operator fatigue and enhance safety.
3. **Accessibility and Maintenance:** All essential parts (filters, nozzles, tank) should be **easy to access, clean, and maintain** to prevent clogging and cross-contamination between chemicals.
4. **Leak-Proof System:** Must have **robust, high-quality seals and fittings** to prevent leaks from the tank, hoses, or nozzle, which ensures operator safety and prevents environmental contamination.

Types of Sprayers

Sprayers are often classified based on their power source, mounting, and the mechanism used to atomize the liquid:

Classification by Power Source/Mounting

Sprayers are classified based on the source of energy used for spraying operations. The main types are:

1. Manual (Hand-Operated) Sprayers

Operated by hand or foot power.

Examples: Knapsack sprayer, foot sprayer, hand compression sprayer. Suitable for small areas and garden use.

2. Power-Operated Sprayers

Powered by electric motor, engine, or tractor PTO. Examples: Power sprayer, mist blower.

Used for large-scale spraying in fields and plantations.

3. Tractor-Mounted Sprayers

Attached to a tractor's 3-point linkage and powered by the tractor's PTO.

Suitable for large farms and commercial operations Examples: Boom sprayer, air-assisted sprayer.

4. Aerial Sprayers

Mounted on aircraft or drones for large area coverage.

Used for forest, plantation, and pest control over wide areas.Components of a Typical Sprayer

A complex sprayer system (like a power or boom sprayer) generally consists of the following key components:

1. **Tank (Liquid Container):** Stores the spray solution (chemical mixture). Made of materials resistant to corrosion, such as polyethylene, fiberglass, or stainless steel.
2. **Pump:** The "heart" of the sprayer, responsible for drawing the liquid from the tank and pressurizing it. Common types include:
   - **Diaphragm Pumps:** Good for high-pressure spraying and handling abrasive chemicals.
   - **Piston Pumps:** Can produce very high pressure.
   - **Centrifugal Pumps:** High-volume, low-to-moderate pressure.
3. **Power Source:** The mechanism driving the pump, such as a manual lever, battery, electric motor, internal combustion (IC) engine, or a tractor's PTO.
4. **Agitator:** A mechanism (mechanical or hydraulic bypass) to constantly mix the spray solution in the tank to prevent chemicals from settling.
5. **Strainers/Filters:** Placed at various points (tank filling, suction line, pressure line) to remove dirt and debris, protecting the pump and preventing nozzle clogging.
6. **Pressure Regulator and Gauges:**

   Pressure Regulator: A valve that controls and maintains the desired spray pressure, diverting excess fluid back to the tank (bypass).

   Pressure Gauge: An instrument that shows the actual pressure in the system, crucial for ensuring the correct application rate.
7. **Valves and Plumbing (Hoses/Pipes):**

   Valves: Control the flow to the boom or individual spray lines (e.g., master shut-off, section control valves).

   Hoses/Pipes: Carry the liquid throughout the system.

8. **Boom / Spray Lance / Spray Gun:** The output mechanism:

   Boom: A long horizontal arm with multiple nozzles for wide-area coverage (used in field sprayers).

   Spray Lance / Gun: A handheld device for targeted spraying (used in knapsack or power sprayers).

9. **Nozzles (Spray Tips):** The most critical component for atomization. They break the liquid stream into droplets, distribute the spray in a specific pattern, and determine the flow rate. Nozzle types include flat-fan, cone, and flood tips, each used for different applications.

Nozzle Types

Flat-Fan Nozzles:

Produce a wide, flat spray pattern, ideal for uniform coverage in applications like herbicide and foliar fertilizer application.

Full-Cone Nozzles:

Deliver a circular, filled-in spray, providing good coverage for deep penetration through dense areas.

Hollow-Cone Nozzles:

Create a cone-shaped spray with a hollow center, excellent for fine misting or applications where a fine spray is needed without full coverage.

Solid-Stream Nozzles:

Provide a concentrated, straight stream of liquid, suitable for deep penetration into dense thickets or soil treatments.

Manual Sprayer (Hand-Operated Sprayer): A device where the operator manually uses a pump or lever to build up air pressure inside a liquid-filled tank. The stored pressure is what forces the spray liquid out through a nozzle. They are typically portable, low-cost, and used for small areas like gardens or for spot treatments.

Power Sprayer (Motorized Sprayer): A spraying unit that uses an engine (like gasoline or electric motor) to drive a pump. This pump continuously generates high, consistent hydraulic pressure, allowing the user to apply liquids over larger areas without the physical exertion of manual pumping. They are commonly used for medium to large-scale agriculture and orchards.

Hydraulic Sprayer: A broad class of sprayer where the force of the liquid itself (hydraulic energy) is used to break the spray solution into droplets. The liquid is pressurized by a pump (which can be manual or motorized) and then forced through a nozzle's small opening, where the sudden drop in pressure and high velocity create the spray pattern. Many common farm and garden sprayers, including boom sprayers, operate on a hydraulic principle.

Aerial Sprayer: A highly specialized system for applying liquid substances (like pesticides, fertilizers, or seeds) from an aircraft (fixed-wing airplane or helicopter) or increasingly, a large drone. It is used to cover vast tracts of land quickly and efficiently, making it suitable for large-scale commercial agriculture.

Conclusion

In conclusion, sprayers—ranging from portable **manual** and **hydraulic** units to high-capacity **power** and specialized **aerial** systems—are indispensable tools for effective fluid application across various sectors, most notably agriculture.

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WORLD'S FIRST CRISPR-EDITED SPIDER PRODUCES GLOWING RED SILK FROM ITS SPINNERET

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Abstract

In a groundbreaking scientific development, researchers have successfully created the world's first CRISPR-edited spider capable of producing red fluorescent silk directly from its spinnerets. Using the CRISPR-Cas9 gene-editing system, scientists integrated the gene for a red fluorescent protein (RFP) into the silk-producing genes of the orb-weaving spider (Nephila clavipes). The resulting silk glows under ultraviolet light while retaining its original tensile strength and elasticity. This innovation marks a significant leap in biomaterial science and synthetic biology, paving the way for futuristic applications in medicine, textiles, and environmental monitoring.

Keywords: CRISPR-Cas9, gene editing, spider silk, fluorescent protein, biomaterial engineering, synthetic biology, biotechnology innovation

Introduction

Spider silk has long fascinated scientists for its extraordinary strength, elasticity, and biodegradability. The silk produced by orb-weaving spiders is five times stronger than steel by weight and has a wide range of potential uses, from sutures to bulletproof fabrics. However, spiders are territorial and cannibalistic, making large-scale silk harvesting impractical. Genetic engineering, particularly using the CRISPR-Cas9 system, now provides an effective pathway for tailoring silk properties by directly modifying spider DNA.

The latest success — producing spiders that secrete red fluorescent silk — exemplifies the power of genome editing in manipulating natural materials. This innovation offers a vivid visual marker

for understanding silk protein synthesis while also demonstrating possibilities for designing customizable biopolymers.



CRISPR-Cas9 and Spider Genome Editing

The CRISPR-Cas9 tool enables precise genetic modifications by targeting specific DNA sequences. In this experiment, researchers introduced a gene encoding red fluorescent protein (RFP), originally derived from coral, into the fibroin gene sequence of Nephila clavipes. This integration ensures that the fluorescent protein fuses with the silk fibroin during synthesis.

The editing process was performed on spider embryos using microinjection techniques. Once the spiders matured, their silk was analyzed for structural and fluorescent properties. When exposed to ultraviolet light, the silk emitted a bright red glow, confirming successful transgene expression without compromising its mechanical integrity.

Properties and Applications of Glowing Silk

The CRISPR-edited silk retained the spider's natural spinning efficiency while gaining fluorescence, allowing for visual tracking of silk production pathways. This discovery holds immense potential for several fields:

1. Biomedical Applications: Fluorescent silk can be used in surgical sutures, tissue scaffolds, and drug delivery systems for real-time visualization during medical procedures.
2. Textile Innovation: The bioluminescent fibers could lead to glow-in-the-dark fabrics, providing both aesthetic and safety uses in apparel and outdoor gear.
3. Environmental Monitoring: As a biodegradable material, fluorescent silk could serve as a biosensor, detecting environmental pollutants or radiation when coupled with responsive fluorescent markers.

4. Scientific Visualization: The fluorescent properties enable detailed study of silk protein pathways, gland function, and material formation at the molecular level.



Ethical and Technical Challenges

Despite its promise, CRISPR editing in spiders presents several challenges. Spiders' complex reproductive systems make controlled gene transmission difficult, and there are ecological concerns regarding the potential release of genetically modified organisms (GMOs). Moreover, ensuring biosafety and ethical compliance remains essential in biotechnology research. Continued work is needed to refine embryo microinjection techniques, ensure stable gene inheritance, and assess long-term ecological impact.

Conclusion

The development of the world's first CRISPR-edited spider that produces glowing red silk represents a remarkable milestone in biomaterial research. By merging genetic engineering and material science, scientists have opened new avenues for sustainable, customizable biofibers. As this technology matures, it could revolutionize fields ranging from medicine to fashion while deepening our understanding of silk biochemistry and genetic innovation.

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HUMAN-WILDLIFE CONFLICT

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Introduction

According to the IUCN SSC, human-wildlife conflict occurs when the behavior or presence of wildlife is perceived as a persistent threat to human interests or needs. This can lead to interpersonal disputes and may result in harm to both humans and animals.

Human-wildlife conflict is when encounters between humans and wildlife lead to negative results, such as loss of property, livelihoods, and even life. Defensive and retaliatory killing may eventually drive these species to extinction. These encounters not only result in suffering for both people and wildlife immediately impacted by the conflict; they can also have a global reach, with groups such as sustainable development agencies and businesses feeling its residual effects. The scope of the issue is significant and truly global, but we are nowhere near being able to address it at the scale needed.

Why is Human-Wildlife Conflict on the Rise?

As human populations and demand for space continue to grow, people and wildlife are increasingly interacting and competing for resources, which can lead to increased humanwildlife conflict. Along with other threats, human-wildlife conflict has driven the decline of once-abundant species and is pushing others to the brink of extinction. But the human-wildlife conflict issue has far-reaching impacts beyond the wildlife and communities immediately affected by it. With human-wildlife conflict centered around the interaction between wildlife and humans, human-wildlife coexistence is strongly linked and important to sustainable development activities. If not effectively managed, human-wildlife conflict has the potential to negatively affect these activities and conservation much more broadly.



An Elephant Herd Raids Crops in India



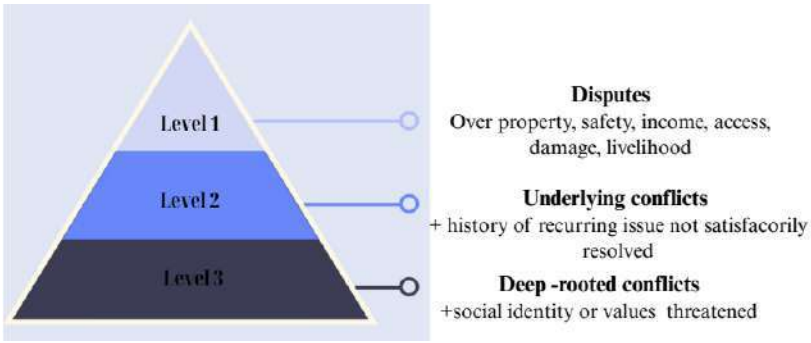
Livestock Guarding Dogs Protect Their Charge Against Predators.

Who is impacted by Human-Wildlife Conflict and in What Ways?

Human-wildlife conflict impacts both animals and people in multiple ways. For wildlife, frequent conflict with humans leads to population declines through retaliatory killings, loss of habitat, and fragmentation, which can even drive certain species to local extinction. On the human side, communities living closest to wildlife experience the most direct consequences. They face economic losses from crop damage, livestock predation, and destruction of property, as well as threats to food security when harvests and animals are lost.

Human safety and health are also at risk, as conflicts sometimes cause injuries, deaths, or the spread of zoonotic diseases. In addition, livelihoods become more difficult to sustain, forcing many rural families deeper into poverty. The burden of these conflicts is not shared equally marginalized and rural communities with limited economic opportunities face the greatest challenges, often without sufficient support or compensation. Yet, the benefits of conserving wildlife and healthy ecosystems—such as climate stability, biodiversity, food resources, and overall human survival—extend globally, meaning that while local communities pay the heaviest price, the entire world relies on the outcomes of how human-wildlife conflicts are manage

Level of Conflicts



What can be done?

There are numerous approaches and measures that can be taken to reduce the damage or impacts, de-escalate tensions, address risks to income and poverty, and develop sustainable solutions. These sometimes include barriers (fences, nets, trenches), guarding and early warning systems, deterrents and repellents (sirens, lights, beehives), translocation (moving wildlife), compensation or insurance, providing risk-reducing alternatives, as well as managing tensions between stakeholders involved in these situations.

Efforts to assess and manage complex human-wildlife conflicts require collaboration across disciplines and sectors. For example, collaborations could involve conservation practitioners, community leaders, governments, researchers, businesses and other stakeholders; and need expertise in ecology, social psychology, economics, peace building and environmental law.



Asian Elephants damage crops in Assam, India , Assam Haathi Project/Chester Zoo

Case Studies

Species	Region	Type of Conflict	Impact on Communities	Impact on Wildlife
Elephants	India (Assam, Odisha, Karnataka)	Crop raiding, property damage, human injuries/deaths	Huge crop losses, financial hardship, human fatalities	Retaliatory killings, habitat loss
Lions	East Africa (Kenya, Tanzania)	Livestock predation	Loss of cattle/goats, reduced income, food insecurity	Lions speared/poisoned by pastoralists

Leopards	Indian Himalayas (Uttarakhand, Himachal)	Attacks on goats, occasional human encounters	Economic losses, fear among villagers	Decline in leopard populations, increased conflict
Polar Bears	Arctic (Canada, Greenland)	Entering human settlements due to food scarcity	Risk of injury/death, property damage	Starvation, population stress, conflicts with hunters

Conclusion

Human–wildlife conflict is one of the most pressing challenges at the interface of conservation and development. It affects both humans and animals undermining food security, safety, and livelihoods for rural communities, while also threatening the survival of many endangered species. The burden is heaviest on marginalized populations who live closest to wildlife habitats, yet the benefits of biodiversity conservation are shared globally. Real-world cases, from elephant crop raiding in India to lion predation in Africa and polar bears entering Arctic settlements, show that this issue is widespread and complex.

Sustainable solutions lie in promoting coexistence through habitat conservation, community-based management, fair compensation mechanisms, and innovative conflict-mitigation strategies. Ultimately, balancing human needs with wildlife survival is essential to secure healthy ecosystems, resilient communities, and a sustainable future for all.

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ADAPTING AGRICULTURE: MANAGING PESTS IN A WARMING WORLD

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Abstract

Climate change is making pest management more challenging. Warmer temperatures allow pests to breed faster and spread to new regions, causing severe crop damage. This article discusses the impact of climate change on pest populations and suggests strategies for effective pest management in a changing world.

Keywords: Climate change, pest control, invasive species, food security

Introduction

Rising temperatures are increasing pest activity and expanding their geographical range. Insects are cold-blooded, meaning they grow and reproduce faster in warm conditions. This leads to more crop damage, threatening global food security. Understanding how climate change affects pest populations is essential for developing sustainable pest management strategies.

How Climate Change Affects Pests

1. **Faster Reproduction and Spread:** Higher temperatures shorten insect life cycles, leading to more generations per year and larger populations.
2. **Emergence of New Pest Species:** Warmer climates encourage the migration of pests into new areas where they were previously unable to survive.
3. **Weakened Plant Defenses:** Heat stress and drought reduce plant resistance, making them more vulnerable to pest attacks.
4. **Pesticide Resistance:** Increased pest populations and frequent pesticide use contribute to pesticide resistance, reducing effectiveness over time.

Sustainable Pest Management Strategies

1. **Integrated Pest Management (IPM):** Combining biological, cultural, and chemical methods to control pests with minimal environmental impact.
2. **Climate-Smart Pest Management (CSPM):** Strategies like crop rotation, intercropping, and habitat management help reduce pest outbreaks.
3. **Biological Control:** Using natural predators such as lady beetles and parasitoid wasps to control pests without chemicals.
4. **Resistant Crop Varieties:** Developing and promoting crop varieties that naturally resist pests can reduce reliance on pesticides.
5. **Early Warning Systems:** Monitoring pest populations and using predictive models to implement timely control measures.

The Role of Collaboration

Farmers, researchers, and policymakers must work together to develop climate-resilient pest management strategies. Education and training programs can help farmers adopt sustainable practices that protect crops while minimizing environmental harm.

Conclusion

With rising temperatures, pest management must evolve to protect global food security. By implementing sustainable and climate-smart strategies, we can reduce crop losses, lower pesticide dependency, and ensure a resilient agricultural system.

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FUCOIDAN FROM MARINE MACROALGAE: A MULTIFUNCTIONAL BIOPOLYMER FOR BIOMEDICAL AND INDUSTRIAL APPLICATIONS

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Abstract

Fucoidan, a sulfated polysaccharide from brown macroalgae, has emerged as a promising bioactive compound with diverse therapeutic and industrial potential. Its biological functions—including antioxidant, anticancer, antiviral, anticoagulant, and immunomodulatory activities—are governed by molecular weight, degree of sulfation, and monosaccharide composition. Advances in green extraction and structural modification have expanded its use in regenerative medicine, drug delivery, and food applications. This short communication summarizes recent progress in fucoidan's structural diversity, biological actions, and biotechnological applications, emphasizing its potential as a sustainable alternative to synthetic bioactives.

Keywords

Fucoidan; Brown seaweeds; Sulfated polysaccharides; Antioxidant; Anticancer; Regenerative medicine; Drug delivery; Food industry

Introduction

Marine macroalgae, particularly brown seaweeds of the class *Phaeophyceae*, are a rich source of bioactive polysaccharides with commercial and pharmacological importance. Among these, fucoidan—a fucose-based, sulfated heteropolysaccharide—has gained attention for its broad spectrum of biological activities. Structurally, fucoidan occurs mainly as α-(1→3)- or alternating α-(1→3)/(1→4)-linked L-fucopyranose units, with sulfate groups conferring negative charge and bioactivity.

The composition and properties of fucoidan vary significantly with species, season, and extraction method. Seaweeds such as *Fucus vesiculosus*, *Undaria pinnatifida*, *Sargassum* spp.,

and *Laminaria* spp. are major industrial sources. Sustainable cultivation practices and improved extraction techniques have facilitated commercial production. Fucoidan's multifunctionality makes it suitable for nutraceuticals, cosmetics, regenerative therapies, and biopolymer development.

Methods

1. Extraction and Purification

Traditional extraction employs hot water or dilute acid, often assisted by chelating agents. Recent eco-friendly techniques—ultrasound, microwave, enzyme-assisted, and pressurized liquid extraction—have improved yields and structural integrity while reducing chemical waste. Purification is achieved through ethanol precipitation, ion-exchange, and membrane filtration.

2. Structural Characterization

Structural elucidation utilizes FTIR, NMR, and mass spectrometry to determine linkage patterns, sulfation sites, and molecular size. The degree of sulfation (15–30%) and molecular weight (10–2000 kDa) strongly influence biological performance.

3. Functional Evaluation

In vitro and in vivo assays have been used to assess antioxidant capacity, anticoagulant effects, anticancer activity, and immunomodulatory potential. Studies employ cell lines such as RAW264.7 macrophages, Caco-2, and MCF-7 for bioactivity screening.

Conclusion

Fucoidan from brown seaweeds is a multifunctional marine polysaccharide with demonstrated biological and industrial relevance. Its antioxidant, anticancer, antiviral, and regenerative properties position it as a key candidate for next-generation biopharmaceuticals and functional foods. The integration of green extraction methods, molecular tailoring, and scalable aquaculture will be critical to commercial success. Continued interdisciplinary research is needed to standardize fucoidan production, ensure structural consistency, and validate its efficacy through clinical studies.

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CLIMATE CHANGE -INDUCED FLOOD RISK AND ITS IMPACT ASSESSMENT ON AGRICULTURE IN ASSAM : A CASE STUDY

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Introduction

Assam, located in the northeastern part of India, is a state rich in natural resources, agriculture and cultural diversity. However, it is one of the most flood-prone regions in the country with the annual monsoon season from June to September bringing not only heavy rains but also the threat of devastating floods. The primary cause of these floods is the region's geographical configuration, particularly the presence of the mighty Brahmaputra River which is one of the largest rivers in the world along with its numerous tributaries and channels. This complex river system, while being vital for agriculture and transportation, often results in significant flood risks when river water overflows due to excessive rainfall. (Mahanta and Das, 2017)

Flooding in Assam occurs in multiple forms, including riverine floods, flash floods and local inundations all of which pose a severe threat to both urban and rural populations. The Brahmaputra's unpredictable and dynamic nature makes the state highly vulnerable to these hazards. The river and its tributaries, during the monsoon season, often overflow their banks, submerging vast areas of agricultural land. In addition to river floods, heavy rainfall can lead to flash floods that quickly inundate smaller areas with little warning, causing rapid destruction. (Debnath et al., 2022).

The impact of these floods on Assam's agricultural sector is profound and multi-faceted. Agriculture is the primary source of livelihood for a significant portion of Assam's population, with nearly 70% of the population engaged in farming activities. The fertile plains of the Brahmaputra basin support a variety of crops, with rice being the staple crop, followed by tea, jute and a variety of fruits and vegetables. However, the recurring floods disrupt this fragile agricultural system, often destroying crops, eroding soil and damaging irrigation infrastructure. These floods can result in the total loss of crops like rice and jute, leading to food insecurity and significant financial distress for farmers. For instance, in flood-prone areas, rice paddies are often submerged, rendering them unharvest able, while the flooding of tea gardens and jute fields not only results in crop losses but also damages the livelihoods of farmers and workers dependent on these sectors. (Hazarika et al., 2022), (Chakraborty and Joshi, 2016).

The annual floods cause soil erosion and water logging, which degrade the quality of agricultural land over time. Furthermore, the excessive flooding leads to the deposition of silt, which may initially seem beneficial but often disrupts soil structure and reduces soil fertility in the long run. These environmental changes force farmers to continuously adapt and, in many cases, abandon their land for more fertile but distant areas. Flooding also disrupts transportation and market systems, making it difficult for farmers to sell their produce, further exacerbating the economic burden. (Pal, Singh and Walia, 2013).

The socio-economic distress caused by floods is compounded by the loss of livestock, as many animals either drown or are forced to move to areas where grazing is limited. Livestock farming, a significant supplementary livelihood for many, faces severe setbacks due to this. In addition, the floodwaters often damage rural infrastructure like roads, bridges and irrigation systems, making it more difficult for farmers to recover. The immediate aftermath of floods often forces rural populations to migrate temporarily or permanently in search of better living conditions and livelihoods, leading to rural-urban migration. (Mahanta & Das, 2017).

Given that agriculture forms the backbone of Assam's economy, any disruption caused by flooding can have long-lasting effects on the overall socio-economic fabric of the state. Additionally, floods exacerbate poverty, increase unemployment rates and slow down recovery efforts for affected communities. (Pal et al., 2013).

The changing climate and increasingly unpredictable weather patterns only add to the vulnerability of Assam's agricultural landscape. Prolonged periods of drought, followed by

intense rainfall, can increase the frequency and severity of floods. This makes it all the more important to understand flood risks and devise comprehensive strategies for mitigating these impacts, enhancing flood resilience and ensuring the sustainability of agriculture in Assam. As the state grapples with the challenges posed by regular flooding, it becomes essential for local governments, policy-makers, farmers and communities to adopt strategies that build resilience and help the agriculture sector recover quickly from flood-related disasters. (Debnath et al., 2022).

Flood Risk Assessment and Mitigation in Agriculture-

The flood risk assessment process for Assam's agriculture involves four critical steps:

1. **Data Collection** – Gathering climate, hydrological and agricultural data specific to Assam.
2. **Risk Assessment** – Identifying flood-prone regions and assessing the severity of flood risks.
3. **Impact Analysis** – Evaluating the effects of flooding on crops, soil, water resources, livestock and livelihoods.
4. **Risk Mitigation Strategies** – Proposing adaptive measures to reduce the risks and impacts of flooding.

1. Data Collection: Gathering Climate, Hydrological and Agricultural Data

Key Data Sources and Their Importance:

Effective flood management in Assam relies heavily on the systematic collection of diverse data types, including climate, hydrological and agricultural information. Historical rainfall data, tracked by Assam's Regional Meteorological Centre, is crucial for identifying patterns in monsoon activity and predicting potential flood events. Flood records maintained by the Central Water Commission help determine the severity and frequency of past floods, offering valuable insights for preparedness. Hydrological data from the Water Resources Department, such as river flow and dam levels, further supports flood forecasting efforts. Agricultural data, gathered by the State Agriculture Department, assesses how floods affect crop yields and farming practices, while soil data maintained by the Soil Conservation Department evaluates the impact on soil fertility and erosion. Additionally, socio-economic data collected through surveys and censuses identifies vulnerable communities and the broader effects of flooding on

livelihoods, migration, and local economies. Together, these data sources form a comprehensive foundation for planning and mitigation strategies.

Example: Assam's Flood Monitoring System Assam has implemented flood forecasting systems in collaboration with the CWC. This system uses river gauge data, satellite imagery, and rainfall forecasts to track flood-prone areas in real-time, helping farmers and communities prepare in advance.

2. Risk Assessment: Identifying Flood-Prone Areas

Assam's flood risk assessment is conducted using hydrological models, flood forecasting and vulnerability mapping to identify regions that are most likely to be affected by floods. The major factors considered include rainfall patterns, river discharge levels and flood frequency.

Commonly Used Flood Indices and Tools:

Assam's flood risk assessment combines advanced hydrological models, flood forecasting techniques and vulnerability mapping to pinpoint areas most susceptible to flooding. Key factors in this assessment include rainfall intensity, river discharge levels and the frequency of past flood events. Various tools and indices are used to support this analysis. Flood Frequency Analysis helps predict the recurrence of flood events by examining historical data, especially in districts along the Brahmaputra River. Hydrological modelling is employed to simulate river flow and surface runoff, providing valuable forecasts of potential flood scenarios. Satellite-based flood mapping offers real-time monitoring of inundated areas using remote sensing technology, enabling timely response during flood events. Additionally, Flood Vulnerability Mapping identifies high-risk zones by analyzing population density, infrastructure resilience and historical flood impacts. This is particularly crucial in both rural areas and urban centers like Guwahati, where frequent flooding poses significant risks to lives and livelihoods.

Example: Risk Assessment in Assam

- Assam is divided into various flood-prone regions, with the Brahmaputra River and its tributaries being the primary cause of flooding.
- Districts like Dhemaji, Lakhimpur, Barpeta and Majuli are among the most vulnerable, facing annual flooding that severely impacts agriculture and local economies.
- Flood mapping indicates that these areas experience recurrent flooding during monsoon months, with the river levels rising above danger marks.

3. Impact Analysis: Evaluating Flood Effects

Flooding in Assam has far-reaching consequences for agriculture, rural livelihoods, and food security:

A. Crop Production Losses:

- Floodwaters inundate farmlands, submerging crops like rice, jute and tea, causing significant losses.
- **Example:** According to a report by the Assam State Disaster Management Authority (ASDMA) dated July 16, 2019, approximately 163,962 hectares of agricultural land were affected by floods in Assam.

B. Soil Erosion and Water logging:

- The force of floodwaters erodes topsoil, degrading soil quality and making land less fertile for future cultivation.
- **Example:** In 2017, floods in the Kaziranga region caused significant soil erosion along the Brahmaputra's banks, reducing soil fertility for farming communities.

C. Livestock Mortality:

- Floods disrupt grazing areas, flood livestock shelters, and drown animals.
- **Example:** During the 2020 floods in Assam, approximately 10,000 livestock were lost due to drowning or lack of grazing resources.

D. Socio-Economic Impacts (Food Security and Migration):

- Floods cause food insecurity by destroying crops and increasing food prices. Migrant populations also swell as people from flood-hit areas move to urban centers.
- **Example:** In 2018, floods in Assam led to a rise in food prices, particularly rice and vegetables, and forced thousands of farmers to migrate to urban areas like Guwahati in search of work.

4. Risk Mitigation Strategies: Adapting to Flood Risks

Several adaptive strategies can be employed to reduce the risks and impacts of floods on agriculture in Assam:

1. **Flood-Resilient Crop Varieties**
    - Promote rice varieties like **"Sub1"** developed by IRRI that can survive submergence and recover quickly.
    - **Example**: Farmers in flood-prone areas of Assam use Sub1 to reduce yield losses.

2. **Deepwater Rice Varieties**
    - Introduce varieties that can thrive in prolonged standing water.
    - **Example**: Assam Agricultural University is testing deepwater paddy strains for chronically flooded areas.
3. **Flood Protection Infrastructure**
    - Construct embankments, levees, and improve river channels to protect farmland.
    - **Example**: **Flood Control and Drainage (FCD)** projects reinforce embankments along the Brahmaputra.
4. **Retention Basins and Water Diversion Channels**
    - Build basins and channels to temporarily hold excess water and reduce flood pressure.
    - **Example**: Low-lying areas near Barpeta are being developed as water retention zones.
5. **Early Warning Systems**
    - Expand forecasting systems for timely alerts.
    - **Example**: **CWC and IMD** models provide 2–3-day flood forecasts to farmers.
6. **Localized Weather Alert Apps**
    - Use mobile technology to inform farmers about extreme weather.
    - **Example**: The **DAMINI app** sends storm and rainfall alerts in local languages.
7. **Soil Conservation Techniques**
    - Use bunding, terracing, and cover crops to prevent erosion and waterlogging.
    - **Example**: ASDMA promotes bunding in sloped areas of Dima Hasao and Karbi Anglong.
8. **Check Dams and Bioengineering**
    - Build small check dams and use vegetation to control soil erosion.
    - **Example**: Bioengineering methods are applied in erosion-prone districts like Dhemaji.
9. **Livelihood Diversification**
    - Encourage farmers to take up fish farming, poultry, and other income sources.
    - **Example**: Flood-affected communities in Majuli are supported to start fish ponds.
10. **Training and Support for Alternate Incomes**

- Provide training in non-farm activities.
- **Example**: **Krishi Vigyan Kendra (KVK)** runs programs on mushroom cultivation, agroforestry, and beekeeping.

11. **Community-Based Disaster Preparedness Plans**

- Involve local communities in creating flood response and evacuation plans.
- **Example**: ASDMA collaborates with village committees to set up flood shelters and mock drills in Dhubri district.

12. **Crop Insurance Schemes**

- Offer government-backed insurance to protect farmers from crop losses.
- **Example**: **Pradhan Mantri Fasal Bima Yojana (PMFBY)** is widely promoted in Assam to cover flood-related damages.

13. **Elevated Seed Storage Facilities**

- Construct flood-safe storage units to protect seeds and grain stock.
- **Example**: Farmers in Nalbari use raised seed banks built on stilts to prevent losses during floods.

14. **Floating Agriculture Techniques**

- Grow vegetables and other crops on floating beds made from aquatic weeds and bamboo.
- **Example**: Pilots of floating farms are being tried in parts of lower Assam using techniques adapted from Bangladesh.

15. **Use of Solar-Powered Pumps and Tools**

- Employ solar energy for irrigation and drainage in flood-prone areas.
- **Example**: Solar pumps installed in Jorhat help drain floodwater while ensuring water availability during dry spells.

Conclusion: Strengthening Flood Resilience in Assam's Agriculture

Key Takeaways:

- Assam faces significant flood risks, particularly along the Brahmaputra and its tributaries, which directly impact agriculture.
- Data collection through rainfall, hydrological data, and flood records helps predict and assess the flood risks in the region.
- Flooding leads to crop losses, soil erosion, livestock mortality, and socio-economic distress, threatening the livelihoods of farmers and rural communities.

- Mitigation strategies such as flood-resistant crops, improved flood infrastructure, early warning systems, and livelihood diversification can help reduce the adverse impacts of floods on agriculture.

Way Forward:

- **Strengthen Early Warning Systems:** Expand the reach of early flood warnings to rural farming communities to allow timely preparedness.
- **Promote Flood-Resilient Agriculture:** Encourage the adoption of flood-tolerant crop varieties and sustainable farming practices.
- **Invest in Infrastructure:** Build flood control infrastructure and improve drainage systems to minimize flood damage to crops.
- **Enhance Livelihood Support:** Provide financial and technical support for farmers to diversify their livelihoods and adapt to the changing climate.

By adopting these strategies, Assam's agricultural communities can become more resilient to floods, ensuring food security and sustainable livelihoods for future generations.

This comprehensive approach to flood risk assessment and mitigation will help build resilience in Assam's agricultural sector, protecting livelihoods and ensuring food security despite recurrent flooding.

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FARM BUND RECONSTRUCTION AND SOIL EROSION CONTROL MEASURES

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Introduction

In recent weeks, excessive rainfall and flooding across various parts of Maharashtra and other regions in India have caused severe damage to agricultural lands. Along with crop losses, a more serious concern has been the breaching of farm bunds, leading to the erosion of the fertile topsoil layer, known as the A-Horizon. The loss of this vital layer has reduced the soil's natural fertility, organic carbon content, and water-holding capacity, putting the future productivity of farmlands at risk. This situation is not temporary; it threatens the long-term health of the soil. Therefore, immediate as well as long-term measures are essential. Scientific reconstruction of breached bunds, engineering interventions for erosion control, and bio-engineering techniques using vegetation-based stabilization can provide sustainable solutions. Integrating such practices with on-farm water management systems will make farmlands more resilient to extreme rainfall events.

1. Causes of Farm Bund Failure

Recent heavy rains have caused many farm bunds to collapse or be completely washed away. This damage is not solely due to rainfall intensity but also due to design and maintenance shortcomings. Major causes include:

1.1. Excessive water pressure: Continuous and intense rainfall causes large volumes of

water to accumulate behind the bund. Without proper drainage, this pressure directly affects the bund, leading to cracks and breaches.

1.2. **Improper slope and drainage:** Fields lacking adequate gradient accumulate water on one side. This uneven pressure accelerates erosion and bund failure.

1.3. **Poor construction quality:** Bunds built without suitable clayey soil or proper compaction remain weak. Absence of grass or root-binding vegetation further reduces stability.

1.4. **Lack of overflow arrangements:** Many farms lack designated outlets or spillways. Overflowing water erodes the crest, weakening the bund over time.

1.5. **Absence of vegetation cover:** Raindrops directly hitting bare soil loosen the surface, initiating erosion. Continuous runoff deepens the base, weakening the foundation.

1.6. **Movement of heavy vehicles or livestock**: The movement of tractors or cattle over bunds creates surface cracks, allowing water to seep in and weaken the structure internally.

Combined, these factors gradually undermine the bund, leading to failure under hydraulic pressure, resulting in loss of fertile soil, water storage, and crop productivity.



2. Technical Guidelines for Bund Reconstruction (Agricultural Engineering Perspective)

2.1. Basic Components and Design Parameters

Core Section: Use well-compacted, low-permeability clay soil at the center. Each layer should be 15–20 cm thick and compacted at optimum moisture content.

Crest Width: Maintain a minimum width of 1.0 meter for small bunds to ensure structural stability.

Freeboard: Keep an additional height of 0.5–0.75 meters above the designed water level to accommodate sudden water rise.

Slope and Stability: Side slopes should generally range between 1:2 and 1:2.5 (vertical:horizontal) for adequate stability and erosion control.

2.2. Types of Bunds and Their Suitability

Contour Bunds: Constructed along natural contour lines to reduce runoff and enhance water infiltration. Best suited for low rainfall regions with gentle slopes.



Graded Bunds: Built with a mild gradient (0.2–0.4%) to enable controlled water drainage through safe channels. Ideal for heavy rainfall areas and poorly drained clayey soils.

Criteria	Contour Bunds	Graded Bunds
Topography	Gentle slope (0–6%)	Steeper slope (>6%)
Rainfall	<600 mm (low rainfall)	>600 mm (high rainfall)
Soil Type	Well-drained, non-clayey soils	Heavy, clayey soils
Gradient	Along contour (0%)	0.2–0.4% controlled gradient
Purpose	To retain and infiltrate rainwater	To safely drain excess runoff

2.3. Water Drainage and Stabilization Measures

2.3.1. Spillways and Outlets

- Design controlled overflow channels with proper capacity.
- Use stone-pitched chutes or concrete structures to safely discharge excess water.
- Install sediment traps and energy dissipators to reduce flow velocity and erosion.
- Protect pipe inlets and outlets with stone pitching or concrete collars.

2.3.2. Bio-Engineering for Sustainable Reinforcement: Combine structural and biological methods for long-term stability.

- Grasses and Plants: Use Vetiver (Khass), Saccharum munja, or Bamboo along bunds. Deep roots of Vetiver effectively hold soil together.



- Prepare 20 cm deep and 30 cm wide trenches for planting.
- Napier Grass and Arundo donax (Giant reed) can be used along drainage channels and riverbanks to prevent erosion.

2.3.3. Construction Process

- Survey and Soil Testing: Analyze soil texture, Atterberg limits, and permeability.
- Core Placement and Compaction: Compact soil layers at optimum moisture.
- Erosion Control: Apply stone pitching, geotextiles, or grass mats to minimize erosion.

3. Maintenance and Monitoring

Sustainable performance of bunds depends on post-construction maintenance:

- Pre-Monsoon Inspection: Measure storage capacity, inspect cut-outs and outlets before rainfall.
- Routine Maintenance: Remove silt, trim grass, and ensure proper seepage control.
- Monitoring: Use piezometers, staff gauges, or simple observation wells to monitor water levels and seepage.

Conclusion

Temporary repairs after heavy rainfall are not sufficient. Sustainable reconstruction of farm bunds must integrate agricultural engineering, soil and water conservation, and bio-engineering techniques. Proper design, gradient, drainage, erosion control, and vegetation-based stabilization together make bunds stronger and resilient against future floods. By implementing these scientific and sustainable practices, farmers can protect their fertile soil, conserve water resources, and ensure long-term agricultural sustainability.

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SAMBA SEASON TRADITIONAL RICE VARIETIES AND AROMA RICE VARIETIES – A GLANCE

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Introduction

Rice serves as a crucial staple food for over half of the global population, with Asia contributing 90% of the world's production. The conservation of traditional paddy varieties, known as landraces, is essential for maintaining genetic diversity, particularly in the face of widespread highyielding rice cultivation. These landraces, as highlighted in ancient Indian Ayurvedic texts for their medicinal properties, have long been used for healing. They are also deeply embedded in cultural traditions, playing important roles in festivals, ceremonies, and social customs. The scented rice are mainly cultivated and consumed in India, Pakistan, Thailand, Bangladesh, Afghanistan, Indonesia, Iran and United States. Of these, the major exporter of fine-grained fragrant rice includes India, Pakistan and Thailand. Beyond its role in nutrition, rice offers several health benefits. Various components of rice have demonstrated significant health benefits, leading to their growing inclusion in dietary supplements, culinary additives, and pharmaceutical applications.

Traditional paddy varieties are tailored to meet specific nutritional needs, benefiting various groups such as children, women, and pregnant or lactating women. Additionally, they offer economic benefits to farmers by enabling the preservation and marketing of unique, high-

quality rice products with distinct flavors, textures, and nutritional values. The nutritional profiles of various traditional rice varieties exhibit considerable diversity. Researchers have highlighted the importance of landraces and traditional rice types for their high contents of minerals, protein, and antioxidants. Consuming colored rice, in particular, can enhance human health by lowering the risk of non-communicable diseases. Traditional rice varieties are notably rich in dietary Fibers, resistant starch, minerals, carotenoids, flavonoids, and polyphenols.



Tamil Nadu is one among the important rice growing states in India had immense number of landraces but as of now only hundreds of them are available for cultivation. The most widely consumed of all human foods, rice (*Oryza sativa*), stands prominent in the path of transformation. During the lengthy epoch of history, rice has been intensively grown under favorable conditions for development of local forms, transforming the crop into an enormous complex of forms, showing great variations in morphological and physiological characters.



Every farmer should able to access healthy seeds which are genetically pure, with high seed vigour and good germination percentage. Timely availability of good quality seeds at reasonable price ensures good yield and profit to the farmers. The seeds plays a vital role in agriculture and acts as a carrier of the genetic potential of varieties. Quality seed production which follows efficient certification procedures plays a major role in the increase of food production of our country.

Crop seasons

S. No	**Crop Season**	**Month**	**Tamil Month**
1.	Samba	July Mid – January Mid	Adi – Margazhi
2.	Late samba	September Mid – February Mid	Puratasi – Thai
3.	Navarai	December Mid – March Mid	Margazhi – Masi

S. No.	Traditional rice varieties	Duration	Yield per acre	Nutritional Benefits
1.	Adukkunel	140 days	1 tons	High in total ash and protein. Very high in fat
2.	Ambemohar	135 days	600 kgs	In terms of minerals, it is high in potassium, magnesium, zinc and very high in calcium, iron and phosphorus
3.	Garudan samba	130 days	900 kgs	Very high in fat
4.	Iluppai poo samba	120 days	700 kgs	It is high in protein and fat
5.	Iravaipandi	120 days	1350 kgs	High in total ash and

				protein
6.	Kadaikazhuthan	170 days	1350 kgs	Very high in calcium
7.	Kaivari samba	130 days	650 kgs	Rich in folic acid which is required for the growth of the foetus.
8.	Kalanamak	120 days	640 kgs	It is very high in protein and high in fat.
9.	Kalarpalai	130 days	550 kgs	High in protein
10.	Kaliyan samba	160 days	1200kgs	Very high in calcium
11.	Kamban samba	140 days	1300 kgs	High in protein
12.	Kappakar	150 days	1350 kgs	Very high in iron, calcium, magnesium and phosphorus
13.	Karungkuruvai	125 days	825 kgs	very high in iron, calcium, zinc and phosphorus.
14.	Karuppukowni	130 days	800 kgs	very high in iron, calcium and phosphorus.
15.	Kaatuyanam	150 days	900 kgs	High in protein and fat.
16.	Kitchili samba	140 days	1125 kgs	Calcium, magnesium and zinc are high in minerals
17.	Koomvazhai	130 days	1350 kgs	High in total ash and protein.
18.	Kothamalli samba	135 days	1000 kgs	High in protein and fat
19.	Kottara samba	130 days	700 kgs	High in total ash and

				protein
20.	Kudaivazhai	130 days	1600 kgs	High in total ash and protein
21.	Kuzhiadichan	120 days	975 kgs	Very high in iron, calcium and magnesium
22.	Kullakar	120 days	1500 kgs	The Glycemic Index is low.
23.	Mapillai samba	160 days	750 kgs	Very high in fat
24.	Mozhikaruppu samba	120 days	600 kgs	Very high in fat.
25.	Mullan kaima	150 days	850 kgs	Very high in fat
26.	Neelam samba	180 days	1500 kgs	The Glycemic Index is low. Traditionally it is considered as very good for lactating mothers, since it increases the milk flow.
27.	Ottadai	150 days	1000 kgs	High in total ash and protein.
28.	Pal kudaivazhai	130 days	600 kgs	Very high in fat.
29.	Pisini	130 days	1350 kgs	High in total ash and protein.
30.	Poompalai	150 days	1100 kgs	In terms of minerals, it is high in potassium, iron,calcium, magnesium, zinc, and phosphorus
31.	Salem samba	135 days	1200 kgs	High in total ash and protein. Very high in

				fat.
32.	Samba mosanam	170 days	1800kgs	High in total ash, protein and fat.
33.	Sanna samba	140 days	1800kgs	High in total ash and protein.
34.	Seeraga samba	130 days	1500 kgs	It is high in potassium, iron, magnesium, zinc, and phosphorus
35.	Sivappu kowni	130 days	800 kgs	High in total ash . Very high in fat.
36.	Sivappu kuruvikaar	125 days	1050 kgs	High in total ash. Very high in fat.
37.	Sooran kuruvai	135 days	1200 kgs	High in total ash . Very high in fat.
38.	Thanga samba	165 days	1500 kgs	High in total ash and protein. Very high in fat.
39.	Thengaipoosamba	120 days	950 kgs	high in protein,very high in fat.
40.	Thooyamalli	140 days	1125 days	High in protein. Very high in fat.

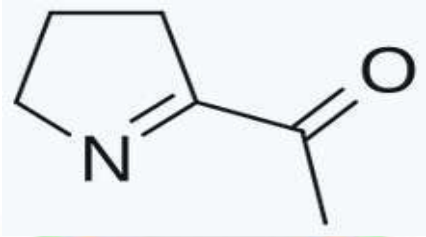
Aroma Responsible for Rice

It was reported that rice aroma was controlled by single recessive nuclear gene in rice. The biochemical analysis of rice grain reveals the presence of numerous volatiles in fragrant rice revealing the major aromatic compound, 2-acetyl 1-pyrroline (2AP). Recent advances had also discovered the biochemical pathway for biosynthesis of 2-Acetyl-1-pyrroline (2AP) from different types of amino acids and polyamines. Based on the rice genome sequence information, the *OsBadh2* gene (present on chromosome 8) is identified as a candidate gene for aroma, which is the most important aroma gene till now. However, several other genes and locus had been reported to be the contributor for aroma. Rice aroma quality evaluation is quite complex due to

the complex interaction of numerous volatile compounds, and many affecting factors during planting and processing.

2-acetyl-1-pyrroline (2-AP) content varies significantly depending on the source, such as a specific variety of rice. It is the key aroma compound in fragrant rice and its concentration can be influenced by factors like genetic variation, cultivation methods, and environmental conditions.

Aroma might be arising after cooking or during cooking or inherently present in nature in the whole plant or in polished or unpolished grains.



As per the evidences from vedic or old tamil sangam literatures, aromatic rices like Punugu samba, Kasthuri samba, Manakkathai, Karpoorapalai, were reported to be in existences.

Puzhugu Samba: It is the kind that is most favoured by the farmers. This is due to the fact that it satisfies both thirst and hunger, as well as that it fortifies the body, eliminates exhaustion, and offers a pleasant sensation. This has the scent of civet cat.

Manakathai: If one consumes this kind on a consistent basis, it prevents skin disorders, mitigates the effects of poison bites, and cures ulcers. The aroma of this rice is similar to that of a wood with a nice scent.

Besides aroma, the scented landrace Punugu samba was preferred by the farmers because of its ability to quench thirst and hunger and strengthens the body, removes fatigue and provides a pleasant feel. Aromatic rice Manakathai was reported to control skin diseases, helps in poison bites, heals ulcers if one takes this variety regularly. This rice has the odour of the pleasant smelling wood. But due to green revolution and introduction of high yielding rice varieties many of these aromatic rice land races were lost and the only scented rice landraces available for cultivation in Tamil Nadu were Seeraga samba and Thulasi vasanai seeraga samba.

The application of organic fertilizers and soil improvement practices based on soil testing also improved the soil quality. Farmers, who adopted the SRI method, opined that the yield obtained was good, but due to heavy labour charges and planting method, could not be adopted on a large scale.

Conclusion

Traditional paddy varieties hold significant cultural and medicinal importance for Indian communities, yet their full potential remains largely unexplored by scientific research. This lack of understanding impedes broader recognition of their functional benefits. To unlock these advantages, stakeholders must prioritize comprehensive research on local varieties, empowering consumers to integrate them into their diets or specialized functional foods. Beyond their cultural significance, traditional paddy varieties offer sustainability and resilience, requiring fewer resources and demonstrating greater climate resilience compared to modern counterparts. Aroma in rice is a key quality trait determining its acceptability and marketability. 2AP has gained major importance among other volatiles as the primary compound for aroma. It will accelerate the cultivation of new aromatic rice varieties with high quality and yield.

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TURMERIC PROCESSING: STAGES, QUALITY CONTROL AND CHALLENGES

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Abstract

Turmeric (*Curcuma longa*), commonly known as "haldi" in India, is one of the most valued spices, not only for its culinary importance but also for its medicinal and industrial applications. The primary bioactive compound, curcumin, imparts therapeutic benefits, vibrant yellow colour, and antioxidant properties (Prashar, Kaur, & Kaur, 2013; Majeed & Rajendra, 2014). Turmeric processing involves multiple stages including cultivation, harvesting, cleaning, boiling (to preserve colour and inactivate enzymes), drying (sun or mechanical), polishing, grinding, and packaging (Jolad & Rao, 2004). Quality control is critical, as turmeric is highly susceptible to adulteration and pesticide contamination, which can compromise its efficacy and safety (Sasidharan & Chen, 2011). Challenges in processing include labour-intensive methods, environmental concerns, and the need for sustainable practices. Therefore, modernised, efficient, and eco-friendly processing techniques are essential to meet both domestic and global demand while ensuring quality and safety.

Keywords: harvesting, quality control, contamination, sustainable, adulteration, development, labour-intensive etc.

1. Introduction

Turmeric (*Curcuma longa*) is a rhizomatous herbaceous plant, native to South and Southeast Asia, widely cultivated in India. Known for its striking yellow colour and pungent flavour, turmeric is integral to Indian cuisine and traditional medicine, including Ayurveda and Unani systems (Prashar et al., 2013). The spice's health-promoting properties, attributed mainly

to curcumin, include anti-inflammatory, antioxidant, and antimicrobial activities (Majeed & Rajendra, 2014). Processing plays a pivotal role in retaining the colour, aroma, and medicinal properties of turmeric. From harvesting to final packaging, each stage affects its quality, shelf-life, and consumer acceptability (Jolad & Rao, 2004). This article discusses the stepwise processing of turmeric, quality control measures, uses, and challenges, highlighting the need for sustainable practices.



Turmeric processing stages

2. Turmeric Cultivation and Harvesting

a. Cultivation



Cultivation of turmeric

Turmeric is a tropical plant that thrives in warm, humid climates with well-drained loamy soil. It is predominantly grown in Indian states such as Tamil Nadu, Andhra Pradesh, Karnataka,

Maharashtra, and West Bengal. The plant grows optimally at elevations from sea level to 1,500 metres, with an annual rainfall of 1,500–2,000 mm and temperatures ranging between 20°C and 30°C (Kochhar, 1998). Proper soil fertility, organic matter content, and irrigation management are critical for producing high-quality rhizomes.

b. Harvesting



Harvesting of turmeric

Turmeric requires 9–10 months to mature. Harvesting is typically carried out when the leaves and stems start yellowing and drying, indicating the rhizomes have reached full maturity (Jolad & Rao, 2004). Careful excavation is essential to avoid bruising, cutting, or breaking the rhizomes, as damaged rhizomes are prone to microbial infection, reduced curcumin content, and poor shelf-life. Harvesting is labour-intensive, often done manually using hand tools such as spades, and requires skilled labour to ensure minimal loss and maintain quality.

3. Cleaning and Sorting



Cleaning and Sorting

Post-harvest, turmeric rhizomes undergo thorough cleaning to remove soil, mud, and residual plant material. Typically, the rhizomes are soaked in water for several hours and scrubbed manually or mechanically to ensure cleanliness (Houghton & Raman, 1998). After cleaning, rhizomes are sorted based on size, shape, and colour. Large, firm, and well-formed rhizomes are preferred for premium-grade turmeric powder, while smaller, irregular, or damaged rhizomes may be used for industrial applications or lower-grade products (Jolad & Rao, 2004). Sorting ensures uniformity in drying, polishing, and grinding processes, and contributes to the overall quality and market value of turmeric.

4. Boiling (Pre-treatment)



Boiling (Pre-treatment)

Boiling or steam-curing is a critical step in turmeric processing. The rhizomes are immersed in hot water for 30–45 minutes. The key objectives of boiling include:

- **Preservation of colour and flavour:** Heat treatment deactivates polyphenol oxidase and other enzymes that can lead to browning and loss of characteristic yellow colour (Jolad & Rao, 2004).
- **Softening of rhizomes:** Boiling softens the outer skin, making it easier to peel during polishing (Houghton & Raman, 1998).
- **Enzyme inactivation:** Boiling inactivates amylases and other enzymes, preventing microbial spoilage and enhancing shelf-life (Sasidharan & Chen, 2011).
- **Reduction of moisture content:** Partial removal of water content facilitates faster and more uniform drying.

Boiling is traditionally done in large open vessels, but modern mechanised steam boilers ensure more uniform heating, energy efficiency, and reduced nutrient loss.

5. Drying

Drying is essential to prevent spoilage and maintain curcumin content. Two primary methods are employed:

a. Sun Drying



Sun Drying

Sun drying is the traditional and widely used method, particularly in rural India. Boiled rhizomes are spread on mats, bamboo trays, or tarpaulins under direct sunlight for 7–10 days (Kochhar, 1998). Moisture is reduced to 8–10%, which is ideal for storage. Sun drying also contributes to flavour development but is weather-dependent and labour-intensive.

b. Mechanical Drying



Mechanical Drying

Mechanical dryers, including hot air, tray, or solar tunnel dryers, are used to overcome climatic limitations and accelerate the drying process. Drying time reduces to 2–3 days, and

uniform moisture content is maintained, reducing the risk of microbial contamination (Houghton & Raman, 1998). Mechanised drying ensures consistent quality, better colour retention, and reduces post-harvest losses.

6. Polishing and Grinding

a. Polishing



Polishing:

After drying, the rhizomes undergo polishing to remove the outer skin and enhance visual appeal. Traditionally, polishing is done manually by rubbing rhizomes against stones, while modern methods employ tumbling machines (Jolad & Rao, 2004). Polishing not only improves appearance but also prepares the rhizomes for grinding.

b. Grinding



Grinding

Polished rhizomes are then ground into powder using stone mills or industrial grinders. The powder is sieved to achieve uniform particle size, ranging from coarse to fine depending on the intended use (Sasidharan & Chen, 2011). Grinding facilitates ease of storage, packaging, and

transportation. Proper grinding ensures that curcumin content is preserved and the powder is free-flowing.

7. Packaging and Storage



Packaging

a. Packaging Materials:

Turmeric powder is packed in air-tight plastic or glass containers for retail sale, while bulk packaging uses vacuum-sealed bags or drums for industrial or export purposes (Majeed & Rajendra, 2014).

b. Storage Conditions:

The powder should be stored in a cool, dry, and dark place to protect it from heat, moisture, and light, which can degrade curcumin and affect shelf-life (Prashar et al., 2013). Proper storage prevents microbial contamination and maintains aroma, flavour, and medicinal value.

8. Quality Control and Certification

Quality control is critical for ensuring safety and authenticity. Key tests include:

- **Purity:** Screening for adulterants such as starch, chalk powder, or artificial colourants (Sasidharan & Chen, 2011).
- **Pesticide residues:** Detection of chemical residues is essential for consumer safety (Jolad & Rao, 2004).
- **Curcumin content:** Quantitative analysis ensures the active ingredient meets the required standard (Prashar et al., 2013).

Certifications such as ISO, FSSAI, Fair Trade, and organic certifications enhance credibility and market access (Kochhar, 1998).

9. Uses of Turmeric

- **Culinary:** Turmeric is indispensable in Indian cooking, including curries, dals, rice dishes, pickles, and beverages like haldi doodh (golden milk) (Majeed & Rajendra, 2014).
- **Medicinal:** It is valued for anti-inflammatory, antioxidant, antimicrobial, and hepatoprotective properties (Prashar et al., 2013).
- **Cosmetic:** Used in skincare preparations for brightening, reducing inflammation, and treating acne (Sasidharan & Chen, 2011).
- **Industrial:** Employed as a natural dye in textiles and food colouring (Kochhar, 1998).

10. Challenges in Turmeric Processing

- **Adulteration:** Adulterants like starch, chalk powder, and synthetic dyes compromise safety and quality (Jolad & Rao, 2004).
- **Pesticide residues:** Excessive chemical use in cultivation can affect curcumin quality and consumer safety (Sasidharan & Chen, 2011).
- **Labour-intensive methods:** Harvesting, cleaning, and traditional sun drying require significant manual effort, and mechanisation is costly for small farmers (Houghton & Raman, 1998).
- **Environmental concerns:** Open boiling and sun drying require fuel and land area, contributing to environmental footprint.

Conclusion

Turmeric processing is a meticulous and delicate procedure that influences the final quality, flavour, and medicinal value. Each stage, from cultivation and harvesting to packaging and storage, plays a crucial role. With the increasing domestic and global demand for turmeric, it is essential to adopt sustainable, mechanised, and quality-oriented processing techniques. Addressing challenges such as adulteration, pesticide contamination, labour intensity, and environmental concerns is critical to ensure that turmeric reaches consumers in a safe, high-quality, and authentic form (Prashar et al., 2013; Majeed & Rajendra, 2014).

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RESILIENT FODDER SYSTEM FOR WATERLOGGED, DROUGHT, SALINE AND ACID SOILS

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Introduction

Fodder is the backbone of livestock farming, but not all crops grow well in every situation. Farmers often face challenges like limited rainfall, waterlogging, salty soils or acid soils, which affect crop growth and animal feed availability. Choosing the right fodder crop for the right condition not only improves yield but also ensures healthy and sustainable livestock production. This article highlights suitable fodder options for rainfed, waterlogged and saline soils, helping farmers make smart choices for better productivity. Most wastelands are often dominated by unpalatable and invasive weed species such as Parthenium hysterophorus and Ziziphus jujube etc… which offer little or no value for livestock feeding. Replacing these undesirable species with productive and palatable fodder crops such as Stylosanthes spp. (Stylo) and Panicum maximum (Guinea grass) can significantly improve the utility of these lands. The establishment of these species not only enhances fodder availability but also contributes to soil improvement and ecosystem restoration. Thus, converting wastelands into productive pasture areas provides a sustainable means of supporting livestock nutrition.

Waterlogged soils

Para grass (Brachiaria mutica) is considered one of the most suitable fodder crops for waterlogged soils, undulated low-lying areas, bunds of farm ponds, and seasonally or permanently inundated fields. Its remarkable tolerance to excess soil moisture and partial

submergence enables it to thrive in conditions where most conventional fodder species cannot establish. Being a perennial species, para grass provides a continuous supply of green fodder once established, with minimal management requirements. Vegetative propagation using superior clonal slips planted along bunds and pond embankments ensures rapid establishment and long-term persistence. The crop is capable of producing 80–120 tonnes of green fodder per hectare annually, depending on soil fertility and management. Nutritionally, para grass contains 8–12% crude protein, with a digestibility of around 55–60%, making it a valuable feed resource for dairy and draught animals in flood-prone or waterlogged ecosystems.

Although no distinct improved varieties have been released, the selection of superior local material and proper vegetative multiplication are sufficient to maintain high biomass productivity and sustainability under challenging soil-water environments.

Drought Situations

In drought-prone areas and under orchard systems, Guinea grass (Panicum maximum) is highly suitable for fodder development. It can withstand prolonged dry spells once established, making it ideal for rainfed and drought-affected regions. It also performs well in degraded soils, drylands and wastelands where conventional crops fail. Guinea grass produces small, light-weight seeds that disperse naturally by Self-propagation. After initial establishment, the grass propagates on its own and gradually expands its area without human intervention. More compatibility in orchards because It grows well under partial shade, providing a permanent fodder source without disturbing orchard trees. It also ensures year-round fodder availability, reduces pressure on cultivable land, and improves soil cover, thereby minimizing erosion.

Wastelands

Wastelands, which are generally unsuitable for agricultural crop production, can be effectively utilized for fodder development. Under tree plantations and in orchard systems, Stylo hamata is a highly suitable leguminous fodder crop.

Ground Cover Varieties of stylo are low-growing types provide effective soil cover, reducing erosion and conserving soil moisture. Tall Varieties are upright and heighted varieties can provide higher biomass yield, serving as quality fodder for livestock.

Additional Benefits are it is a perennial legume and enriches soil fertility through nitrogen fixation and enhances sustainability. It also performs well in degraded soils, drylands, and wastelands where conventional crops fail.

Saline and Alkali Soils

Dinanath grass and certain sorghum cultivars are moderately tolerant to salinity. These Can be established in problem soils where traditional fodder crops fail. Helps in utilizing unproductive saline soils for livestock fodder. Many conventional fodder crops, especially fodder maize, are not suitable under saline conditions due to their high sensitivity.

Recommended options

Dinanath grass (Pennisetum pedicellatum) – moderately salt tolerant.

Sorghum varieties – some cultivars can tolerate mild salinity.

Para grass (Brachiaria mutica) – suitable in areas with salinity combined with waterlogging.

Acid Soils

Acidic soils, generally characterized by low pH and aluminum or manganese toxicity, pose major constraints to fodder production. Nevertheless, several fodder species exhibit strong adaptability to such environments. Among grasses, Pennisetum purpureum (Napier grass), Panicum maximum (Guinea grass), Brachiaria mutica (Para grass), demonstrate good tolerance to soil acidity and sustain high biomass yields. Acid-tolerant leguminous fodders such as Stylosanthes guianensis, Desmodium intortum and Dolichos lablab (Lablab) not only provide quality forage but also improve soil fertility through biological nitrogen fixation. Adoption of these species helps maintain livestock productivity and promotes sustainable forage-based farming systems in acid soil regions.

Conclusion

In our country, the livestock sector plays a crucial role in supporting rural livelihoods and contributing to the national economy. However, the rapid increase in animal population, coupled with the declining availability of quality feed and fodder resources, has created a severe imbalance between feed demand and supply. This shortage of nutritious fodder is one of the major constraints limiting livestock productivity and reproductive efficiency. To mitigate this challenge, it is essential to bring marginal, fallow, and unproductive agricultural lands under fodder cultivation. The integration of suitable cereal and leguminous fodder crops on such lands can enhance biomass yield, improve soil fertility through biological nitrogen fixation, and ensure year-round feed availability. Adoption of region-specific, climate-resilient fodder species will further strengthen sustainable livestock production systems and contribute to nutritional security at the national level.

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NAVIGATING THE NANO-FRONTIER: A REVIEW OF PROMISE AND PERIL

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Abstract

Nanotechnology, the understanding and control of matter at dimensions between approximately 1 and 100 nanometers, has evolved from a foundational concept to a pervasive cross-disciplinary field. This review article comprehensively examines the prospects of nanotechnology, tracing its journey from synthesis and characterization to its transformative applications in medicine, energy, electronics, materials science, and environmental remediation. It critically addresses the concomitant challenges of nanotoxicity and ethical implications, evaluates the commercial landscape, and finally, envisions future directions where nanotechnology will converge with other fields to address humanity's grand challenges.

1. Introduction

The unique physical, chemical, and biological properties that emerge at the nanoscale form the bedrock of the nanotechnology revolution. At this scale, quantum effects dominate, and the high surface-area-to-volume ratio of materials imparts novel characteristics not observed in their bulk counterparts. Gold nanoparticles can appear red or purple, zinc oxide becomes transparent yet UV-protective, and carbon nanotubes exhibit unparalleled strength and electrical conductivity. This ability to engineer materials from the "bottom-up" has unlocked unprecedented potential across virtually every sector of science and technology. This review aims to dissect this potential, providing a balanced overview of the groundbreaking applications and the significant hurdles that must be overcome to realize the full promise of nanotechnology.

2. Synthesis and Fabrication:

The pathway to functional nanomaterials is divided into two broad paradigms: top-down and bottom-up.

Top-Down Approaches: These methods involve sculpting or etching bulk materials down to the nanoscale. Techniques like photolithography and electron-beam lithography are the workhorses of the semiconductor industry, allowing for the precise patterning of nanoscale features on silicon wafers.

Bottom-Up Approaches: These methods construct nanostructures atom-by-atom or molecule-by-molecule. This includes chemical synthesis (e.g., producing quantum dots), sol-gel processes, and chemical vapor deposition (e.g., for growing graphene). Bottom-up methods often allow for greater control over the material's composition and structure at the atomic level.

A key prospect lies in the convergence of these approaches and the development of self-assembly, where molecules spontaneously organize into desired nanostructures, mimicking biological processes.

3. Characterization Tools:

The advancement of nanotechnology is inextricably linked to the development of tools capable of visualizing, probing, and manipulating the nanoworld.

Microscopy: Scanning Probe Microscopies, such as Atomic Force Microscopy (AFM) and Scanning Tunneling Microscopy (STM), provide topographical and electronic information at atomic resolution. Advanced Transmission Electron Microscopy (TEM) allows for direct imaging of atomic lattices.

Spectroscopy: Techniques like Raman spectroscopy, X-ray Photoelectron Spectroscopy (XPS), and Nuclear Magnetic Resonance (NMR) are crucial for determining the chemical composition, bonding, and electronic structure of nanomaterials.

Future prospects include in-situ and operando characterization, where nanomaterials can be studied in real-time under realistic operating conditions (e.g., inside a battery or a living cell).

4. Nanotechnology in Medicine:

Nanomedicine represents one of the most promising frontiers.

Diagnostics: Nanoparticles are used as contrast agents for enhanced imaging (e.g., superparamagnetic iron oxide nanoparticles in MRI). Nanosensors and lab-on-a-chip devices enable early, sensitive, and rapid detection of diseases from minimal sample volumes.

Therapeutics: Targeted drug delivery is the holy grail. Nanoparticles can be functionalized with ligands to seek out specific cells (e.g., cancer cells), delivering high drug doses directly to the disease site while minimizing systemic side effects. Examples include liposomal doxorubicin and Abraxane.

The prospect lies in developing theranostic platforms that combine diagnosis and therapy in a single nanoscale entity.

5. Energy Applications:

Nanotechnology is pivotal in the global transition to sustainable energy.

Harvesting: Nanostructured materials like quantum dots and perovskite nanoparticles are dramatically improving the light absorption and conversion efficiency of next-generation solar cells.

Storage: Nanotechnology is revolutionizing batteries and supercapacitors. Nanostructured electrodes (e.g., silicon nanowires in Li-ion anodes) increase energy density and charging rates. Nanomaterials also enhance hydrogen storage for fuel cells.

Conversion: Nanocatalysts, with their high surface area, are making chemical reactions more efficient, such as in the production of biofuels and in fuel cell electrodes.

6. Electronics and Computing:

As silicon-based electronics approach physical limits, nanotechnology offers pathways beyond.

New Materials: Graphene, carbon nanotubes, and transition metal dichalcogenides (TMDs) are being explored for faster, more flexible, and lower-power transistors.

Novel Computing Paradigms: Nanotechnology enables new architectures, including spintronics (using the electron's spin) and neuromorphic computing (nanodevices that mimic the brain's neural networks). The prospect of quantum computing also relies on controlling quantum states in nanoscale systems.

7. Materials Science:

The integration of nanomaterials into bulk materials leads to transformative improvements.

Enhanced: Carbon nanotube and graphene composites are creating materials with exceptional strength-to-weight ratios for aerospace and automotive applications.

Intelligent: "Smart" or functional materials are emerging. These include self-healing coatings, textiles that repel stains or monitor vital signs, and sensors embedded directly into infrastructure.

8. Environmental Nanotechnology:

Nanotechnology offers powerful tools for environmental protection.

Remediation: Nanoscale zero-valent iron (nZVI) is used for in-situ groundwater remediation, breaking down toxic contaminants like chlorinated solvents. Nanocatalysts and nanofilters can degrade or remove pollutants from air and water.

Monitoring: Networks of nanosen sors can provide real-time, distributed monitoring of environmental pollutants, enabling rapid response to contamination events.

9. Toxicity and Environmental Impact:

The unique characteristics of nanomaterials that make them beneficial may also present dangers. Their minute size lets them cross biological boundaries, and their high reactivity can cause cell damage. The long-term journey and effect of these human-made particles in the environment remain largely unknown. A major focus of current research is to decipher how a nanoparticle's physical and chemical traits influence its interaction with living systems, guiding a "safe-by-design" philosophy.

10. Ethical, Legal, and Social Implications (ELSI)

The powerful capabilities of nanotechnology raise profound ELSI questions. These include:

Equity: Will nanotechnologies widen the gap between rich and poor ("nano-divide")?

Privacy: The potential for ubiquitous nanosensor networks raises concerns about surveillance.

Human Enhancement: The use of nanotechnology for human augmentation (e.g., cognitive or physical) challenges definitions of normality and fairness.

Regulation: Current regulatory frameworks struggle to keep pace with the rapid development of new nanomaterials, necessitating adaptive and proactive governance.

11. Commercialization and Market Prospects

The global nanotechnology market is substantial and growing, driven by sectors like electronics, healthcare, and energy. However, the path from lab to market is fraught with challenges, including high manufacturing costs, scalability issues, and regulatory uncertainty. Successful commercialization requires close collaboration between academia, industry, and government to translate scientific breakthroughs into viable, safe, and cost-effective products.

12. Future Outlook

The future of nanotechnology lies not in isolation, but in its convergence with other transformative fields—artificial intelligence (for materials discovery and diagnostics),

biotechnology (for advanced therapeutics), and information technology (for data-handling sensors).

Key directions include:

Developing scalable and green synthesis methods.

Establishing robust regulatory and safety frameworks.

Focusing on sustainable nanotechnologies for a circular economy.

Exploring advanced concepts like molecular manufacturing.

Conclusion

Nanotechnology holds immense potential to address critical challenges in health, energy, and sustainability. However, this promise must be tempered with thoughtful consideration of risks and societal impacts. The future development of nanotechnology will depend on sustained research, balanced regulation, and ongoing public engagement to ensure that these powerful technologies benefit society broadly and responsibly.

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COFFEE LEAF RUST DISEASE: SYMPTOMS, ETIOLOGY AND MANAGEMENT

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Introduction

Among the several diseases that challenge coffee cultivation worldwide, Coffee Leaf Rust (CLR) stands out as the most devastating and persistent. Caused by the fungus *Hemileia vastatrix*, this disease has influenced coffee breeding, economics and farming practices for more than a century. It was responsible for the decline of coffee plantations in Sri Lanka in the 19th century and continues to threaten the sustainability of Arabica coffee across tropical regions. In India, the disease was first recorded in 1879 on *Coffea arabica* in Coorg. Since then, it has re-emerged in waves, compelling breeders and farmers to adapt through resistant varieties, shade management and fungicide innovations. This article presents an easy-to-understand overview of coffee leaf rust its symptoms, the pathogen behind it and modern management strategies, including eco-friendly and genetic approaches developed by the Central Coffee Research Institute (CCRI).

Historical Background

Coffee Leaf Rust was first described scientifically in 1869 by Berkley and Broome from infected leaves in Ceylon (now Sri Lanka). Within a few decades, it had spread across Asia, Africa and Latin America, severely affecting *Arabica* plantations. The British colonial trade network and the movement of infected seedlings accelerated its global dispersal. India's early coffee industry, heavily dependent on Arabica, faced major setbacks as CLR spread through Chikmagalur, Coorg and Wayanad. The epidemic forced many planters to replant with the hardier Robusta (Coffea canephora) and motivated the establishment of CCRI (1925) to study

and combat the disease. The institute's subsequent development of rust-tolerant varieties such as S. 795, Cauvery (Sln. 12) and Chandragiri transformed the country's coffee resilience.

Symptoms of Coffee Leaf Rust

Coffee Leaf Rust primarily affects leaves, but its indirect consequences defoliation, reduced photosynthesis and lower yields can devastate entire plantations. The following are key field symptoms that growers can recognize easily:




1. **Initial Yellow Spots**
    - Small, pale-yellow, circular spots (2-3 mm) appear on the upper leaf surface.
    - These lesions are often visible 2–3 weeks after infection.
2. **Orange Powdery Lesions**
    - On the underside of leaves, the spots correspond to orange, powdery pustules that are the hallmark of CLR.
    - The orange colour is due to masses of urediniospores, the asexual spores responsible for disease spread.
3. **Lesion Expansion and Coalescence**
    - Individual spots enlarge (up to 2 cm diameter) and may merge, forming irregular patches.
    - The surrounding tissue turns yellow and necrotic.
4. **Premature Defoliation**
    - In severe cases, leaves drop prematurely, leading to bare branches and reduced berry setting.
    - Plants become weak and berries on defoliated nodes may not mature properly.
5. **Yield Reduction and Plant Weakening**
    - Severe rust outbreaks can reduce yields by 30–80 % and may cause die-back in neglected fields.

Disease Cycle

1. Spore Germination – Spores deposited on leaf surfaces germinate under warm (22–28 °C) and humid (> 90 %) conditions.
2. Penetration – Germ tubes enter through stomata on the lower leaf surface.
3. Colonization – The fungus develops haustoria (feeding organs) inside host cells, absorbing nutrients and disrupting photosynthesis.
4. Sporulation – Within 3 weeks, new pustules form and release millions of spores, which wind and rain spread to nearby leaves.
5. Cycle repetition – Several infection cycles occur annually in conducive climates, particularly during post-monsoon humidity.

Epidemiology in India

CLR epidemics in India typically peak from October to December after the southwest monsoon when temperatures are mild and humidity remains high. Areas like Coorg, Chikmagalur, Wayanad and Thandikudi record high incidence in alternate years, depending on rainfall patterns. Arabica plantations at elevations 900-1,400 m are most vulnerable. Robusta plantations usually show minor infection unless shade and moisture are excessive. The introduction of new races of *H. vastatrix* is a constant concern. So far, more than 50 physiological races have been identified globally, of which 9-11 races are known in India. Continuous monitoring by CCRI's pathology division helps in identifying virulent forms and guiding resistant-variety development.

Integrated Disease Management

Managing Coffee Leaf Rust requires a holistic approach combining resistant varieties, cultural practices, biological control and fungicides. Relying solely on chemicals is neither sustainable nor economical.

1. Cultural and Agronomic Measures

- Pruning and Sanitation: Remove infected leaves and branches after harvest. Maintain open canopies for better sunlight and air circulation.
- Shade Regulation: Avoid excessive shade; maintain optimal (40–50 %) to reduce humidity.
- Nutrient Management: Balanced fertilization strengthens plant immunity. Deficient plants are more prone to infection.

- Drainage Improvement: Prevent prolonged leaf wetness by ensuring good drainage and proper spacing.

2. Chemical Control

Where disease pressure is high, fungicidal sprays are necessary. Recommended fungicides include:

- Copper-based sprays such as 1 % Bordeaux mixture (6:6:50).
- Systemic fungicides like Triadimefon 0.1 %, Hexaconazole 0.1 %, or Propiconazole 0.1 %.
- **Spray schedule:**
    - Pre-monsoon (May–June): preventive copper spray.
    - Mid-monsoon (July–August): systemic fungicide spray.
    - Post-monsoon (October–November): copper or combination fungicide spray.

Alternate chemical groups should be used to prevent resistance build-up.

3. Biological Control and Eco-Friendly Approaches

Recent CCRI and ICAR studies explore the use of endophytic fungi (*Trichoderma harzianum*, *Cladosporium* spp.) and antagonistic bacteria (*Bacillus subtilis*) that inhibit rust spore germination. Application of neem-based bio-fungicides (Azadirachtin 1 %) and chitosan sprays can also reduce spore load in organic plantations.

4. Forecasting and Early Warning

CCRI's Rust Forecasting Model, based on micro-climatic data, helps predict outbreak probability. Mobile advisories are issued to farmers during high-risk months, guiding spray schedules and shade management.

CCRI's Role in Coffee Leaf Rust Research

Since its inception, CCRI has maintained dedicated pathology and breeding programs to manage CLR. Major contributions include:

- Identification of rust races and maintenance of live cultures for screening.
- Breeding rust-resistant lines through crosses such as *Kent* × *S.288* (S.795), *Caturra* × *HDT* (Cauvery) and *Villa Sarchi* × *HDT* (Chandragiri).
- Development of forecasting models and weather-based disease prediction tools.
- Training and extension programmes to educate growers on integrated management.

Collaborative projects with international institutions, including World Coffee Research, continue to enhance CCRI's understanding of rust epidemiology and genetic resistance.

Future Perspectives

With climate change altering rainfall and temperature regimes, new rust races may emerge faster. Future management will depend on:

- Genomics and marker-assisted breeding for durable resistance.
- CRISPR and RNA-interference tools to silence susceptibility genes.
- Remote-sensing and AI-based disease monitoring for early detection.
- Promotion of resilient agroforestry systems that maintain ecosystem balance.

CCRI is already experimenting with multi-parent populations that combine cup quality, rust tolerance and pest resistance laying the foundation for India's next generation of climate-smart coffees.

Conclusion

Coffee Leaf Rust remains the most serious constraint to Arabica coffee cultivation worldwide. Yet, through sustained research, India has transformed this challenge into an opportunity for innovation. The synergy between CCRI's scientific breeding, planters' adaptive management and extension support has built a resilient coffee industry that withstands both pathogens and climate shocks. Understanding the disease its symptoms, lifecycle and control is vital for every grower. Timely detection, integrated management and the adoption of improved varieties ensure that India's coffee continues to flourish, aroma intact, despite the orange dust of its most notorious enemy.

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SCOPE OF CHATBOTS IN FISHERIES EXTENSION

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Abstract

Chatbots are computer programmes designed to communicate with humans through text-based communication. Their application in different sectors, including business, customer service, e-commerce, healthcare, finance and education are becoming increasingly popular. However, the use of chatbots in agriculture and its allied sectors, especially in fisheries and aquaculture are limited. The literature search using the key word 'chatbot' in 'Web of Science' showed that only 392 peer reviewed articles are available to attempt the present study. Review of these articles revealed that chatbots, from being a psychotherapist mimic to becoming an Artificially Intelligent (AI) application has evolved drastically. By understanding this evolution, chatbot technologies has been categorized belonging to the following four eras: Pre-internet, Internet, Weak AI and Natural Learning Programme (NLP) and Initial phase of Strong AI. The study also has attempted to provide suggestive measures for the efficient use of chatbot technology in fisheries and aquaculture sector by inculcating similar applications in agriculture and veterinary sciences.

Keywords: Chatbot, Artificial Intelligence, Natural language processing, Fisheries and Aquaculture.

Introduction:

A chatbot is a computer program designed to stimulate conversation with human, typically through text-based communication. The term "chatbot" initially was proposed by Michael Mauldin in 1977 by word "chatterbot" that describe robots that communicate with human. Chatbots are programmed to perform a variety of tasks, such as answering common questions, providing customer support or helping users to complete simple tasks (Deryugina, 2010). They are also known as chatterbot, smart bots, or digital assistants used in messenger apps, websites or mobile apps. They can provide 24/7 customer service, and provide personalized assistance without the need of human intervention. They have become increasingly popular in recent years, and are now being used as digital assistant tools in various sectors such as business, customer service, e-commerce, healthcare, finance and education.

They help companies to save time and resources by automating simple task and handling routine enquiries allowing employees to focus on more complex tasks. In transfer of technologies i.e. extension service, they are being extensively used in agriculture sector especially in India. However, in fisheries and aquaculture sector, their application is almost nil. Therefore, this article attempts to suggest application of chatbot as an efficient extension tool in transfer of fisheries and aquaculture technologies by comprehending the evolution of chatbot technology and its existing applications in agriculture and allied sector.

Types of chatbot:

Chatbots have come a long way since their inception, with significant advancements in technology and programming. Researchers have classified chatbots into different types based on their capabilities and functionality. Kar and Haldar (2016) have classified chatbots into two types: Simple Chatbots and Smart Chatbots. Simple chatbots are rule-based and programmed with pre-defined commands that have limited ability to handle complex conversations. On the other hand, Smart Chatbots are AI chatbots with natural language processing models that are capable of human-like conversations. Meanwhile, Nimaval and Champaneri (2017) has further classified using other parameters such as level of interaction, and the method of response generation. This classification was further enhanced by Adamopoulou and Moussiades, (2020) who broadly classified chatbots into more specific categories. However, a chatbot can simultaneously belong to multiple categories as most of the recent chatbots are multi-funtional.

We have rearranged types of chatbot (Fig-1) under four major categories that are discussed below:

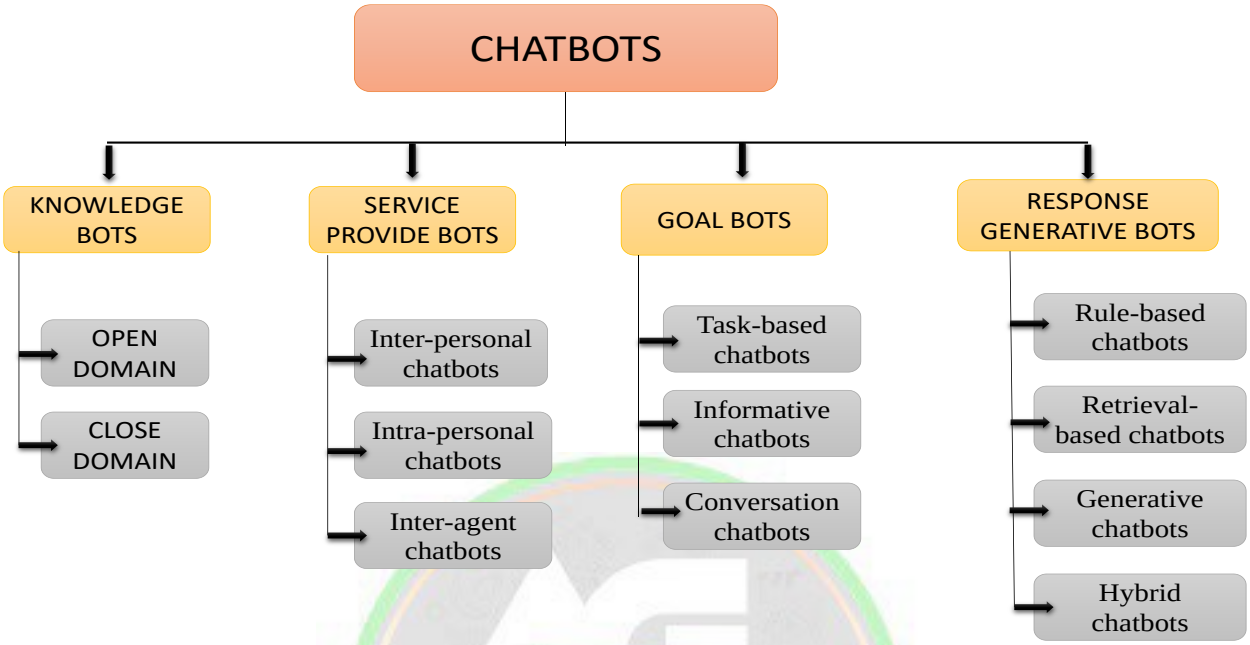


Figure 1: Classification of Chatbots

Differences and similarities of Chatbots and Expert system:

Chatbots and expert systems in agriculture are similar in that both provide farmers with valuable, timely advice and decision support, helping to address issues like crop management, soil health, and pest control using artificial intelligence or knowledge databases. The main difference is that chatbots are designed for interactive communication, enabling farmers to ask questions in natural language and receive instant responses, such as AgroBuddy advising on the best time to plant rice based on real-time data. In contrast, expert systems excel at processing complex agricultural problems through structured logic and rules, offering analysis and recommendations for specific scenarios like diagnosing plant diseases or selecting fertilizer—such as an online expert system for identifying crop infections. While chatbots focus on conversational accessibility and user-friendliness, expert systems offer deep analytical expertise for more technical, specialized tasks.

Chatbot's general applications:

In earlier days i.e. chatbots in the pre-internet era were mostly used in the form of simple rule-based system that could only respond to limited set of pre-defined inputs. Other applications of chatbots include gaming virtual-assistant and language translation. However, these early

limited applications have paved the way for development of more sophisticated chatbots that can now perform multiple functions by using AI and other advanced technologies. Chatbots are now significantly more powerful with internet and AI. Internet has given the connection and infrastructure such as data algorithm, while AI has made it possible for chatbots to understand and respond in more human like manner. Internet and AI has empowered Chatbot to use the following four important advancements in computer technology:

(a) Natural Machine Processing (NLP): NLP is a branch of AI that focuses on teaching machines to understand and process human language. With NLP, chatbots can understand user queries, identify keywords and phrases, and respond in a way that is both accurate and natural-sounding.

(b) Machine learning (ML): ML allows chatbots to learn from user interactions and improve their responses over time. By analyzing user data and feedback, chatbots can adapt to users' needs and preferences, providing more personalized and relevant responses.

(c) Cloud computing: The usage of cloud computing has greatly benefited chatbots, particularly in the context of the Internet. With cloud computing, chatbots can operate remotely, accessing data and processing power from servers located around the world.

(d) Application Programming Interfaces (APIs): The integration of application programming interfaces (APIs) has further empowered chatbots by enabling them to seamlessly access data and features from third-party applications and services. This integration allows chatbots to connect with payment gateways, customer relationship management (CRM) software, and other systems, enhancing the user experience with a more unified and streamlined approach.

Application of Chatbot in Agriculture and allied sector:

Application of chatbot in the field of agriculture and allied sector is a potential concept that is gaining popularity due to many proven benefits it offers. International Business Machines (IBM) Corporation's Watson Assistant is one of the best example for application of chatbot in agriculture. This chatbot uses NLP and ML algorithm in disseminating weather advisory. Since then, many other AI chatbots have been developed and are available for different applications in agriculture and allied sector. The following are the proven benefits that has been obtained by using chatbots in fisheries and allied sector:

1. **Improved Access to Information**: Chatbots help farmers access critical information such as weather patterns, soil conditions, and market prices in real-time. This can help farmers make informed decisions and improve productivity (Eaton *et al.*,2018). A rule-based Chatbot can be implemented involving web-based information and NLP to utilize the information-sharing platform to disseminate knowledge. (Ong *et al.*,2021)
2. **Improved Customer Service**: Chatbots can help farmers provide better customer service by answering queries from customers about farming practices, crop quality, and product availability (Maginga *et al.*, 2022).
3. **Crop Monitoring**: Chatbots can help farmers monitor crop growth, detect pests and diseases, and identify potential problems early on. This can help farmers take corrective action before the problem escalates (Maginga *et al.*, 2022).
4. **Resource Optimization**: Chatbots can help farmers optimize their use of resources such as water and fertilizer by providing recommendations on the best farming practices (Momaya *et al.*,2021)
5. **Data Analytics**: Chatbots can collect data on crop growth, weather patterns, and market trends. This data can be analyzed to identify patterns and make predictions, leading to better decision-making (Kshetri, 2018).
6. **E-agriculture Marketing**: "AGROBOT" chatbot developed by,Chandolikar *et al*.,(2022) allows farmer to obtain information of market and demand; farmers can easily communicate with this chatbot.
7. **Nutrition and animal health management**- A chatbots "Milchbot" by Herrera *et.at*,(2022) designed to provide farmers with information on good nutrition and care for dairy cows by answering queries about feeding are care process about dairy cows.

Chatbot in fisheries/aquaculture – the way forward:

Adoption of chatbot technology in India that too for application in agriculture sector is evident from the recent lauch of Ama Krush AI- India's first Agri chatbot launched by Odisha State Government of India. "Ama Krush AI" chatbot will assist farmers to get awareness about Government schemes, agronomic practices, and loan product from more than 40 cooperative and commercial banks. Although the agriculture sector especially in India have adopted the chatbot technology, adoption of chatbot in fisheries/aquaculture is comparatively nil. Al-Rasyid et al., (2020) proposed an integrated IoT and chatbot for real-time monitoring of aquaculture conditions

integrated with smart aerator. This Indonesian study can be claimed to be one of the earlier study globally, that tried to harness the advantage of the disruptive technology like Internet of Things (IoT) with chatbot. Similar Indian attempt has been done by Jasmine et al., (2022), who designed AI-based "Aqua-gent" chatbot to provide services and support to shrimp aquafarmers. This is the only chatbot developed in fisheries/aquaculture sector in India so far. Fisheries being one of the promising sector of India should try to inculcate the disruptive technologies especially in transfer of technologies where there is lack of extension personnel. India's flagship fisheries development scheme "Pradhan Mantri Matsya Sampada Yojana (PMMSY)" with a total budget outlay of Rs.20,000 crore has provisions to encourage adoption of innovative technologies for the sector's development. The irony is that India has not much innovations in adopting weak AI technologies but the world is in the initial phase of adopting strong AI like ChatGPT. To become a global leader in food production and self-reliance, Indian National Agriculture Research System (NARS) must conduct more field trials with AI powered chatbots by using the PMMSY scheme.

Probable applications of Chabot's for fisheries:

Chatbots can be used to disseminate information about new technologies and innovations in the fisheries and aquaculture industry. This includes best farming practices, disease control, types of feed, as well as informing farmers and fishers about new regulations, market trends, and industry news. By providing instant responses, it can help them stay up-to-date with the latest developments in their field.Chatbots can also provide real-time technical assistance to farmers and fishers. They can answer questions about maintaining water quality, managing waste, preventing diseases, choosing fishing gear, minimizing bycatch, and identifying fish species. By offering prompt and accurate information, chatbots can help improve production processes, resulting in better yields and more sustainable practices. An integrated IoT and chatbot system for real-time monitoring of aquaculture conditions, developed by Al-Rasyid et al. (2020), exemplifies this concept. It can also be used to conduct surveys and gather feedback from farmers and fishers. These surveys can be customized to address industry-specific questions, allowing for the analysis of responses to improve production processes. For instance, surveys can assess the effectiveness of new fishing gear, identify the most caught and sold species, and gauge the ease of use, catch quality, and environmental impact. The insights gained from these surveys can inform the design of fishing gear and the development of new technologies that cater to the

needs of the industry.Additionally, chatbots can be used to provide training to farmers and fishers. Video tutorials on using new farming equipment can be uploaded to chatbots, allowing users to access them at any time. An experimental chatbot model developed by Radhian and Afrianto found that 72% of farmers agreed that this chatbot application could help increase their knowledge of livestock cultivation, and 78% agreed that it made it easier for them to find information on livestock farming.

Conclusion:

Artificial Intelligence has empowered conventional chatbots to the next level of information dissemination.AI-driven chatbots like "Aqua-gent" and "Ama Krushi" AI exemplify their capability to provide tailored and accurate assistance even for complex task in aquaculture. Chatbot have the potential to empower fishers and aquafarmers by disseminating information on government initiatives and sustainable practices, promising a transformative impact on fisheries, aquaculture and related sectors.

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WATER BUDGETING AND MANAGEMENT IN INDIA

Article ID: AG-V05-I10-164

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Abstract

A water budget is a measure of the amount of water entering and the amount of water leaving a system. It is a way to evaluate all the sources of supply and the corresponding discharges with respect to a basin or aquifer. It is a basic tool that can be used to evaluate the occurrence and movement of water through the natural environment. To maintain a balance in the ecological system, one must account for the incoming (source of water) and outgoing (water losses in the system) water resources. A water budget may be used to manage development of water resources within a region, and to ensure a sustainable supply of water over time. Water budget commonly provides knowledge about how much water is available, where is it available with detailed understanding of the flow dynamics. These flow dynamics include the origin and movement of groundwater and surface water as well as the interaction between the two systems. Water budget studies consider the volumes of water within the various reservoirs of the hydrologic cycle and the flow paths from recharge to discharge.

Keywords: water budget; evaporation; water management; transpiration; surface water; groundwater.

1. Introduction

The water budget takes into account the water cycle, evapo-transpiration, groundwater and surface water supplies, and inter basin (import and export) transfers of the water. Thus, a water budget is important to understand since it provides crucial information regarding the carrying capacity of the land with regard to water resources. The Figure 1 shows the conceptual model of water budget.

2. Materials and Methods

2.1. Components of Water Budget

The most basic equation for water budgets is based on the hydrologic cycle, where water moves from the atmosphere to the Earth's surface to various destinations, and finally back to the atmosphere:

$$P = I + ET + R \quad (1)$$

Where, P = precipitation; I = infiltration; ET = evapo-transpiration,; R= runoff

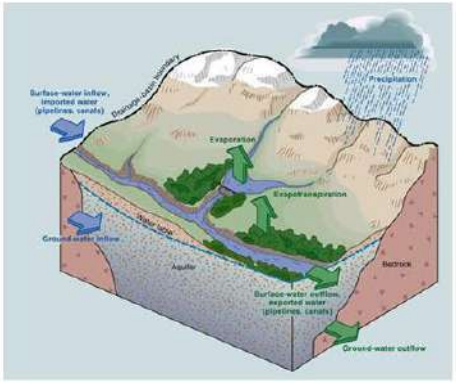


Fig. 1: A conceptual water budget.

2.2. Precipitation

Precipitation is the sole input to the water budget under natural conditions. Precipitation comes in various forms.

2.3. Infiltration/Recharge

Infiltration of water into the land surface is a critical component of a water budget. Without infiltration, all water would either evaporate from the land surface or runoff to surface waters. The term "infiltration" means that the water moves downward from the land surface into the soil. Some infiltration water moves toward streams just below the land surface. This water is not used for potable water supplies, generally, but is invaluable for ecosystem health. Other infiltrated water penetrates more deeply in to soil layers and can recharge aquifers. Under natural conditions, water from aquifers is transmitted to surface waters after periods ranging from years to millennia. Infiltration is highly dependent on the amount, intensity and season of precipitation. A lower percentage of precipitation infiltrates to become ground water during periods, where soils are very dry (e.g., summer), brief storms, high-intensity storms, and when the ground is frozen.

2.4. Evapo-Transpiration

Evapo-transpiration is a combination of two terms evaporation and transpiration. Evaporation involves the transformation of surface water to atmospheric water. Transpiration occurs when water in plants moves from shallow soils to the root system to the leaves, transporting nutrients and energy, and then evaporates from the leaves. The two terms are usually considered together in water budget calculations. Both evaporation and transpiration tend to be higher during periods of hot weather, low humidity and high wind. Of course, nearly all transpiration occurs during the growing season in case of agricultural crops and round the years for natural vegetation like forest.

2.5. Runoff

Runoff occurs when precipitation falls onto the land surface and moves toward surface waters. Runoff is affected by a wide variety of factors, such as:

1.Soil type and depth

2.The presence or absence of vegetation

3.The presence or absence of impervious surfaces such as pavement or buildings

4.General topography

5.The extent to which water is trapped in puddles and never gets to major surface waters,

6.The intensity of the precipitation

7.The form of the precipitation (such as snow or rain), and

8.The amount of moisture in the soil just before the precipitation

2.6. Factors affecting Water Budget of a Watershed

The natural "water budget" accounts for all the water entering the watershed, how it travels through the watershed or is stored, and all the water leaving the watershed. The natural factors affecting water budget of a watershed are as below:

1.rainfall and snowfall

2.temperature and wind

3.vegetation

4.soil properties (surface and subsurface)

5.stream and channel characteristics (vegetated or clear channels)

In addition to these natural factors, human activities and alterations of the watershed greatly affect the water budget.

3. Results and Discussion

In simple terms, a water budget for a given area (watershed or basin) can be looked at as water inputs, outputs and changes in storage. The inputs into the area of investigation (precipitation, groundwater or surface water inflows, anthropogenic inputs such as waste effluent) must be equal to the outputs (evapo-transpiration, water supply removals or abstractions, surface or groundwater outflows) as well as any changes in storage within the area of interest.

In the simplest form this can be expressed as:

Inputs = Outputs + Change in storage

$$P + SW_{in} + GW_{in} + ANTH_{in} = ET + SW_{out} + ANTH_{out} + \Delta S \quad (2)$$

Where; P = precipitation, SW_{in} = surface water flow in, GW_{in} = groundwater flow, $ANTH_{in}$ = anthropogenic or human inputs such as waste discharges, ET = evaporation and transpiration (evapo-transpiration), SW_{out} = surface water flow out, GW_{out} = groundwater flow out, $ANTH_{out}$ = anthropogenic or human removals or abstractions, ΔS = change in storage (surface water, soil moisture, groundwater). More detail is incorporated into the water budget to account for additional physical aspects. Essentially, three compartments are considered in the water budget determination i.e. the ground surface; the unsaturated zone and the saturated zone.

Precipitation falls onto the ground surface and then can either:

1.evapo-transpirate back to the atmosphere

2.runoff from the surface to surface water bodies (e.g. streams, lakes and wetlands)

3.move downward to the unsaturated zone, or

4.be removed for human water supply purposes

In turn, water that moves to the unsaturated zone can either:

1. evapo-transpirate back to the atmosphere;

2. move laterally as interflow to discharge to local surface water bodies; or

3. move downward to the saturated zone

Similarly, water that moves to the saturated zone can:

1. evapo-transpirate back to the atmosphere (e.g. via plants whose roots extend to near the water table)

2. move in the groundwater system and eventually discharge into a surface water body; or

3. be removed for human water supply purposes

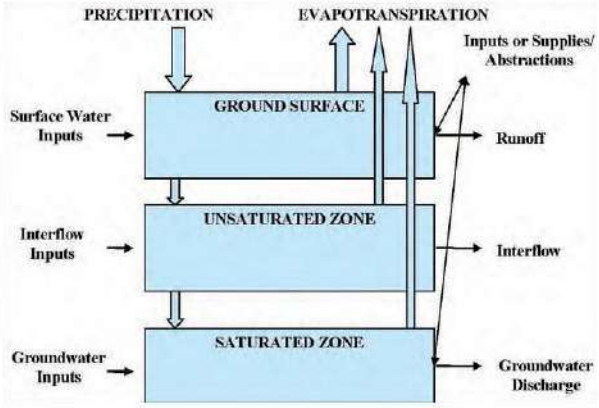


Fig. 2: Various water budget components.

The Fig. 2 illustrates that evapo-transpiration can occur from any of the three compartments (ground surface, unsaturated and saturated zones). This figure also shows anthropogenic inputs and/or abstractions. These are both related to human intervention in the water cycle. Inputs would occur in an instance, where water external to a watershed was being brought into and disposed of within the watershed, thereby increasing the water volume in the watershed. Supplies or abstractions would occur, where water was being withdrawn from either a surface water body or the groundwater system and was being removed from the watershed. It is important to note that these human interventions are often difficult to account for in a water budget owing to the fact that a certain portion of the withdrawn water is likely re-circulated back within the same watershed (e.g. through irrigation or through leakage from municipal infrastructure, etc.). Figure 21.2 also shows inputs into the three compartments (i.e. surface water inputs, interflow inputs and groundwater inputs). Water budgets are generally carried out on a watershed or sub-watershed scale and the surface water inputs and interflow inputs tend to be negligible.

Mathematically, the water budget can be expressed as follows:

$$P = RO + AET + I + D + A \pm \Delta I \pm \Delta s \pm \Delta g \quad (3)$$

Where; P = precipitation; RO = surface runoff; AET = actual evapo-transpiration; I = interflow;D = groundwater discharge; A = anthropogenic inputs (septic systems) and/or supplies/abstractions; ΔI = change in land surface storage; Δs = change in soil moisture storage; Δg = change in groundwater storage.

Following the above water budgeting equation:

$$\text{Stream Flow Discharge (SFD)} = I + D + RO \quad (4)$$

Infiltration = P – AET – RO – ΔS – ΔI (5)

Aquifer Recharge = P – AET – RO – ΔS – ΔI – I (6)

Over long periods of time in an unstressed, natural state basin (no groundwater pumping or other anthropogenic influences), the natural inputs will balance the natural outputs so that the change in storage will be zero. Soil moisture storage may vary considerably on a daily basis but the net change (Δs) over an annual cycle will be negligible compared to other water budget components. Similarly, groundwater storage and land surface storage may fluctuate on a monthly or annual basis, but Δg and ΔI will approach zero (steady state) over an extended period of time provided other water budget components remain essentially constant. If Δs, ΔI and Δg equal zero, then substitution of equation (6) into equation (3) reveals that

Aquifer recharge, R = D + A (7)

Substitution of equation (3) into (2) gives us

Stream flow discharge, SFD = P – AET – A (8)

If groundwater pumping is small, (i.e., A~0), then annual recharge can be equated to groundwater discharge and stream flow discharge will be the difference between precipitation and actual evapo-transpiration.

R = D (9)

Conclusion

The preceding quantification assumes the groundwater divides would have to correspond to a large degree to the surface water divides in a 3-dimensional sense and this depends on the size of the study area and the nature of the groundwater flow system. It is important to understand the relationship between the groundwater and surface water divides. Where these divides are not coincidental, groundwater inputs within the surface watershed may not be reflected in the groundwater discharge within the surface watershed.

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INDIGENOUS FISH PROCESSING AND PRESERVATION PRACTICES AMONGST WOMEN IN NORTH EASTERN STATES OF INDIA

Article ID: AG-V05-I10-165

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Abstract

Indigenous knowledge (IK) is the community – based knowledge, which every culture has evolved over a considerable period of time in many generations to address specific needs. For the native communities of northeast India, fermentation is a way of life. Fermented fish locally known as 'Hidol' in Assam, 'Tungtap' in Meghalaya , 'Shidol' in West Bengal and Tripura. The culinary tradition of fermented fish is linked with the geography and weather conditions of the land. The presence of vast wetlands that become hotbed for various fishes in monsoon is obvious . In these shallow waters *Puntius sophore* (*Hamilton*) or Pool Barb, locally known as 'Punti' ,which propagates in large numbers are preserved by the locals for a longer period of time with the activity of salt-free fermentation and the fish is dried in the sun over two or three days. Then the dried fish is grained in a Smasher locally called as 'Urun' to make fine powder, and pieces of stem of Edible taro (*Colocasia esculenta*) and some Garlic bulb is added with it and make a paste , after one or two days they add turmeric powder massaged with oil—to prevent external moisture. After that they give their desired shape to the thick paste and dried under the Sun. Over the course of time, the proteins, fatty acids and lipids break down giving it a characteristic unpleasant aroma. The existence of shidol dates back to the British era i.e., before the year 1824. Shidol has a strong flavour, palatability, dark brown color and texture which makes it highly demanded in Assam and Northeast India . Moreover, the products possess high nutritional value.

Different communities within Assam use fermented fish product (shidol) to provide the basic nutritional value in their diet. Shidol being treated as a remedy for cold, fever and loss of appetite. This fermented product prepared only by the specific community people specifies their ethnic knowledge which has been passed through generation to generation However, these practices are confined to some very specific places due to the advancement of processed foods.

Key words: Indigenous knowledge, Fish processing, Shidol, Urun, Appetite

Introduction

Indigenous Knowledge: A Global and Local Perspective

Indigenous knowledge (IK) has been widely recognized as one of the most valuable repositories of community-centered knowledge systems. Unlike formal scientific knowledge, which is codified in textbooks, laboratories, and written documents, IK emerges from centuries of practical experience and oral transmission. It represents adaptive strategies that people employ in response to their environment, resources, and socio-cultural needs (Agrawal, 1995).

Globally, indigenous communities have relied on IK for survival in some of the world's most ecologically diverse but often fragile ecosystems. From the Inuit of the Arctic who developed techniques of fish drying and meat preservation in freezing climates, to the Pacific islanders who perfected fermentation of breadfruit and taro, the value of IK in ensuring food security cannot be overstated. Such knowledge is holistic, combining ecological insights, nutritional strategies, cultural rituals, and social systems.

In the context of food preservation, IK is especially critical. Before the advent of modern refrigeration and industrial processing, traditional communities developed unique ways to extend the shelf life of perishable products such as fish, meat, fruits, and vegetables. Fermentation, sun-drying, smoking, and salting are ancient preservation techniques that remain relevant today, both as cultural heritage and as sustainable food technologies.

North Eastern India: A Unique Bio-Cultural Region

The North Eastern Region (NER) of India is one of the country's most distinctive cultural and ecological landscapes. Geographically, the region is bound by the Eastern Himalayas, the Indo-Burma ranges, and the floodplains of the Brahmaputra and Barak rivers. Its eight states—Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura—are home to over 220 ethnic groups and tribes, each with its own language, food habits, and cultural practices (Barooah & Goswami, 2014).

The humid subtropical climate, characterized by high rainfall and humidity, creates conditions that favor both the growth of freshwater fish and the need for preservation techniques. Seasonal floods, abundant wetlands, and rivers like the Brahmaputra provide a rich diversity of fish species such as *Puntius sophore* (Pool Barb), *Channa* spp. (Snakeheads), *Labeo rohita* (Rohu), and *Mystus* spp. (Catfishes). However, due to the lack of refrigeration facilities in rural areas, traditional preservation techniques remain crucial for ensuring year-round availability of fish protein.

Fish is not only a dietary staple but also a cultural and ritualistic element across the NER. It is central to festivals, ceremonies, and daily meals. For example, in Assam, fish is essential in *Bihu* feasts; in Manipur, fermented fish (*ngari*) is a mandatory component of traditional dishes; and in Meghalaya, *tungtap* is considered both a delicacy and a marker of ethnic identity (Jeyaram et al., 2009).

Women and Food Knowledge

In indigenous communities, women are often the custodians of food knowledge. Their role in household nutrition extends beyond cooking to the collection, processing, preservation, and storage of food. Women not only ensure the survival of traditional practices but also serve as transmitters of knowledge to younger generations. This is particularly evident in fish processing and preservation, where women dominate activities such as cleaning, sun-drying, pounding, fermenting, and shaping.

In the North Eastern states, women's involvement in fish processing is closely tied to gendered divisions of labor. While men engage in fishing activities, women handle post-harvest processes. This not only secures food for the family during lean seasons but also generates supplementary income through local market sales. Women's expertise transforms perishable fish into durable, nutritious, and culturally significant products that enhance household food security.

Fermentation as a Way of Life

Fermentation is perhaps the most iconic of the indigenous fish preservation techniques in the NER. Products such as *hidol* in Assam, *shidol* in Tripura and parts of West Bengal, *tungtap* in Meghalaya, and *ngari* in Manipur illustrate the diversity of regional variations. These products share some commonalities: the use of small freshwater fish, the exclusion of salt in many recipes, and the reliance on natural microbial activity to create distinct flavors and aromas.

Fermentation not only extends shelf life but also enhances the nutritional value of fish. Bioactive compounds such as amino acids, fatty acids, vitamins, and probiotics are developed during the fermentation process. The breakdown of proteins and lipids produces the characteristic strong aroma and flavor that defines fermented fish. Communities also attribute medicinal properties to these foods, using them as remedies for fever, cold, and appetite loss (Sarma & Deka, 2019).

Historical Roots and Cultural Continuity

The existence of fermented fish in the NER dates back several centuries. Historical records suggest that *shidol* was widely consumed even before the British colonial era (before 1824). Its strong flavor, dark brown color, and palatability have made it highly demanded across the region. Such products are not merely food items; they are cultural artifacts that reflect historical continuity, ethnic identity, and community resilience.

However, these practices face growing threats from modernization, urbanization, and the penetration of industrially processed foods. Younger generations are often less inclined to engage in the labor-intensive processes of fermentation and drying. At the same time, ecological changes such as irregular rainfall and declining fish stocks affect the availability of raw materials.

State-Wise Documentation of Indigenous Fish Processing Practices

Assam

In Assam, fermented fish known as *hidol* and *shidol* occupies a central place in food culture. *Puntius sophore* (locally *Puthi* or *Punti*) is the most commonly used species, given its abundance in floodplains and wetlands during the monsoon. The process involves:

1. Sun-drying small fish for 2–3 days.
2. Pounding the dried fish in a wooden mortar (*urun*).
3. Mixing with taro stems (*Colocasia esculenta*), garlic, and turmeric.
4. Shaping into cakes or pastes, followed by sun-drying again.

Women oversee each stage, often working collectively in household courtyards. *Shidol* is highly valued as a side dish with rice, and it is also sold in local markets, forming an important income source for rural women. Communities attribute medicinal qualities to *shidol*, particularly for appetite stimulation and relief from colds (Sarma & Deka, 2019).

Tripura

Tripura is perhaps the most renowned for *shidol*. Historical evidence suggests its preparation dates back before 1824, during British colonial times (Talukdar & Borthakur, 2017). Unlike Assamese versions, Tripuri *shidol* often uses bamboo tubes for fermentation. The airtight bamboo creates anaerobic conditions that encourage microbial breakdown. The resulting product has a dark brown color, strong odor, and is often consumed with mustard oil, chili, and vegetables.

Women's cooperatives in Tripura have begun to commercialize *shidol*, selling packaged versions in regional markets. However, traditionalists argue that modern packaging alters the flavor and compromises authenticity.

Meghalaya

In Meghalaya, particularly among Khasi and Garo tribes, fermented fish called *tungtap* is a delicacy. Preparation involves wrapping small dried fish in banana leaves and storing them in bamboo containers. This eco-friendly method minimizes contamination and extends shelf life. Unlike *shidol*, *tungtap* is usually consumed in smaller quantities as a flavor enhancer in chutneys.

Women not only prepare *tungtap* but also sell it in local *haats* (weekly markets), contributing to household income. The use of banana leaves demonstrates ecological adaptation, as they act as natural preservatives and impart a distinct aroma.

Manipur

Manipur is famous for *ngari*, a fermented fish product central to Manipuri cuisine. Traditionally prepared from *Puntius sophore* and *Esomus danricus*, *ngari* is sun-dried and fermented in earthen pots. The product is so integral that no Manipuri feast is considered complete without it.

Unlike *shidol*, *ngari* is often prepared with salt, which gives it a different flavor profile and longer shelf life. Women dominate *ngari* production, and its sale in markets like *Ima Keithel* (the world's largest women-run market in Imphal) illustrates the intersection of food, gender, and economic agency (Devi, 2018).

Nagaland

In Nagaland, smoking and drying remain the dominant preservation methods. Fish are often smoked over kitchen fires, which serve dual purposes: cooking meals and preserving fish.

Smoked fish is stored in bamboo baskets lined with leaves, lasting several months. Fermented fish is less common here compared to neighboring states, but smoked fish has equal cultural significance. Women are responsible for tending the fires, ensuring even smoking, and storing the products.

Mizoram

Mizo households employ both smoking and small-scale fermentation. Fish are often smoked along with meat, creating mixed preservation practices. Women emphasize the importance of flavor rather than shelf life, making smoked fish central to festive meals. Fermentation is practiced on a smaller scale but remains vital in remote areas where refrigeration is absent.

Arunachal Pradesh

Tribes such as the Adi and Apatani rely on sun-drying and bamboo storage. Fish are gutted, cleaned, and dried on bamboo racks above fireplaces. This semi-smoking technique preserves fish for long periods while keeping them available for use in soups and stews. Women oversee the process, ensuring cleanliness and maintaining the firewood supply.

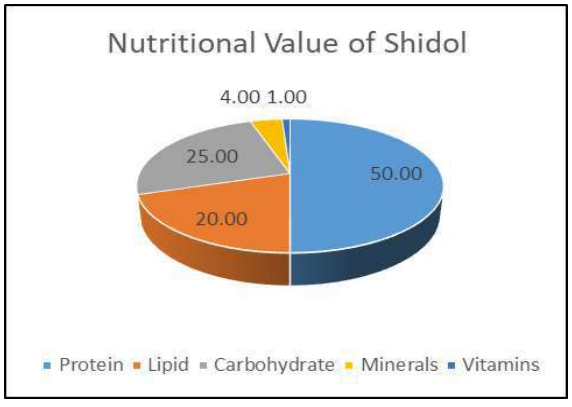
Sikkim

Although Sikkim is less fish-centric compared to Assam or Tripura, certain communities like the Lepchas preserve fish through fermentation and drying. Given the cooler climate, fermentation cycles differ, often taking longer. Women play a smaller but significant role, particularly in transmitting practices as part of cultural heritage rather than daily food necessity.

Nutritional and Medicinal Value

Fermented fish products in the NER are nutritionally dense. Laboratory analyses of *shidol* and *ngari* reveal:

- **Proteins**: 40–50% dry weight, rich in essential amino acids.
- **Fats**: 10–20%, with high levels of polyunsaturated fatty acids (PUFAs).
- **Vitamins**: High in B12, A, and D, supporting immunity and neurological health.



- **Minerals**: Iron, calcium, and zinc in bioavailable forms.

Fermentation enhances digestibility by breaking down proteins into amino acids and peptides. It also generates lactic acid, which acts as a preservative. Communities believe fermented fish boosts appetite, aids postpartum recovery, and acts as a remedy for fever and colds. Scientific validation supports many of these claims, especially regarding immune support and micronutrient supply (Jeyaram et al., 2009).

Socio-Cultural Significance

Fermented fish is more than a food product—it is a cultural symbol. Its pungent aroma often evokes nostalgia among diasporic communities. Culinary traditions surrounding fermented fish are tied to festivals, marriages, and rituals. For instance, in Manipur, *ngari* is indispensable during *Ningol Chakouba* (a festival celebrating sisters).

Gender roles are reinforced through fish processing. Women's collective labor in preparing fermented fish strengthens social cohesion and intergenerational learning. Food preparation becomes a space where skills, stories, and cultural values are passed down.

Economic Importance

Fermented fish contributes significantly to rural economies. Women sell products in local markets, generating cash income that supplements agriculture. In Tripura, women's cooperatives have formalized production, improving packaging and shelf life. However, commercialization also creates tension between authenticity and market demands.

Market prices for fermented fish are considerably higher than for fresh fish, reflecting labor inputs and cultural value. For instance, 1 kg of *shidol* may cost 5–6 times more than the equivalent weight of fresh *Puntius sophore*.

Challenges

1. **Modernization and Lifestyle Change**

   Younger generations prefer industrially processed foods due to convenience, threatening the survival of traditional practices.

2. **Climate Change**

   Unpredictable rainfall disrupts sun-drying cycles, leading to spoilage. Floods also affect fish availability.

3. **Health and Hygiene**

   Traditional processing often occurs in open-air environments, creating risks of

contamination. Lack of formal training in hygienic practices limits large-scale commercialization.

4. **Declining Knowledge Transmission**

   As rural-to-urban migration increases, fewer young women learn these skills from elders.

5. **Market Competition**

   Packaged fish products from outside the region compete with indigenous products, undermining local economies.

Opportunities and Policy Implications

1. **Scientific Validation and Promotion**

   Nutritional and medicinal properties should be documented through laboratory studies to enhance market credibility.

2. **Women's Empowerment**

   Formation of cooperatives can formalize production, provide better market access, and empower women economically.

3. **Agro-Ecotourism**

   Showcasing traditional practices to tourists can generate pride and revenue while preserving IK.

4. **Policy Integration**

   Government fisheries departments should include indigenous preservation practices in development schemes.

5. **Climate Adaptation**

   Research into improved drying technologies (solar dryers, hygienic bamboo containers) can adapt practices to changing environmental conditions.

Conclusion

Indigenous fish processing and preservation practices in North Eastern India represent a remarkable blend of ecological adaptation, nutritional ingenuity, and cultural resilience. Women are at the heart of these practices, transforming perishable fish into products of high cultural and nutritional value. From *shidol* in Tripura to *ngari* in Manipur, fermented fish embodies not only survival strategies but also symbols of identity, memory, and continuity. Despite challenges posed by modernization, climate change, and declining knowledge transmission, these traditions remain resilient. They continue to nourish communities physically, economically, and culturally.

To safeguard them, urgent efforts are needed in documentation, scientific validation, women's empowerment, and policy support.

Far from being relics of the past, indigenous fish processing practices hold lessons for sustainable food systems globally. They demonstrate how communities can harness natural microbial processes, renewable resources, and collective knowledge to achieve food security. In a world facing ecological uncertainty, such knowledge is not only relevant but indispensable.

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PRECISION BREEDING: REVOLUTIONIZING CROP IMPROVEMENT FOR A SUSTAINABLE FUTURE

Article ID: AG-V05-I10-166

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Abstract

Feeding an expanding global population projected to reach nearly 10 billion by 2050 remains one of the greatest challenges of our time. Agricultural systems must simultaneously increase productivity, adapt to climate change, and reduce their ecological footprint. Traditional crop breeding has played a crucial role in past agricultural revolutions but is now limited by its long breeding cycles, narrow genetic base, and dependence on environmental selection. Recent breakthroughs in precision breeding, including genome editing, genomic selection, and high-throughput phenotyping, have redefined crop improvement strategies. These technologies allow for targeted genetic modifications with unparalleled accuracy and speed, enabling the development of climate-resilient, nutrient-rich, and high-yielding crop varieties. This review highlights the principles, methodologies, applications, and future prospects of precision breeding as a sustainable approach to global food security.

1. Introduction

The twenty-first century faces an unprecedented convergence of agricultural challenges: climate volatility, soil degradation, diminishing water resources, and increasing demand for food, feed, and fuel. Conventional plant breeding, though responsible for the Green Revolution, is inherently slow, taking 10–15 years to produce a new variety.

Precision breeding marks a paradigm shift by combining the tools of molecular biology, bioinformatics, and artificial intelligence to make deliberate, predictable changes in plant genomes. Unlike transgenic modification, which introduces foreign DNA, precision breeding fine-tunes the plant's own genes to enhance desired traits. It represents a scientifically guided evolution—accelerating natural processes to meet human needs efficiently and sustainably.

2. Limitations of Conventional Breeding

Traditional breeding methods rely on hybridization followed by repeated selection and backcrossing to combine beneficial traits. However, this process is often laborious and imprecise.

Time Constraint: Developing a stable, improved variety can take over a decade, which is inadequate to cope with rapid climate shifts.

Linkage Drag: Desirable genes are frequently inherited alongside unfavorable alleles, leading to unwanted characteristics that must be bred out over many generations.

Narrow Genetic Base: Breeding is limited to sexually compatible species, excluding valuable genes present in wild relatives or distant species.

While Marker-Assisted Selection (MAS) improved precision by linking genetic markers (SSRs, SNPs) to desirable traits, it remains constrained for complex traits like yield or drought tolerance, which are controlled by multiple genes.

3. Genomic Selection: Accelerating Genetic Gain

Genomic Selection (GS) revolutionizes breeding by using genome-wide marker data to predict the performance of individuals before phenotypic evaluation.

In GS, a training population is genotyped using high-density markers and phenotyped for target traits. Statistical models correlate marker patterns with performance, enabling estimation of Genomic Estimated Breeding Values (GEBVs) for new, untested individuals.

This approach is particularly powerful for polygenic traits, such as yield or stress tolerance, which are influenced by numerous genes of small effect.

Benefits include:

Shorter breeding cycles by bypassing long field trials.

•Enhanced selection accuracy.

•Integration of large-scale genomic data into predictive models.

Thus, GS allows breeders to make early and data-driven decisions, accelerating the rate of genetic improvement per unit time.

4. Genome Editing: The Core of Precision Breeding

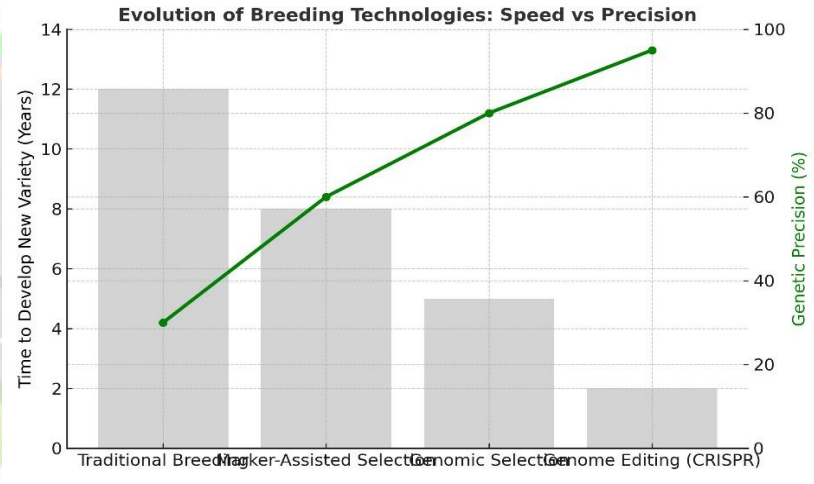
Among all precision tools, CRISPR-Cas genome editing stands out as the most transformative. It enables precise, targeted modification of specific DNA sequences, allowing direct manipulation of genes underlying key agronomic traits.

Mechanism of CRISPR-Cas System

The CRISPR-Cas9 system consists of a guide RNA (gRNA), designed to match a specific DNA sequence, and the Cas9 endonuclease, which cuts DNA at the targeted site. The plant's natural repair mechanisms—Non-Homologous End Joining (NHEJ) or Homology-Directed Repair (HDR)—then modify the sequence:

•NHEJ introduces small insertions or deletions that can inactivate genes (gene knockouts).

•HDR allows precise insertion or correction of specific sequences using a donor template.



Advantages over older methods

Compared with Zinc-Finger Nucleases (ZFNs) and TALENs, CRISPR is simpler, cheaper, and more versatile. Its ability to perform multiplex editing, modifying several genes simultaneously, makes it highly suitable for complex crops like wheat or potato.

Next-Generation Editing Technologies

Recent innovations have further refined genome editing:

•Base Editing enables single nucleotide substitutions without DNA breaks.

•Prime Editing functions as a "search-and-replace" tool, capable of all base conversions and small insertions or deletions.

Together, these systems enhance editing precision and minimize off-target effects, expanding the potential of precision breeding.

5. Applications of Precision Breeding

5.1 Enhancing Climate Resilience

Global warming and erratic rainfall threaten crop stability. Precision breeding helps develop drought-tolerant and heat-resistant varieties by modifying genes that regulate stomatal closure, root depth, or heat-shock proteins. For instance, editing genes involved in abscisic acid signaling can improve water-use efficiency without yield penalties.

5.2 Disease and Pest Resistance

Many plant pathogens exploit host susceptibility (S) genes for infection. CRISPR-mediated knockout of such genes can confer broad-spectrum resistance. For example, in wheat, CRISPR edits in the MLO gene provide resistance to powdery mildew. Similar strategies are applied to combat viral, bacterial, and fungal pathogens, reducing reliance on chemical pesticides.

5.3 Nutritional Improvement (Biofortification)

Precision breeding enables targeted enhancement of nutritional traits without introducing foreign genes.

Examples include:

•Increasing vitamin, iron, and zinc content in staple cereals.

•Altering fatty acid composition in oilseeds to improve heart health.

•Removing allergens or toxins, such as in peanuts and potatoes, for consumer safety.

This approach aligns agricultural productivity with public health objectives.

5.4 Agronomic and Sustainability Traits

Editing genes responsible for plant height, root structure, and branching can optimize crop architecture for high-density planting and mechanical harvesting. Enhancing Nitrogen Use Efficiency (NUE) genes allows crops to maintain yields with reduced fertilizer input, promoting eco-friendly agriculture.

6. Phenomics: Linking Genotype to Phenotype

Precision breeding depends not only on genetic data but also on accurate phenotypic assessment. Phenomics bridges this gap by using automated, high-throughput systems to measure traits quantitatively and objectively.

Modern phenomics platforms employ drones, hyperspectral cameras, and LiDAR sensors to monitor plant growth, canopy temperature, and water stress.

These data are analysed using machine learning and computer vision algorithms to identify subtle trait variations. Integration of phenomics with genomics enables breeders to rapidly associate genetic markers with complex traits, improving selection efficiency in both controlled and field environments.

7. Regulation and Public Acceptance

The regulatory treatment of precision-bred crops varies worldwide.

•In product-based systems (e.g., the United States, Australia, Argentina), regulation depends on the final product rather than the method used, allowing faster commercialization of non-transgenic genome-edited crops.

•In process-based systems (e.g., the European Union), all genome-edited crops are regulated as GMOs, creating significant delays and limiting innovation.

Public understanding is equally crucial. Transparent communication that genome editing involves no foreign DNA and mimics natural mutations is essential for consumer trust. Emphasizing benefits—such as environmental sustainability, reduced pesticide use, and improved nutrition—can enhance acceptance and adoption.

8. Future Prospects

The frontier of precision breeding is moving toward engineering complex biological systems rather than single-gene traits. Current research aims to introduce C_4 photosynthesis in rice to increase yield efficiency and to enable biological nitrogen fixation in cereals to reduce fertilizer dependency. Simultaneously, the convergence of genomics, phenomics, and artificial intelligence is creating digital breeding platforms capable of predicting gene interactions and simulating crop performance under future climate scenarios. This data-driven approach could make plant breeding faster, cheaper, and more predictive than ever before.

9. Conclusion

Precision breeding stands as the cornerstone of modern agricultural innovation. By integrating molecular biology, genomics, and computational tools, it allows scientists to design crops tailored for specific environments and nutritional goals. The transition from conventional selection to precise genome engineering marks a transformative era in agriculture—one that promises sustainability, resilience, and food security for future generations. As technology continues to evolve, precision breeding will serve as the foundation for "designed crops," engineered not only for productivity but also for ecological harmony and human well-being.

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NANOTECHNOLOGY MEETS SOIL SCIENCE: INNOVATIONS FOR A SUSTAINABLE PLANET

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Abstract

Nanotechnology has emerged as a transformative approach for promoting sustainable soil management by integrating advanced materials science with modern agricultural practices. Engineered nanomaterials (ENMs) such as nano-fertilizers, nano-adsorbents, and carbon-based nanostructures provide innovative strategies for improving nutrient efficiency, remediating pollutants, and restoring soil quality. The use of nanoscale carriers enables controlled and targeted nutrient release, reducing losses through leaching and volatilization while enhancing nutrient uptake efficiency by 20–40% compared to conventional formulations. Similarly, nanostructured oxides and bioactive nanoparticles play a significant role in detoxifying heavy metals and organic contaminants, often achieving removal efficiencies exceeding 80% in experimental trials. In addition to soil amendments, nanosensors are transforming soil monitoring systems. They allow in-situ, real-time detection of soil nutrients, moisture, and contaminant levels with ultra-high sensitivity—down to nanomolar concentrations (10^{-9} M)—enabling precise soil management decisions. Advances between 2020 and 2025 have

demonstrated the integration of nanosensors with wireless and AI-assisted networks, paving the way for smart agriculture systems capable of dynamic soil health assessment.Equally vital are the considerations of ecological safety and sustainable production methods. Green synthesis of nanoparticles using biological agents such as microbes, algae, and plant extracts has gained attention as an environmentally sound alternative to conventional chemical routes. These methods minimize potential toxicity and improve the biocompatibility of nanomaterials within soil ecosystems. However, large-scale applications and long-term field trials remain limited, emphasizing the need for continuous research on risk assessment, degradation behavior, and interactions with soil biota.This paper compiles and analyzes recent progress (2020–2025) in the use of nanotechnology for soil enhancement, pollution control, and environmental monitoring. It also introduces conceptual figures and comparative data summaries that outline the pathways through which nanotechnology contributes to sustainable soil systems, circular nutrient management, and climate-resilient agriculture. The integration of nanotechnology with precision farming tools and soil microbiome research represents a crucial step toward realizing smart, self-regulating soils capable of maintaining fertility and productivity under changing environmental conditions.

Introduction:

Soils underpin terrestrial life, but their degradation — through erosion, salinization, nutrient depletion, and contamination — now constrains productivity and resilience. Conventional approaches (bulk fertilizers, heavy mechanical remediation, coarse monitoring) often lack precision, increasing the risk of nutrient losses, greenhouse gas emissions, and off-site pollution. Nanotechnology offers a different route: by exploiting high surface area, tunable reactivity, and targeted delivery at the nanometer scale (1–100 nm), researchers are designing solutions that act directly at the root–soil interface with improved efficiency and lower collateral impacts (Figure 1). Soils are the foundation of terrestrial life, providing essential nutrients, water, and habitat for countless organisms, yet they are increasingly threatened by degradation through erosion, salinization, nutrient depletion, and contamination. These challenges reduce soil fertility, constrain agricultural productivity, and compromise ecosystem health. Soil erosion alone results in the loss of an estimated 75 billion tonnes of topsoil annually, causing economic losses approaching 400 billion USD each year (Europäische Umweltagentur, 2023). Conventional agricultural practices, including excessive tilling, monocropping, and overuse of

fertilizers, often lack precision, leading to nutrient runoff, greenhouse gas emissions, and off-site pollution, which further exacerbate soil degradation (World Wildlife Fund, 2023). In response, nanotechnology offers a promising avenue for precise and sustainable soil management. By exploiting unique nanoscale properties such as high surface area, tunable reactivity, and targeted interactions at the root–soil interface, nanomaterials can enhance nutrient use efficiency, improve water retention, stimulate beneficial microbial activity, and remediate contaminants with minimal collateral effects. For instance, copper-tin-titanium dioxide nanocomposites have been shown to degrade pesticide residues in contaminated soils under sunlight while exhibiting antibacterial activity, demonstrating their dual potential for soil remediation and crop protection (Times of India, 2023). Similarly, nanofertilizers enable controlled and sustained nutrient delivery, reducing losses to leaching and volatilization while enhancing crop uptake (Springer, 2025). Together, these innovations suggest that nanotechnology could play a transformative role in addressing soil degradation challenges, offering a nanoscale opportunity to increase agricultural efficiency, sustainability, and resilience in a changing climate.

Mechanisms and major application areas

1. Nano-fertilizers — controlled, targeted nutrient delivery

Nano-fertilizers encompass a range of formulations: nutrient ions adsorbed to nano-zeolites or clays, nutrients encapsulated in biodegradable nanopolymers, and engineered nanoparticles that slowly release macronutrients. Mechanistically, the high surface area of nanocarriers increases adsorption capacity and can modulate release kinetics through diffusion-limited transport or responsive coatings (pH-sensitive, root exudate-triggered). Representative trials report nutrient use efficiency (NUE) increases of ~20–50% and modest yield gains (10–25%) depending on crop and environment. Such improvements are often most pronounced in sandy soils or nutrient-deficient systems where losses from leaching are high. Figure 2 illustrates a representative nutrient-release profile for conventional vs nano-formulated fertilizers.

Key practical points: optimal dosing reduces the risk of overdosing; encapsulant biodegradability matters for long-term soil health; and comparative field trials across agroecological zones are still limited.

2. Nano-remediation — rapid and site-specific pollutant transformation

For contaminated soils, nanoscale zero-valent iron (nZVI) is the most widely studied reactive nanoparticle. nZVI provides strong reducing power to convert toxic oxyanions (e.g.,

Cr(VI)) into less mobile forms (Cr(III)), and can be combined with sorbents (biochar) to increase long-term stability. Laboratory-to-field reports show rapid reductions in contaminant concentrations — in some studies decreasing Cr(VI) to <5% of initial concentration within 2–14 days when properly dosed (Figure 3). However, mobility, agglomeration, and secondary impacts on microbial communities remain active research concerns; supporting amendments and immobilization matrices (biochar, clay supports) mitigate these issues.

3. Nanosensors — real-time, high-resolution soil diagnostics

Nanosensors leverage carbon nanotubes, graphene, metal-oxide nanoparticles, and quantum dots to detect pH, moisture, ionic nutrients (NO_3^-, PO_4^{3-}, K^+), and certain organics with high sensitivity. When networked and combined with low-power telemetry, arrays of nanosensors enable precision irrigation and fertigation regimes, reducing both water and nutrient waste. Conceptual sensor networks and node placements are shown in Figure 4. Key challenges include sensor fouling, power/autonomy in field conditions, calibration drift, and data integration into farmer workflows.

4. Soil physical improvements and drought resilience

Certain nanomaterials (nano-silica, nano-clays, nanoparticulate biochar) can enhance aggregate stability and water retention. These changes support seedling establishment and improve drought resilience in semi-arid lands. While promising, physical soil amendments must be validated over multiple seasons to assess persistence and interaction with soil biology.

Environmental safety, socioeconomics, and regulation

The promise of nanotech must be balanced with precaution. Potential risks include nanoparticle impacts on soil microbiomes, trophic transfer, and altered biogeochemical cycling. Current research emphasizes “safe-by-design” strategies: biodegradable carriers, lower effective doses via targeted delivery, and comprehensive ecotoxicological testing. Regulatory frameworks lag behind technological developments; harmonized testing protocols and field-relevant endpoints (microbial diversity, leaching, crop uptake) are essential before widescale adoption. Socioeconomic dimensions — affordability, ease-of-use for smallholder farmers, and market acceptance — will also determine uptake.

Representative quantitative outcomes and research data

To provide concrete context, a synthesis of representative studies (lab + greenhouse + field; 2020–2025) shows consistent patterns: nano-fertilizers tend to increase NUE by 20–50% in

controlled trials, while nZVI treatments can reduce certain contaminants (Cr(VI), some organics) to non-detectable levels within days to weeks under favorable conditions. A short summary table of representative studies is available with the figures (study details, systems, and headline results). See Figures 2 and 3 for illustrative kinetics.

Implementation roadmap and research priorities

- Standardized multi-site field trials with ecological endpoints to compare nano and conventional treatments across soils and climates.
- Green manufacturing using plant-based or biopolymer synthesis routes to cut production footprints.
- Dose-response and fate studies to map nanoparticle transformation, aggregation, and long-term persistence in soils.
- Farmer-centric design and extension programs to ensure usability, cost-effectiveness, and acceptance.
- Regulatory harmonization with tiered risk assessment frameworks and post-release monitoring.

Figure 1. Schematic: Pathways and interactions of nanomaterials in soil systems

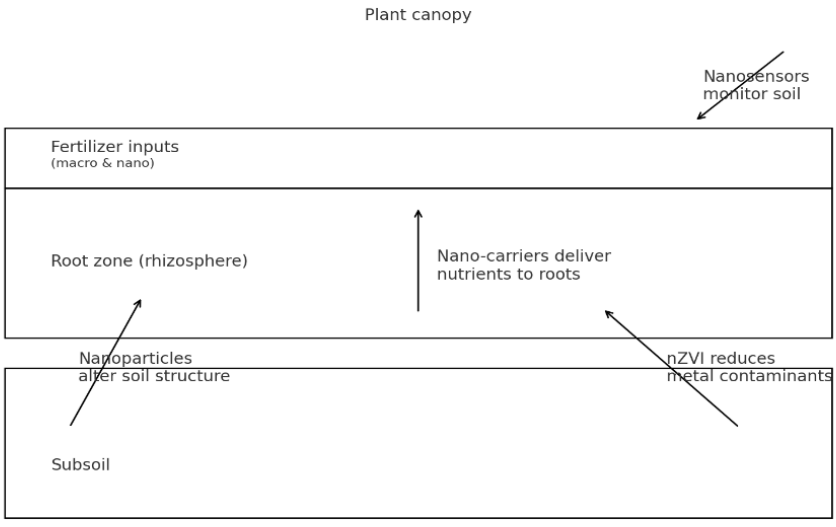


Figure 1 — Nanopathways schematic;

Figure 2. Representative nutrient release: conventional vs nano-fertilizer

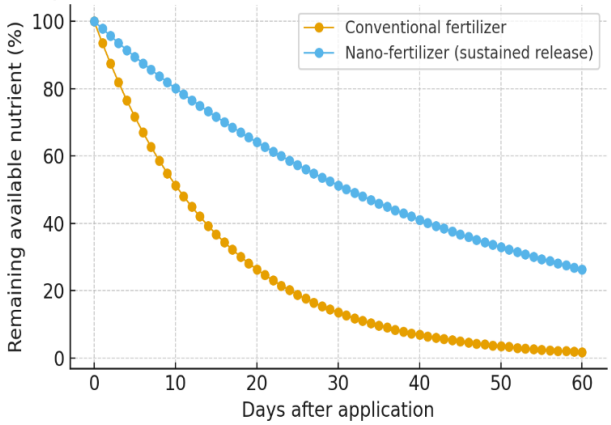


Figure 2 — Representative nutrient release: conventional vs nano-fertilizer;

Figure 3. Representative pollutant (Cr(VI)) reduction: control vs nZVI treatment

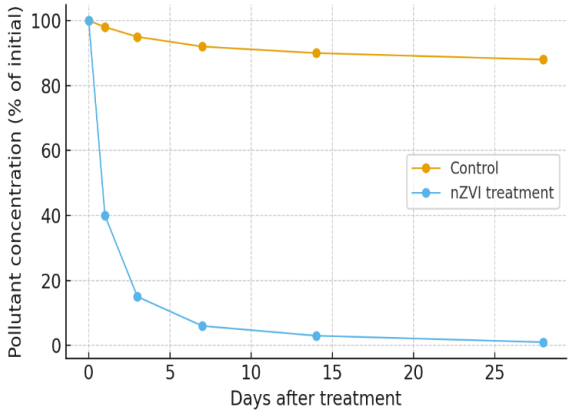


Figure 3 — Representative pollutant (Cr(VI)) reduction: control vs nZVI treatment;

Figure 4. Schematic: Nanosensor network for soil monitoring (conceptual)

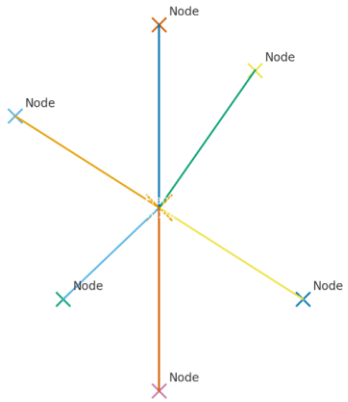


Figure 4 — Nanosensor network schematic (conceptual)

Conclusion

Nanotechnology offers precise and innovative tools that have the potential to revolutionize soil management, enhancing nutrient use efficiency, improving water retention, and mitigating environmental impacts. By enabling targeted delivery of fertilizers, pesticides, and soil amendments, nano-enabled solutions can optimize soil health while reducing chemical overuse and greenhouse gas emissions. However, the widespread adoption of nanotechnology in agriculture depends on rigorous safety assessments, standardized testing protocols, and transparent regulatory frameworks to prevent unintended ecological or human health risks. Equally important is ensuring that these technologies are accessible and practical for farmers, particularly smallholders, through training, cost-effective solutions, and locally adapted approaches. When developed, regulated, and implemented responsibly, nanotechnology could become a key component of sustainable soil management strategies, helping to restore degraded soils, improve crop productivity, and contribute to global food security in a climate-resilient manner. Ultimately, integrating nanotechnology into soil science represents a promising step toward a future where agricultural productivity and environmental stewardship go hand in hand.

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SUCCESSFUL CONTAINMENT OF COFFEE BERRY BORER (*HYPOTHENEMUS HAMPEI*) IN ANDHRA PRADESH BY DR. YSR HORTICULTURAL UNIVERSITY IN ASSOCIATION WITH DEPARTMENT OF HORTICULTURE AND COFFEE BOARD– A TEAM EFFORT TO PROTECT ORGANIC COFFEE

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Introduction

The coffee berry borer (*Hypothenemus hampei*, Coleoptera: Curculionidae), commonly known as CBB, is the most destructive insect pest affecting coffee globally. It impacts both the yield and quality of coffee, causing over US$500 million in damage each year (*Baker, 1999)*. The economic loss occurs when female beetles bore into the coffee fruit (berry) and eventually into the seed, where they create tunnels for reproduction. The larvae then feed on the endosperm. Over the past century, CBB has spread from Africa's humid evergreen forests to nearly all coffee-producing countries worldwide, except Australia, China, and Nepal (*Bottrill et al., 2018).* The CBB was first noticed in India during February 1990 on a few plantations in The Nilgiris in Tamil Nadu and was subsequently reported in other coffee growing states Kerala, Karnataka, and Tamil Nadu. In the present diagnostic visit, the coffee berry borer first time incidence in Andhra Pradesh at ASR district is hereby confirmed.

CBB stands apart from the 850 other insect species that feed on coffee plants because it is the only one capable of feeding and completing its life cycle inside the coffee seed. This unique ability is believed to result from its association with *Pseudomonas* bacteria in its digestive tract,

which detoxifies caffeine. Adult female CBB infest coffee berries when the seed's dry weight reaches 20% and the endosperm is in a semi-consistent developmental stage, about 120–150 days after flowering (*Damon, 2000)*.

The adult coffee berry borer is about 1.5 mm long. It is capable of boring into young as well as ripe berries, generally through the navel region. About 50 eggs, on an average, are laid in the tunnel within the mature bean, with eggs hatching in 5 to 9 days. The grubs feed on the beans, making small tunnels. Complete development from egg to adult takes place in about thirty days. The mating of the beetles usually takes place inside the berries and the female is capable of laying eggs in 3 to 4 days after emergence. The fertilized female leaves the parent tunnel and bores into a fresh fruit for oviposition. The ratio of female to male is about 10:1 and is the reason for the high population spurt of this pest. The male cannot fly and doesn't leave the berry. The average longevity of the female beetle is 156 days.

Damage is caused to young as well as developed berries. Though the beetle doesn't breed in tender berries, some of the affected berries may fall due to injury. Breeding occurs in developed berries from the time the endosperm becomes hard. In case of severe infestation, 30–80% of the fruits may be attacked, resulting in heavy crop loss. They typically bore a small entrance hole (0.6–0.8 mm wide) near or through the floral disc, which offers a rough surface for the beetle to grip while boring. Usually, each berry has only one entrance hole, but when infestation levels are high and berries are scarce, multiple females may bore into the same berry. (*Mendesil,2004;Vega et al., 2011)*

\Steps initiated by Dr .Y.S. R Horticultural University

On 3rd September 2025, a roving survey was taken up in the pest infested area and a preliminary report of coffee berry borer incidence ranging from 10-50% was observed in the fields surveyed at Pakanagudi Village, Araku mandal and it is assumed that this village was the first village in the district where incidence of CBB was recorded . The berry borer incidence was observed in unripe berries aged 130-150 days up to 50% in the 10 year old garden. Good trap catches of adult beetles were also observed in the Broca traps installed in this garden. In few other plantations in the village plantation, beetle population of all stages (larvae, Pupae and adult) was also found to be present ranging from 10-25% in the five year old plantation where the Broca traps were not installed. In the diagnostic visit at Chintapalli mandal conducted on the same day, the incidence was found to be nil in the entire coffee plantations surveyed except at

Horticultural Research Station, Chintapalli, where an incidence of coffee berry borer was observed up to 10-15% in unripe coffee berries and it was assumed that this isolated incidence may be due to the pest migration from the adjacent Eco pulping Unit where coffee is procured from several mandals of Araku and processed in the previous season.

Consequent to the CBB incidence in Araku and Chintapalli divisions, as observed during the rapid survey carried out on the request of the District Collector, Alluri Sitarama Raju District, by the Dr. YSR Horticultural University Scientists in association with the Coffee Board, Department of Horticulture, and ITDA staff, the University has swiftly swung into action and constituted various survey teams comprising scientists from different research stations, scientific staff of KVKs, and PG and UG students from the Colleges of Horticulture at Venkataramannagudem and Parvathipuram to conduct rapid roving and scouting surveys. The objective is to earmark pest-infested areas and to demonstrate eco-friendly management measures as advocated by the University. The random sampling procedure adopted for identifying the intensity of CBB is detailed below.

Random Sampling survey: Procedure adopted

a) Random sampling in a single stretch plantation irrespective o f the area 9 spots shall be identified. (top 2, bottom 2, sides 2+2 , center 1)
b) In a single stretch plantation, in each spot 10 plants shall be covered.
c) If infestation is found in 7-9 spots (heavy- Score-3)
d) If infestation is found 4-6 spots (medium-Score-2)
e) If infestation is found 1-3 spots(low-Score-1)
f) If no infestation Zero(0)
g) Village Name:
h) Extent of Coffee Area (in acres)
i) Name of the Panchayat

Accordingly, the team constituted on various days covered the coffee growing plantations in the district as stated and identified pest infested villages in the district and abstract of the entire survey was presented here under

	09.09.25	10.09.25	11.09.25	12.09.25	Total
Total No of villages covered	21	38	27	19	105
Extent Covered (Ac)	1270	1657	1619	630	5176
Gram Panchayats Covered	5	11	11	6	33
Gram Panchayats Infested	4	6	4	1	15
Pest infested Villages	18	12	4	2	36
Pest infested Villages Extent (Ac)	1173	671	70	7	1921

Survey teams in action

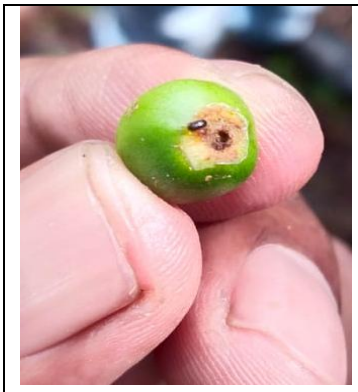








Coffee berry borer, its entry hole and life stages





Probable reasons for coffee berry borer incidence in ASR district

In Araku mandal the probable reasons for entry of this pest may be due to seed material brought from other states. In Chintapalli, its entry might be due to migration of adult beetles from berry infested fruits brought from Araku to Coffee Eco pulping unit present in vicinity of the Horticultural Research Station, Chintapalli.

Management measures suggested

1. Strict adoption of cultural practices and phytosanitary measures suggested should be invariably followed.
2. Coffee berry collection bags should be fumigated before collecting the berries from the field.
3. Clean harvest and use of picking mats while harvesting.
4. Dipping infested berries in boiling water (2–3 min) to kill all the stages of pest.
5. Install Broca traps around the drying yard during harvest to monitor the incidence and also in the field after harvest at the rate of 30 traps per acre.
6. The white muscardine fungus *Beauveria bassiana* is an effective bio-control agent and its application @ 5 g/l of water has given effective results in other states and hence its application can be resorted.

Road map given by DrYSRHU for managing coffee berry borer incidence in ASR district, Andhra Pradesh

1. Identification of coffee berry borer infested plantations in the district and removal of infested berries enforcing clean harvest.

2. Transportation of infested coffee berries to other uninfected areas should not be carried out so as to regulate the pest spread, a vital step in pest management.
3. Intensive surveys for identifying the pest infested areas should be done to map the area of infestation and fix the zones of local quarantine so as to monitor the status of the pest and contain its spread.
4. Installing Broca traps around drying yard to trap escaping beetles and also in probable pest entry plantations identified based on surveys.
5. Awareness programmes on coffee berry borer management should be conducted in association with Universities, state Departments of Agriculture/Horticulture, Coffee Board of India, ITDA, Paderu and NGOs.
6. As white muscardine fungus *Beauveria bassiana* is an effective bio-control agent, large scale production and promotion of spraying activity of this bio agent for carrying out in spraying operations

Successful field interventions for CBB pest management and its containment

The entomopathogenic fungus, *Beauveria bassiana* (Balsamo) Vuillemin is the most prevalent fungus attacking CBB populations. The fungus is a widespread soil borne pathogen of insects (Butt *et al.,* 2001). A key advantage for microbial control agents is their potential to replicate and persist in the environment, offering continued suppression of insect pest populations. These pathogenic fungi infect insects by breaching the host cuticle. They secrete proteases, chitinases and lipases that degrade the major constituents of the cuticle (*i.e.,* protein, chitin and lipids) and allow hyphal penetration (Cho *et al.,* 2006).

In the areas surveyed, demonstrations on the spraying of the bio-control agent *Beauveria bassiana* @ 5 g/l of water were conducted in Coffee Berry Borer (CBB)-infested coffee plantations to educate farmers and promote bio-control–based pest management practices. As part of the University's proactive efforts under the disaster management initiative, immediate steps were taken to procure and supply *B. bassiana* cultures to the affected regions. Accordingly, a total quantity of 500 kg of ready-to-use talc-based formulation of *Beauveria bassiana* was procured by Dr. Y.S.R. Horticultural University from the University of Agricultural Sciences, Raichur, and formally handed over by University officials to the District Horticulture Officer (DHO), Araku, on 11.09.2025, for immediate distribution to farmers in the pest-affected coffee-growing

areas of Araku to ensure timely and effective management of Coffee Berry Borer infestation.

Furthermore, the University has issued directions to the bio-control laboratories at three centers of Dr. Y.S.R. Horticultural University — namely, HRS, Ambajipeta; HRS, Venkataramannagudem; and RHRS, Kovvur — to take up large-scale production of *Beauveria bassiana*. Pure cultures/slants were obtained from CCRI, Chikmagaluru, and UAS, Raichur, and detailed production plans were drawn up to ensure a continuous and adequate supply of the bio-agent to farmers and field units as and when required in the ensuing season. In addition, efficacy studies of *Beauveria bassiana* cultures against Coffee Berry Borer (CBB) were conducted at HRS, Ambajipeta, to validate the effectiveness of the bio-agent under local conditions.

Managing the adult CBB field population with traps

The Coffee Development Board supplied Broca traps along with attractant lures, which were distributed to farmers by the Department of Horticulture for installation in the affected coffee-growing areas. A total of 5,600 traps were installed — 3,500 in Dumbriguda Mandal and 2,100 in Araku Valley Mandal — to monitor and manage the Coffee Berry Borer population. Broca traps were also placed along the boundaries of the Horticultural Research Unit, Chintapalli, where isolated incidences of CBB were noticed, to attract and trap dispersing female beetles. A request was made to the Coffee Board to supply additional traps for wider coverage and sustained pest monitoring.

Further, demonstrations on clean harvest practices were conducted jointly with Coffee Board staff. Infested berries collected from affected plantations were destroyed by dipping them in boiling water (2–3 minutes) to kill all stages of the pest. Awareness programs were also organized through print and electronic media to educate farmers on pest identification, management, and the importance of collective action in controlling the Coffee Berry Borer.

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collector, ASR district, Project officer ITDA Paderu for providing the logistics to the staff and students involved in survey.

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BREWING THE PERFECT PLANT: HOW SCIENTISTS USE MAGIC TO CREATE BETTER CROPS

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Introduction

A multi-parent advanced generation inter-cross (MAGIC) population is a set of immortal fixed lines that are a mixture of the genomes of multiple founder parents. MAGIC populations are created by intercrossing multiple parents, which allows for a greater sampling of genetic variation. MAGIC populations are simple extensions of Advanced Inter Cross (AIC) lines (Mackay and Powell *et al.*, 2008).

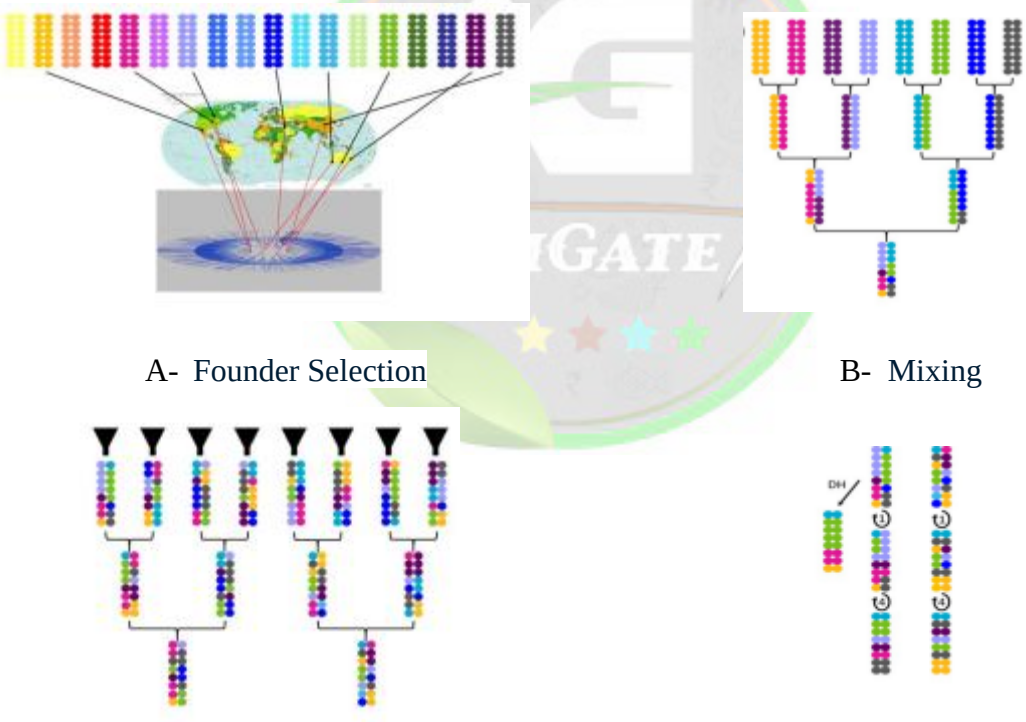
Historical Background of MAGIC population

- The first MAGIC population was proposed in mice with 8 strains by Mott *et al.*, 2000.
- The term MAGIC – Multi parent Advanced Generation Inter Cross was coined by Ian Mackay and Wayne Powell (2008).
- The first MAGIC population in plants was developed in Arabidopsis thaliana with 19 founder parents by Kover *et al.*, 2009.
- Wheat – First MAGIC population was developed using four elite cultivars by Huang *et al.*, 2012.
- In Rice Bandillo *et al.*, 2013 developed four MAGIC populations from 8 *indica* and 8 *japonica* founder parents.

Development of MAGIC as a mapping population

A multi-parent advanced generation intercross (MAGIC) population is a genetic and breeding material used for molecular breeding and quantitative trait locus (QTL) mapping. MAGIC populations are considered a powerful next-generation mapping resource in plant genetics. The main objective of developing MAGIC populations which is to promote intercrossing and shuffling of the genomic regions. MAGIC populations have significant genetic diversity, high power and resolution for mapping quantitative trait loci (QTL) and little population structure (Arrones *et al.*, 2020). Steps in development of MAGIC population are

- Founder Selection,
- Mixing,
- Advanced Intercross and
- Inbreeding.



A- Founder Selection B- Mixing

C- Advanced Intercross D- Inbreeding

Figure. 1: Development of MAGIC as a mapping population (Huang *et al.*, 2015)

Founder Selection Founder lines have to be selected before population development based on genetic and/or phenotypic diversity; this can come from material with a more diverse origin (global germplasm collections, distant relatives) or material with a more restricted set of origins

(e.g., elite cultivars). Developing optimal level of genetic diversity is very tedious job. Landraces can be used as founder parents which may introduce greater genetic diversity, but simultaneously reduce the generalizability to the current breeding populations. More diversified founder collections could offer biological insight into a wider range of traits; on the other hand, founders chosen for a breeding program based on their significance for specific traits could produce a MAGIC population that produces superior breeding lines more quickly (Huang *et al.*, 2015) (Fig. 1A).

Mixing multiple parents are intercrossed to form a broad genetic base in the first stage of population development, The inbred founders are paired off and intercrossed in a funnel, or set order, for every line at this stage. In the case where every recombinant inbred line (RIL) is the result of a two-way cross which will be needed for the next mixing stage. A group of lines whose genomes are incorporated were contributions from each of the founders as the outcome of this stage (Fig. 1B).

Advanced Intercross, the mixed lines from different funnels are randomly and sequentially intercrossed as in the advanced intercross (AIC). The main aim of this intercrossing is to increase the number of recombinations in the population (Fig. 1C).

Inbreeding, in this stage, the individuals resulting from the advanced intercrossing stage are progressed to create homozygous individuals (Fig. 1D). RILs of plants can be generated via Single Seed Descent or Doubled Haploid production. Generation of DH is often faster than the multiple generations of SSD.

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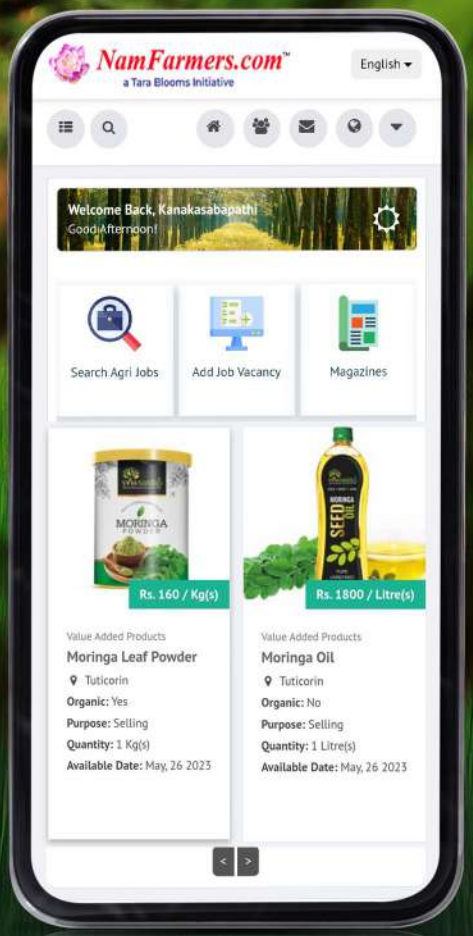
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