भाकृअनुप
ICAR

Agrivision
A forum of Agricultural Students

SOUVENIR & ABSTRACTS

AGRIVISION - 2025

9th National Convention

On

सशक्त युवा– समृद्ध कृषि: कौशल, नवाचार एवं उद्यमिता

Empowered Youth-Prosperous Agriculture: Skill, Innovation and Entrepreneurship

Organised By

Bharat Ratna C. Subramaniam Auditorium, NASC Complex, ICAR, Pusa, New Delhi-110012

विद्यार्थी कल्याण न्यास
भोपाल

In Collaboration With

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Empowered Youth–Prosperous Agriculture: Skill, Innovation and Entrepreneurship
July 26-27, 2025

Organizing Secretary
Dr Raghuraj Kishore Tiwari, JNKVV, Jabalpur, MP

Co-Organizing Secretary
Dr Amit Kumar Goswami, ICAR-IARI, New Delhi

Organizing Convener
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National Convener
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Editors:
Dr Raghuraj Kishore Tiwari
Dr Neeraj Kumar
Dr Utkarsh Tiwari
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Mr Shubham Singh Patel
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Dr Amit Kumar Goswami

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सत्यमेव जयते

डॉ. एम. एल. जाट
सचिव (डेयर) एवं महानिदेशक (भाकृअनुप)

Dr M. L. Jat
SECRETARY (DARE) & DIRECTOR GENERAL (ICAR)

भारत सरकार
कृषि अनुसंधान और शिक्षा विभाग एवं
भारतीय कृषि अनुसंधान परिषद
कृषि एवं किसान कल्याण मंत्रालय, कृषि भवन, नई दिल्ली 110 001

GOVERNMENT OF INDIA
DEPARTMENT OF AGRICULTURAL RESEARCH & EDUCATION (DARE)
AND
INDIAN COUNCIL OF AGRICULTURAL RESEARCH (ICAR)
MINISTRY OF AGRICULTURE AND FARMERS WELFARE
KRISHI BHAVAN, NEW DELHI 110 001
Tel.: 23382629; 23386711 Fax: 91-11-23384773
E-mail: dg.icar@nic.in

MESSAGE

I am delighted to extend my warmest greetings and best wishes to all attendees of the 9th National Convention of Agrivision on "Empowered Youth–Prosperous Agriculture: Skill, Innovation and Entrepreneurship," being held at the NASC Complex from 26–27th July 2025. This convention marks a significant milestone as we collectively shape the roadmap for the future of Indian agriculture in the context of Vikasit Bharat, sustainability and global leadership.

The Indian Council of Agricultural Research (ICAR) remains steadfast in its mission to strengthen the pillars of agricultural research, education, and extension. By integrating frontier technologies, promoting entrepreneurship, and nurturing human capital, especially our youth, we aim to build a resilient and self-reliant agricultural economy that not only meets domestic needs but also contributes to India's emergence as a global leader in agri-innovation, trade, and sustainability.

I commend Agrivision for organizing this convention and providing a platform for scientists, policymakers, industry leaders, and young minds to converge and deliberate on strategies for a vibrant agricultural future. Your insights and collaborative spirit will be vital in crafting actionable solutions that align with the vision of Viksit Bharat.

As you engage in meaningful dialogue and innovation-led discussions, I extend my best wishes for a successful and inspiring convention. May your efforts serve as a catalyst for transforming Indian agriculture into a cornerstone of national progress and international leadership.

(M.L. Jat)

Dated the 25th July, 2025
New Delhi

भा.कृ.अनु.प
ICAR
डा. जे. के. जेना
उप महानिदेशक (मत्स्य विज्ञान एवं कृषि शिक्षा)
Dr. J.K. Jena
Deputy Director General (Fisheries Science & Agricultural Education)

भारतीय कृषि अनुसंधान परिषद
कृषि अनुसंधान भवन - II, पूसा, नई दिल्ली-110 012
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
KRISHI ANUSANDHAN BHAWAN-II, PUSA, NEW DELHI-110 012
Phone : 011-25846738 (Fisheries); 011-25846738 (Education)
E-mail : ddgfs.icar@gov.in; ddgedn@gmail.com

MESSAGE

I am delighted to know that the AGRIVISION, in collaboration with different Departments of the Government of India, is organizing the 9th National Convention on the theme "Empowered Youth-Prosperous Agriculture: Skill, Innovation and Entrepreneurship at Dew Delhi during 26-27 July, 2025. The theme of this convention truly resonates with our national vision of a developed Bharat by 2047. At the heart of this transformation lies the need for robust human resource development in agriculture and allied sciences. Empowering our youth with cutting-edge knowledge, practical skills, and entrepreneurial capabilities is essential for building a resilient, inclusive, and innovation-driven agri-economy.

India's vast agricultural landscape demands a new generation of professionals who are not only technically sound but also adaptive, visionary, and capable of driving change at the grassroots level. Our agricultural education system, therefore, must evolve to become more multidisciplinary, industry-connected, and oriented towards emerging areas such as digital agriculture, climate-smart practices, agri-business, and value chain management. In this arena, the fisheries and livestock sectors hold strategic importance. These sectors significantly contribute to food and nutritional security, rural livelihoods, and economic development. Strengthening education, training, and entrepreneurship in fisheries and animal sciences will play a vital role in unlocking the potential of these high-growth sectors, particularly in creating employment and enterprise opportunities for youth.

I sincerely believe that the convention will provide a unique platform to reflect on our progress, share innovative practices, and chart a future course for revitalizing human capital in agriculture and allied sectors. The commitment and collective wisdom will be key in shaping strategies that elevate both the quality of education and the impact of agricultural professionals across India. I wish all participants a meaningful and enriching convention. May the deliberations pave the way for a dynamic, skilled, and youth-led agricultural transformation that strengthens every pillar of a developed Bharat.

I wish the programme a grand success!

(J.K. Jena)

भारतीय कृषि अनुसंधान परिषद
कृषि अनुसंधान भवन–I, पूसा, नई दिल्ली–110 012
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
KRISHI ANUSANDHAN BHAVAN-I, PUSA, NEW DELHI 110 012

डॉ. राजबीर सिंह
उप महानिदेशक (कृषि विस्तार)
Dr Rajbir Singh
Deputy Director General (Agricultural Extension)

Tele : 91-11-25843277 (O)
E-mail : ddg-extn.icar@gov.in

Dated: 25th July, 2025

MESSAGE

Dear Delegates, Organizers, and Honored Guests,

On behalf of the Indian Council of Agricultural Research (ICAR), it is my great pleasure to extend my best wishes to all participants of the 9th National Convention of Agrivision on "Empowered Youth–Prosperous Agriculture: Skill, Innovation and Entrepreneurship," being held at the NASC Complex from July 26–27, 2025.

The theme reflects our collective resolve to harness the power of youth in transforming Indian agriculture. At the core of this transformation lies agricultural extension, which plays a pivotal role in connecting knowledge, innovation, and enterprise with the farming community. A dynamic extension system is essential not only for transferring technologies but also for mentoring and capacitating rural youth to become skilled agri-professionals and entrepreneurs.

Empowered youth, equipped with relevant skills and supported by responsive extension networks, can drive innovation, enhance productivity, and catalyze rural development. Agricultural extension today must go beyond traditional dissemination to become a platform for agri-startup incubation, digital engagement, and market-led advisory services that respond to the aspirations of a new generation of farmers and agri-preneurs.

As we gather to deliberate on the future of Indian agriculture, it is vital to reimagine agricultural extension as a key enabler of youth empowerment and sustainable growth. Your contributions during this convention through ideas, innovations, and collaborations will be instrumental in shaping a forward-looking extension ecosystem that supports both prosperity and resilience.

I wish all participants a successful and enriching convention. May this gathering inspire transformative action, strengthen partnerships, and pave the way for a vibrant, youth-led agricultural revolution that contributes to our shared vision of a developed Bharat.

With best wishes,

(Rajbir Singh)

प्रो. संजय कुमार सिंह
उप महानिदेशक (बागवानी विज्ञान)

Prof. S.K. Singh
FNAAS, FIAHS, FDBT
Deputy Director General (Horticultural Science)

भारतीय कृषि अनुसंधान परिषद
कृषि अनुसंधान भवन – II,
पूसा, नई दिल्ली– 110012
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
KRISHI ANUSANDHAN BHAVAN-II,
PUSA, NEW DELHI-110 012 (INDIA)

MESSAGE

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On behalf of the Indian Council of Agricultural Research (ICAR), I am delighted to extend my warmest greetings to all participants of the 9th National Convention of Agrivision on "Empowered Youth–Prosperous Agriculture: Skill, Innovation and Entrepreneurship," being held at the NASC Complex from July 26–27th, 2025.

The theme of this Convention is both timely and visionary, underscoring the pivotal role of youth empowerment in driving agricultural transformation through skill development, innovation, and entrepreneurship. Within this framework, horticultural sciences offer exceptional opportunities for young agri-preneurs to contribute meaningfully to India's rural economy, nutritional well-being, holistic and sustainable development.

Horticulture, encompassing fruits, vegetables, flowers, medicinal and aromatic plants, landscaping and post-harvest processing, serves as a vibrant and high-growth sector with immense potential for employment generation, income enhancement, and climate-resilient practices. By integrating modern technologies, value-chain innovations, and enterprise models, this sector can attract and retain the interest of youth in agriculture.

As we look toward building a prosperous and self-reliant Bharat, it is vital to encourage youth-led innovations in horticulture that align with evolving market demands, health-conscious consumption patterns, and environmental sustainability. This Convention provides a timely platform to highlight success stories, share knowledge, and inspire youth to take leadership roles in shaping the future of Indian Agriculture.

I wish all participants a successful and enriching convention. May this event ignite fresh ideas, foster dynamic partnerships, and accelerate the growth of horticulture as a key pillar of the India's agricultural transformation.

With best wishes!!

23/07/2025

(Sanjay Kumar Singh)

E-mail : ddghort.icar@gov.in **Phone : (Off.) 91-11-25842068**

PREFACE

It is with great pride and pleasure that we present the *Souvenir and Abstract Book* of the **9th National Convention: AGRIVISION-2025**, held from **July 26–27, 2025**, at the **National Agricultural Science Complex, New Delhi**. This landmark event, themed **"Empowered Youth – Prosperous Agriculture: Skill, Innovation and Entrepreneurship,"** brings together a vibrant confluence of young minds, seasoned experts, policymakers, and agri-innovators from across the country to reimagine and revitalize Indian agriculture.

AGRIVISION has grown into a premier national platform that fosters critical discourse, collaborative thinking, and strategic action to transform agriculture into a more inclusive, sustainable, and profitable sector. The 9th edition continues this legacy by placing youth at the centre of the conversation—acknowledging them not just as beneficiaries, but as the drivers of change. The convention highlights the significance of equipping young professionals with cutting-edge skills, fostering an innovation-driven mindset, and promoting agri-entrepreneurship for holistic rural development and food system resilience.

This souvenir and abstract book is a reflection of the intellectual depth and thematic diversity of the convention. It encompasses lead lectures and scientific abstracts that delve into critical areas such as agri-startups, digital agriculture, climate-resilient farming, value chain innovation, and skill-based capacity building. These contributions are a testament to the enthusiasm, creativity, and commitment of India's agricultural research and innovation ecosystem.

We extend our heartfelt gratitude to all contributors, participants, organizing committee members, partnering institutions, and sponsors who made AGRIVISION-2025 a resounding success. It is our sincere hope that this compilation serves not only as a record of the convention's scholarly engagements but also as a source of inspiration for continued efforts toward building a youth-empowered, innovation-led, and prosperous agricultural future.

Organizing Committee
AGRIVISION-2025

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LEAD PAPERS

Entrepreneurial Avenues in Horticulture and Allied sector

Sanjay K. Singh*, Amit Kumar Goswami**, Chavlesh Kumar** and Satyabrata Pradhan**

*Division of Horticultural Science, Krishi Anusandhan Bhawan-II, Indian Council of Agricultural Research, Pusa campus, New Delhi -110012

**Division of Fruits and Horticultural Technology, Indian Agricultural Research Institute, Pusa campus, New Delhi-110012

Corresponding author’s mail: sanjaydr2@gmail.com

Introduction

In 2025, India emerged as a major producer of horticultural crops and is rightly referred to as the Horticulture Bowl of the world. In 2025 the estimated horticultural crops production is at 362,085.722 Ton with substantial increase from the 2024 (354,743.640 Ton). Presently, India ranked second after China. The Horticulture sector *per se* is contributing over 30% share in the agriculture GDP of the country only 8.5% of the cropped area, which is also forming the base for rural entrepreneurship and year-round employment generation. Horticulture signifies diversity in crops ranging from fruit & plantation crops, vegetables, flower and ornamental plants, tuber crops, spices, medicinal and aromatic plants, mushrooms, bamboo production, honey production *etc*. Horticulture in India with its higher annual growth rate has become a major contributor to its growth of Agriculture. It is therefore, important that horticultural crop production is given more emphasis so that it could sustain the desired growth rate in agriculture sector and provide job opportunities to the emerging youth force in Indian economy, which has turned around dramatically in the last few months with the real GDP growth expected to accelerate to 7.2% making India the fastest growing economy in the world.

Horticulture takes care of environment in themost eco-friendly by enriching and sustaining the natural resources by adopting safe practices, thus improving literacy and nutrition awareness. It gives better employment opportunities all through the year unlike field crops, which are seasonal. Horticultural activities generate diverse entrepreneurship avenues for youth in Hi-tech horticulture, modern nursery, bio- inputs, customized fertilizers, botanicals and bio-control molecules, primary and secondary processing, food processing, value-addition in development of hi-value specialized products like nutraceauticals, functional food, promotion of value-chain & export, skill development, mechanization, digital intervention, traceability, etc. There is ample scope for attracting and encouraging youth and women into the scientific horticulture production, food processing, cottage industry, creation of crop- clusters, SHGs/ FPOs, producer and processor cooperatives, small industry sectors *etc*. Farm service sector in horticulture like promoting integrated nutrient management (organic, inorganic, micronutrients, soil reclamation & liming, protected cultivation, natural farming etc.), establishing sound horticulture farm/ nursery, processing industry, Food Park, cold storage, packaging units, cold chain etc. on turnkey basis have huge opportunities. Promoting Hi-tech horticulture, precision farming, vertical farming, off-season production, natural farming, water harvesting, storage and efficient use, peri-urban horticulture, *etc*. can be very rewarding professionally.

Entrepreneurship

In the present times, post COVID-19 era, it is realized that entrepreneurship development and Atma Nirbhar Bharat would contribute to the overall development of the country or on a region in several ways, *viz*. assembling and harnessing the various local inputs, bearing of risks, new innovations in production techniques to reduce the input cost and increase produce quality and quantity, expanding the horizons of the produce in market, and coordinating and managing units at various levels. The overall horticultural development cannot be achieved without the development of entrepreneurs and the entire team in the value-chain. Entrepreneurship, therefore, is regarded as the ultimate determining factor of the agricultural growth of a country or a specific region.

Factors influencing entrepreneurship are individual, political, social, cultural, economic, environmental and existing support systems. Environmental forces consisting of political, social, cultural, economic policies *etc*. The support system factors financial institutions, commercial institutions, research & training supports. The entire process of entrepreneurship development, the dynamics of such development always speaks of the individual's professional effort, the environmental impact and the support systems. In this context, it may be said that the opportunity envelope for setting up a productive activity can be opened only when certain factors like education, training, professional experience, skill development, financial institution schemes, start-ups, governmental support and favorable policies, state govt. initiatives, commodity board initiatives etc.

Entrepreneurship is agriculture is considered as the critical determinant in the development of agrarian economy of the country. Agriculture provides adequate opportunities with good returns and youths through variety of technologies like latest and efficient farm technologies, Hi-tech nursery, water-saving irrigation strategy, organic farming and GAP certification, contract farming, post-harvest management as a part of primary and secondary processing, value-addition, value-chain development, export-based avenues for transforming Horticulture into a successful entrepreneurship.

Types of Entrepreneurial Enterprises

a. ***Farm level Producers***: This enterprise could be family, professional or contract farming enterprise. Emphasis should be on using best varieties, efficient production technologies, safe and sustainable inputs, use of efficient crop cycle/ intercrops, and nutrient recycling and use of bio-agents for IPM/IDM modules etc. depending on the market demand and price realization.
b. ***Service Providers***: These enterprise helps in any individual or a group willing to invest in horticultural activities, by rendering service & expert advice, project formulation, establishment of projects, procurement of implements, inputs, planting material, setting of any facilities, primary processing *etc*.
c. ***Input Producers***: These enterprises deal with production of quality planting material, bio-fertilizers, vermi-compost, customized fertilizers, micronutrient mix, plant growth promoters, farm operation machines, mechanization & farm implements, packaging and primary processing *etc*.
d. ***Processing and Marketing***: These enterprises, work in a crop-cluster or crop belt comprising activities like scientifically managed farms, Hi-tech nurseries, input for primary processing centres, aggregation & packaging houses, refer van services, food parks, cold storages, retail outlets, wholesale marketing, forward and backward linkages, market intelligence, export promotion, organized markets, organic & GAP certification *etc*.

Knowledge of Central sponsored schemes and incentives

It is a must for every entrepreneur that he or she should be thoroughly educated the entire critical issues before venturing in any agri-business, either cultivation, processing, marketing *etc*. Various policy initiatives and measures have been taken up by both the Central and State Governments in order to develop conducive business environment for apt promotion of entrepreneurship in Horticulture sector. The emphasis on horticulture development is mainly focused through the developmental programmes, of the Department of Agriculture, Cooperation and Farmers Welfare, GoI, which are as follows:

National Horticulture Mission (NHM) presently known as MIDH

It as a Centrally Sponsored Scheme with a view to promote holistic growth of the horticulture sector through an area based regionally differentiated strategies, which include research, technology promotion, extension, post-harvest management, processing and marketing, in consonance with comparative advantage of individual state/ region and its diverse agro-climatic feature. Its aims at technology-driven cluster approach with dedicated attention on competitive horticultural crops. The other main objectives of the Mission are to (i) enhance production and productivity of horticulture crops; (ii) increase coverage of crops under improved/ high yielding cultivars; (iii) improve nutritional security and income support to farm households; (iv) enhance production of high value and low volume horticultural products for exports; (v) strengthen infrastructure facilities for marketing and export; (v) establish convergence and synergy among multiple on-going and planned programmes for horticulture development; (vi) promote, develop and disseminate technologies, through a seamless blend of traditional wisdom and modern scientific knowledge; (vii) create opportunities for employment generation for skilled and unskilled persons, especially unemployed youth *etc*. To achieve the above objectives, the Mission is adopting the following strategies, *i.e.* ensuring an end-to-end holistic approach, having backward and forward linkages, covering production, post-harvest management, processing and marketing to assure appropriate returns to growers/ producers; promoting R&D technologies for production, post-harvest management and processing; enhancing acreage, coverage, and productivity through followings;

Holistic Growth and Regional Differentiation

- Promoting a regionally differentiated approach to horticulture development, considering the unique advantages of each state and region.
- Encouraging diversification into high-value crops and the adoption of modern technologies.
- Establishment of Centers of Excellence (CoEs) for specific crops to promote advanced technologies and best practices.

Increased Production and Productivity

- Providing financial and technical assistance for various interventions, including setting up nurseries, establishing new orchards, and rejuvenating unproductive ones.
- Supporting and promoting protected cultivation (poly-houses, greenhouses) to improve productivity and enable off-season production.
- Promoting use of quality planting material, efficient water management through micro-irrigation, and organic farming practices.

Enhanced Farmers’ Income and Nutritional Security

- Increasing farmers’ income by improving productivity, reducing post-harvest losses, and promoting better marketing linkages.
- Supporting the development of post-harvest management and marketing infrastructure, including cold storage, transportation, and processing facilities.
- Safe production practices to produce nutritious horticultural crops to improve nutritional security.

Skill Development and Employment Generation

- Promoting skill development programmes for farmers and technicians, particularly in post-harvest management and cold chain technologies.
- Create employment opportunities for rural youth in the horticulture sector.

Promoting Sustainable Practices

- Promoting sustainable practices like water resource management, organic farming, and bee-keeping for pollination.
- Encouraging the adoption of integrated pest and disease management strategies.
- Supporting the development of farmer producer organizations (FPOs) and farmer interest groups (FIGs) to bring economies of scale.

Other Key Objectives

Capacity building: Capacity building of state governments, State Horticulture Missions (SHMs), and other stakeholders.

Integration with Other Missions: Collaborating with other national missions like the National Mission on Sustainable Agriculture (NMSA) to promote integrated approaches.

Support for Specific Initiatives: Supporting initiatives like the Saffron Mission, Vegetable Initiative for Urban Clusters, and other horticulture-related activities.

Horticulture Mission for North East and Himalayan States

Realizing the potential of horticulture in the North-Eastern region and other special category Himalayan states, a centrally sponsored scheme in eight North Eastern states, Sikkim, Jammu and Kashmir, Himachal Pradesh and Uttarakhand was launched. This scheme is based on the ‘end-to-end approach’ taking into account the entire gamut of horticulture development in a holistic manner, with all the backward and forward linkages. It aims at establishing convergence and synergy among numerous ongoing governmental programmes through horizontal and vertical integration of these programmes, in order to ensure adequate, appropriate, timely and concurrent attention to all links in the production, post harvest and consumption chain. The "Small Farmers’ Agri-Business Consortium” (SFAC) is involved in coordinating this scheme. State level SFACs have also been constituted in most of the implementing states for monitoring and implementing the programmes at the grass-root level. The objectives of the Mission are to:-

- Improve the production and productivity of horticulture crops by harnessing the potential of the region;
- Give special emphasis on low volume, high value, less perishable horticulture crops;
- Develop a horticulture-based farming system, thereby providing viable and ample opportunities for employment, especially for women, besides improving the productivity of land;
- Address the issues of production of quality planting material; of organic farming, of efficient water management as well as of plant health; along with proper development and demonstration of technologies; etc.

Besides, above most significant schemes for farmers by the Central government in the agricultural sector are as follows;

- Pradhan Mantri Krishi Sinchai Yojana.
- Pradhan Mantri Fasal Bima Yojana.
- National Mission for Sustainable Agriculture

Schemes under NMSA are;

- Rainfed Area Development (RAD): RAD is being implemented by RFS Division
- Soil Health Management (SHM): SHM is being implemented by INM Division
- Sub-Mission on Agro-Forestry (SMAF): SMAF is being implemented by NRM Division
- Paramparagat Krishi Vikas Yojana (PKVY): PKVY is being implemented by INM Division
- Soil and Land Use Survey of India (SLUSI): Being implemented by RFS Division
- National Rainfed Area Authority (NRAA): Being implemented by RFS Division

- Mission Organic Value Chain Development in North Eastern Region (MOVCDNER): Being implemented by INM Division
- National Centre of Organic Farming (NCOF): Being implemented by INM Division
- Central Fertilizer Quality Control and Training Institute (CFQC&TI): implemented by INM Division
- Kisan Credit Card.

Besides, the other schemes are;

E-NAM: National Agriculture Market (eNAM) is a pan-India electronic trading portal which networks the existing APMC *mandis* to create a unified national market for agricultural commodities. Small Farmers Agribusiness Consortium (SFAC) is the lead agency for implementing eNAM under the *aegis* of Ministry of Agriculture and Farmers Welfare, Government of India.

Gramin Bhandaran Yojna: The major objectives of this scheme are (i) Create scientific storage capacity with allied facilities in rural areas, (ii) To meet the requirements of farmers for storing farm produce, processed farm produce and agricultural inputs, (iii) Promotion of grading, standardization and quality control of agricultural produce to improve their marketability, and (iv) Prevent distress sale immediately after harvest by providing the facility of pledge financing and marketing credit by strengthening agricultural marketing infrastructure in the country.

Micro Irrigation Fund (MIF): The government approved a dedicated Rs 5,000 crores fund to bring more land area under micro-irrigation as part of its objective to boost agriculture production and farmers income. The fund has been set up under NABARD, which has to provide this amount to states on concessional rate of interest to promote micro-irrigation, which currently has a coverage of only 10 m ha as against the potential of 70 m ha.

Major Entrepreneurial Avenues in Horticulture Sector

Diversification through Horticulture

Diversification in agriculture, horticultural crops provide us an important source in the form of an alternative cropping pattern with higher returns. Among the high value crops in India, horticultural crops command high value not only in terms of their potential in generating income and employment, but also on the basis of export-earning opportunities. With the changing consumption pattern towards horticultural crops and rising per capita income, there is an increase in internal demand as well as export opportunities for horticultural crops. Diversification towards horticultural crops is expounded as the strength of Indian agriculture, due to its potential to produce a wide variety of horticultural crops under varied agro-climatic conditions. The cultivation of horticultural crops is labour intensive and requires a significantly higher labour force, starting from the stage of planting the trees, to the point of its marketing. Thus, horticulture sector has a potential to absorb and employ huge chunk of unemployed youth and farm women in a state.

The new generation of educated farmers and unemployed rural youth has an opportunity to become entrepreneur and adopt horticulture as a full-scale business enterprise. A farmer does not become an entrepreneur only by adopting new agricultural technology but he becomes an entrepreneur when he comes to be an operator of farm business. Infrastructures like roads and markets are building in a phased manner and will surely complement the horticultural marketing. Wastage of produce on farmers' fields can be minimized and horticulture becomes an important source of gainful employment. There is a long term need to remove the distortions in the present supply chain and create better integration between different links of the supply chain. Entrepreneurship development among farmers is an important way of achieving that integration for bringing net gain to producers, consumers and to the nation.

Modern Production systems

Traditionally the financing of fruit crops focused on raising new orchards, expansion and rejuvenation/ replanting and the customer base is the land-owning farmers. Financing is done either for plantation cost during the pre-bearing period (3-6 years) alone or along with infrastructure like fencing and irrigation. With development of technologies on high density orchards, fast increasing cost of land and private sector entering horticulture the focus has shifted to financing high density orchards with integrated investments on drip systems, plantation costs, fencing, farm houses, mechanization etc. The states which have taken leads are Maharashtra, Karnataka, Tamil Nadu, Andhra Pradesh, Gujarat, Uttarakhand, Madhya Pradesh, *etc*. along with planting filler crops like papaya, pomegranate, banana, drumstick to recover the initial high capital costs on drip/ fertigation. In Uttar Pradesh, high density orchards of mango are intercropped with medium duration crops like guava, peach, plum, vegetables, MAPs, etc. for making efficient use of resources.

Hi-Tech Nursery and Tissue culture units

Planting material is the key input in horticulture and banks have been funding crop-specific or multi-crop modern nurseries. Modern nursery facilities like mist chambers, tissue culture labs, hardening chambers have attracted new entrepreneurs from private and corporate sector. Funding of these projects not only includes the land, building, plant & machinery, but also R&D facilities, marketing networks and working capital limits. The new trend emerging in Modern Nursery industry is using of patented planting material, centralised production-cum franchisee marketing strategy for geographical spreads and MOU system of contracts for buy backs. Agri-clinics & Agribusiness centres can set up tissue culture & hardening units in production areas under franchisee arrangement with the tissue culture labs, for rationalizing the costs and rapid spread of technologies, hence the volumes of trade can grow, which is critical in tissue culture industry.

Integrated Systems in Horticulture

The recent trend suggests mixed-cropping of horticultural crops for generating regular and early return and also as an income insurance strategy. Homestead farming in coastal states like Kerala, Goa and mixed horticulture cropping systems in tribal areas of Odisha, Jharkhand, Karnataka, Gujarat, Chhattisgarh, Madhya Pradesh, NE states *etc*. suiting the local production systems and income streams are covered under funding support by financial institutions.

Agri-/Hort- Clinics

These are the Centres are established in any crop cluster/ fruit crop belt, which provide knowledge and services related with diverse horticulture enterprise. It provides expertise, end to end solutions and serves as one stop shop for providing all needs of growers. These also helps in providing services like soil and water tests, seeds, inputs, technical knowledge on crop raising, plant protection, knowledge on popular schemes of Central and State govts./ deptts. etc.

Organic and Natural farming

Organic production system entails two to three years of conversion period and reduced returns during the period. Thus, the credit product for the production system should accommodate investments on crop production, on-farm input production and also provide for concessions on repayment period. Similarly, financial support for granting organic certification by Govt.

approved agencies. Government has announced the Capital Investment subsidy for production of organic inputs, which has a component on converting fruit and vegetable waste to compost, and vermi-hatcheries using horticulture bio-mass like organic waste, farm waste, kitchen waste, crop residues, weed and aromatic grasses, processing house waste etc. A model for financing organic spice production has been developed in stated like Maharashtra, Sikkim, Uttarakhand, where the MAP & spice production costs are integrated with production of on-farm organic inputs. Some states like Sikkim have instituted marketing channels, export promotion, labeling and brand development, *etc*. for organic production.

Vermi-composting

For proper farm waste recycling, this enterprise can generate huge employment and also finance. Several success stories are there, which need to be replicated. Organic waste units in peri-urban and crop clusters can be very effective intervention for promoting safe horticulture production**.**

Bee keeping

Pollination is a major concern in fruit production. To ensure good fruit fruiting, adequate number of pollinizers and pollinator mostly bee colonies need to be ensured. These activities give additional income. It requires skill and should be adopted after thorough training from different government agencies. This sector is gradually expanding and as result honey production has risen in the country.

Contract farming

Under this type of farming system, a paradigm shift is noticed in assessment of loan from the traditional system of "cost basis to "repayment capacity basis. Land leasing by progressive farmers is a major shift noticed in consolidation of agriculture and bank funding is now extended aggressively for crop production on leased lands. Securitisation of land assets and mortgage financing is the revolution waiting to happen in agriculture/horticulture financing in the country. Several successful models are available in the country and such models need to be replicated in different crops and commodities.

Commercial Plantation crops (cashew nut, coconut, oilpalm, cocoa, palmyra palm *etc*.)

These are cash crops in horticulture, hence needs promotion where different produce can be made for humans through value-addition and safe processing. Organic and natural farming is the most favoured produce by different elite consumers. Hence, such ventures fetch high price, when adopted following GAP certification and procedures. These crops are fit for expanding in problematic and even on wastelands and marginal soils.

Growing Native/ Indigenous crops (Opportunity crops)

Several indigenous and underutilized fruits, vegetables, herbs, medicinal plants *etc*. can fit into intercropping in our perennial systems like fruit and plantation crops. This aspect needs to be exploited to meet the demands for cities, metros, retail chains *etc*. during the off-season, early or late season maturity.

Marketing of Horticulture Produce

The demands of investment in post-harvest management in horticulture has come into force with the export of perishables like grape, pomegranate, vegetables, mango from Maharashtra, Karnataka, Tamil Nadu, Gujarat and Delhi. Another driver of this shift in investment demand for marketing infrastructure is the free import of fruits to the country under WTO regime, which demonstrated the paying capacity of the customers. The initial bout of investments in post-harvest management has come in co-operative sectors like HOPCOMS, Karnataka; HPMC, Himachal Pradesh; NDDB-Safal, New Delhi; and HOFED, Uttar Pradesh; where funding has primarily come as equity or grants from NHB, APEDA, Ministry of Food Processing *etc*. Private investments in post-harvest management in horticulture has started in Maharashtra for refrigerated vans, pre-cooling units and packhouses for grapes, mango, pomegranate, banana, high-value vegetables *etc.* Major initiative in creation of cold chain infrastructure in private sector has come with implementation of Capital Investment Subsidy scheme on Cold Stores, onion godowns and multi-commodity cold storages.

Establishing Commodity Co-operatives

For private sector organized marketing network for horticultural produce. A new set of traders, wholesalers and market intermediaries get associated with such a system. The financing model in this may take the rout of escrow account model. Commodity exchanges are opening avenues for funding against stocks, futures and options financing in horticulture. Under Agri-Export zones, common infrastructure of packing houses have been built in different production centers, airports and ship yards with joint funding from APEDA, respective State Marketing co-operative organisations. Funding for these projects has primarily come as grant from APEDA, Ministry of Food Processing, GoI. Investments in these infrastructure projects have long gestation periods. Hence, banks and financial institutions can fund these projects through venture funding, project funding so that the grants from APEDA and MoFP can be leveraged for creation of PHM infrastructure all over the country to create an integrated networks of PHM and cold chain. Agri Export Zones scheme has brought in a subtle change in attitude of banks in terms of role played by market intermediaries from exploiters to channel partners or service providers. Bank funding to farmers is now routed through the traditional market intermediaries like “Adatias” middlemen or “cold store owners” or “processors”.

Formation of Women Self-Help Groups

Several states have huge women work force that are also having entrepreneurial skills. Such group could be promoted for mutual benefit as entrepreneur. These models are very successful in crop clusters. Several such groups are coming up in NE states, Gujarat, Rajasthan, etc. Government has promoted formation of FPOs on mission mode for organizing this sector and empowering the farmers in decision making.

Use of Information Technology (IT), traceability, Digital Interventions & Custom hiring centres

Trained entrepreneurs can also venture in making use of IT as business by providing expertise in almost all aspects of fruit production by rendering services. It may start from farm to fork or export. Such intervention could help in modernizing the application of ICT, drones, market intelligence, entering retail chain, auction centres, grading, packaging, use of sensors, bulk handling, export etc. Making available all big and small equipment and implements for saving time and money for the benefit of the stakeholders. It could be power tiller, harvester, drones, etc.

Training and Skill Development Centres

Horticulture sector is no more traditional and has now more scientific. There are immense avenues that entrepreneurs establish centres for training and skill development in several aspects. Different modules can be offered for all stakeholders in the sectors for regular upgradation in skill and knowledge so that entrepreneurial spirit and continuous zeal to improvise any activity that can be made for achieving efficiency and enhancing productivity, besides creating job opportunities.

Agri-Horti-Tourism

It is an upcoming booming industry in India. With the number of domestic and international tourists rising every year, this is one sector where agri-entrepreneurs must focus on. In different states, like Kerala, Karnataka, Goa, Maharashtra, Gujarat, Uttarakhand *etc*. several agri-prenuers have established theme parks, organic farms, herbal gardens, naturopathy, *etc*. which are attracting domestic as well as international tourists. India owing to its diverse culture and rich heritage has a lot to offer to foreign tourists like hill stations, heritage sites, wildlife, rural life, new and future metros *etc*. which have immense opportunities. At present, attempts are mainly by individuals having overseas exposure, but the greatest problem is the lack of trained professionals for catering this specialized tourism and hospitality sectors.

Tips for Establishing a Successful Small Horticulture Enterprise

Some useful tips for a successful entrepreneur are as given below;

- Have confidence and courage to start an enterprise. Make an initial SWOT analysis.
- Do the research in first, plan carefully and be prepared to put in the hard work.
- Conduct sufficient research, feasibility study to ensure to meet the end-to-end issues.
- Have realistic expectations as different horticultural crops that require intensive management and a significant investment of time and energy.
- Be aware of long gestation time for an enterprise to start producing a profit and some crops.
- Ensure proper availability of skilled and unskilled personnel for different regular on-going management activities such as crop cluster development, hi-tech nursery, ultra high density orcharding, training & pruning, pest and disease control, and irrigation, nutrient management, harvesting, packaging etc.
- A successful horticulturist should be very clear of the primary reasons for establishing an enterprise.
- Timely disposal of produce as per market demand, movement to wholesale or market yards.
- The right varietal selection for particular times of year, climate, soils or markets may make use of early or late season produce arrival with high prices.
- Perfect knowledge for optimum harvest maturity, cooling, drying, packaging and storage requirements, specialized equipment.
- Requirements and costs of machinery, modern equipment and structures, facilities for processing and storage.
- Ensure promotional material and a website, email, e-auctioning etc.
- Easy access to timely advice from experts or horticultural advisor.
- Have a long-term vision for any enterprise, *i.e.* room to grow when planning infrastructure requirements.
- Having sufficient land to expand, resources to harvest and process larger crops and/ or additional storage requirements.
- Always have Plan B in event of any contingency.
- Try to learn as much as possible from senior/experienced people in business, *i.e.* growers, markets, retailers, processors, exporters etc.
- Try to attend seminars, workshops and other training events for gaining knowledge on new developments.
- Visiting successful entrepreneurial ventures.
- Share information with your professional network and try to establish strategic alliances to be able to supply to market, export or purchase inputs in bulk.

- Maintain a proper record of all activities, certifications, and documents required for exports to different markets.
- Early capturing of the niche markets for competitive advantage in domestic and international trade.

Some of the entrepreneurial ventures in horticulture sectors are establishment of Hi-tech fruit farm (protected cultivation of papaya, banana, strawberry), commercial intercropping (flowers, vegetables, MAPs), Roof top and Terrace gardening/ container garden), Vertical Gardening (hi-value crops), Agri-clinics cum Soil and Water testing laboratory, Customized Implement and equipment hiring centres, Fruit cultivation in problematic soils using rootstocks, Aeroponics and Soilless culture, Papain production, Round the year citrus production, Sub-tropical/ low chill fruit production (peach, pear, nectarine, apple), Rainy season guava production, Fruit cultivation in marginal areas (*ber, aonla, bael, jamun, kamalam*), Papaya seed production, Integrated farming with fruit orchard (bund planting, fish culture, poultry, dairy), Exotic vegetables and Off-season vegetables, specialty tropical orchids, cut greens, palms and bamboo production, Ethnic horticultural crops, Organic fruit and vegetable cultivation, Horti-silviculture system (Poplar, teak), Contract farming (banana, pineapple, mango, *aonla, bael, karonda*, lime & lemon), Primary processing centre (grading, packing, minimal processing, waxing, juicing etc.), Cold and Retail chain (reefer vans), Fruit processing centres (pickles, candy, RTS, nectars, vinegar), Food parks/ Processing Units, Formation of Fruit growers’ SHGs, cooperatives etc., off-Season Vegetables and quality cut-flower Production, Commercial Flower Production, Aromatic a nd Herbal Plantations, Primary processing & packaging, Fruit ripening chambers, Natural colours and dyes extraction, Essential oils and fragrances- Aroma therapy, Pot Pouri and drying of flower crops, Agri-Horti Tourism, Auction Centre, Bio-Fertilizers Production and Marketing, Mushroom Production & Marketing, Vermicomposting, Bee keeping and Honey marketing, FPO/ FP Company, Hybrid seed production, Peri-Urban horticulture, Ethnic horticultural produce, Organized trade of GI crops/ produce, Ethnic value-added products etc.

Conclusion

Starting a new horticultural enterprise can be very challenging, especially for those with little experience in horticulture, or business management. Therefore, the immediate task is to motivate young generation, particularly the educated and skilled youth to become Agri-prenuer and become job giver through an array of opportunities in Horticulture sector. This will help in generating more employment opportunities is rural areas and establish themselves as new entrepreneurs. Sky is the limit and in the era of farm innovations and Startups, youths can achieve their dreams which is more rewarding and satisfying and contributing towards the country’s march during the Amrit Kal and making it Viksit Bharat@2047.

Agri-Skills for Youth Empowerment, Promoting Agripreneurship Among Rural Youth for Viksit Bharat

J P Sharma[1] and Reshma Gills[2]

[1]Former Vice Chancellor, SKUAST-Jammu

[2]Senior Scientist, ICAR-NAARM, Hyderabad, Telangana

Email: jpscatat@gmail.com; reshma1818@gmail.com

Introduction

India's youth are central to the vision of Viksit Bharat (Developed India) by 2047, which aims to transform the country into a self-reliant, inclusive, and high-income nation (Tiwari, 2025). India stands at the cusp of a demographic dividend, with over 66% of its population below the age of 35 (Dutta, 2020; Hans, 2023). This burgeoning youth base, especially in rural India where nearly 49% of the population resides, presents a golden opportunity for national development if harnessed effectively (Jain and Srinivas, 2012; Hans, 2023). Youth involvement in national development ensures long-term sustainability and innovation. However, only 4.7% of India's workforce has received formal skill training (Mukherjee and Rastogi, 2018; NSDC, 2020; Khare and Arora, 2023), highlighting a significant gap between potential and preparedness. Rural youth, in particular, face limited access to quality education, training, and employment, which contributes to underemployment and migration to urban areas (Cartmel and Furlong, 2020). Young minds, when empowered with education, skills, and opportunities, become engines of social change and economic transformation. Skilling youth equips them with employable competencies, boosts productivity, and enhances their participation in nation-building (Idike and Eme, 2015; Dutta, 2025). With over 65% of the population residing in rural areas and about 45% of the workforce engaged in agriculture, it remains a vital sector (Rodgers, 2020), yet it is often perceived as unprofitable and outdated by the youth. This perception stems largely from the limitations of traditional knowledge systems, which are proving inadequate in the face of contemporary challenges such as climate change, market volatility, declining soil health, and rapid technological disruptions. The inability of conventional farming practices to ensure stable incomes and sustainable livelihoods has further widened the disconnect between rural youth and agriculture, contributing to rising underemployment and migration to urban centres (Pingali et al., 2019). The situation is exacerbated by a significant skill gap, which impedes innovation, adoption of modern practices, and overall competitiveness of the agricultural sector. As farming transitions into a more knowledge- and technology-intensive enterprise, there is a critical need to equip rural youth with relevant skills across various domains, including climate-resilient agriculture, value chain development, post-harvest management, precision farming, digital agriculture, and agri-finance (Chand et al., 2022; Singh et al., 2022). Agri-skilling not only provides scientific and technical knowledge but also fosters entrepreneurial thinking, enabling youth to explore and establish viable agri-business ventures (Trivedi and Patel, 2024; Amaran et al., 2025). This includes opportunities in input retailing, farm mechanization services, agri-tourism, food processing, and agricultural consultancy, which are rapidly emerging as non-farm avenues within the broader agricultural ecosystem. Investing in agri-skilling and agripreneurship is central to realizing the vision of *Viksit Bharat* (Developed India) by 2047 (Gulati et al., 2024; Mundhe, 2024; Sharma, 2024). It is a strategic pathway to transform Indian agriculture from subsistence-based livelihoods to enterprise-led, value-driven growth. Skilling empowers youth to diversify into high-value crops, organic farming, protected cultivation, and smart farming systems using drones, IoT, and AI-based decision tools (Dhanaraju et al., 2022; Yadav and Sidana, 2023; Ameer et al., 2024). These interventions not only increase productivity and income but also enhance the overall appeal of agriculture as a respectable and rewarding career. Moreover, a skilled rural workforce can serve as the engine for inclusive rural development by generating local employment, reducing migration pressures, and contributing to national food and nutritional security.

1. Government initiatives for the skilling of youth in agriculture

The Government of India has prioritized agricultural skilling for rural youth through flagship initiatives such as PMKVY under Skill India and strategic collaboration between the Ministry of Skill Development & Entrepreneurship (MSDE) and the Ministry of Agriculture & Farmers' Welfare (MoA&FW) (MSDE, 2025). Programs like the Pradhan Mantri Kaushal Vikas Yojana (PMKVY), Deen Dayal Upadhyaya Grameen Kaushalya Yojana (DDU-GKY), and the Agri-Clinics and Agri-Business Centres (ACABC) scheme are some at the forefront of equipping rural youth with domain-specific skills in areas such as organic farming, precision agriculture, post-harvest management, and agri-business development (MoRD, 2025). The Skill Training of Rural Youth (STRY) program, implemented through ATMA and the National Institute of Agricultural Extension Management (MANAGE), provides short-term training across over 700 districts in India (MANAGE, 2025). As of 2023, over 5 lakh rural youth have been trained in agriculture-related skills under these schemes, with over 36,000 agri-ventures established through ACABC alone. These initiatives aim to improve farm productivity, reduce rural unemployment, and promote agripreneurship.

Similar to the various ministerial initiatives, the Indian Council of Agricultural Research (ICAR) has undertaken several targeted youth skilling initiatives to address the challenges of rural unemployment and to foster agripreneurship. Among the most notable is the ARYA (Attracting and Retaining Youth in Agriculture) programme, which is implemented through Krishi Vigyan Kendras (KVKs) in selected districts. ARYA aims to promote location-specific, income-generating enterprises in agriculture and allied sectors by providing hands-on training, technology support, and market linkages to rural youth aged 18–35. Enterprises such as mushroom cultivation, poultry farming, beekeeping, and food processing are promoted under ARYA, with the goal of creating successful agri-based livelihoods and reducing rural-urban migration. The programme's success lies in its integrated model of capacity building, enterprise promotion, and market facilitation through the institutional support of KVKs. Another major initiative is the Student READY (Rural Entrepreneurship Awareness Development Yojana) programme, a flagship effort mandated by ICAR in all agricultural universities. It targets final-year undergraduate students of agriculture and allied disciplines, aiming to build entrepreneurship and practical skills through experiential learning modules. These include internships, rural work experiences, and hands-on agribusiness training. The programme bridges the gap between theoretical knowledge and practical field applications, preparing youth for self-employment and startup creation in agriculture. It has helped thousands of students gain first-hand experience in managing farms, agri-enterprises, and working with rural communities. This not only enhances their entrepreneurial competence but also motivates them to pursue agriculture as a profitable career path rather than a fallback option. In addition, ICAR's KVKs across more than 700 districts serve as grassroots-level hubs for agricultural skill development. These centres conduct short-term training programs in various domains such as organic farming, farm mechanization, precision agriculture, post-harvest technology, and animal husbandry. Aligned with the National Skills Qualification Framework (NSQF), many of these training modules also lead to certification, improving employability. A summary of some of the major initiatives by the government and ICAR is presented in Table 1.

Table 1: Summary of some of the major Agri-skilling initiatives by the government and ICAR

Scheme / Program	Implementing Body	Focus Area	Target Group	Key Features	Support Components
Agri-Clinics and Agri-Business Centres (ACABC)	Ministry of Agriculture & Farmers Welfare (MANAGE)	Agripreneurship & Extension Services	Agriculture graduates / diploma holders	Self-employment through agri ventures	45-day training, project report preparation, subsidy (36-44%), bank loan
RKVY-RAFTAAR – Agripreneurship Incubation	Ministry of Agriculture & Farmers Welfare	Start-up and innovation in agri-business	Young agri-entrepreneurs & startups	Promotes innovative agri-startups through incubators	Idea to prototype stage funding up to ₹25 lakh, handholding, mentorship
Deen Dayal Upadhyaya Grameen Kaushalya Yojana (DDU-GKY)	Ministry of Rural Development	Rural skill development & placement	Rural youth (15–35 yrs), poor households	Placement-linked skilling across sectors	Residential training, soft skills, job placement, stipend support
Pradhan Mantri Kaushal Vikas Yojana (PMKVY)	Ministry of Skill Development & Entrepreneurship (MSDE)	Short-term skill training in agriculture and allied sectors	Youth aged 15–45 years	NSQF-based, industry-linked agri training	Recognition of Prior Learning (RPL), certification, placement assistance
National Rural Livelihoods Mission (NRLM)	Ministry of Rural Development	Livelihood promotion, SHGs, and microenterprises	Women and youth in SHGs	Capacity building, enterprise development	Start-up capital, training, credit linkages
Skill India Mission	Ministry of Skill Development & Entrepreneurship	Nationwide skill development	All youth, including rural/agri sectors	Umbrella mission integrating various skilling programs	PMKVY, NSDC support, SSCs, training partners
Startup India Scheme	DPIIT, Ministry of	Promotion of startups including agri-tech	Young entrepreneurs	Funding, ease of business, regulatory support	Tax exemptions, self-certification, fund-of-funds

	Commerce & Industry				
Mission for Integrated Development of Horticulture (MIDH)	Ministry of Agriculture & Farmers Welfare	Horticulture-based agripreneurship	Farmers, youth, FPOs	Nursery, protected cultivation, cold chains	Capital subsidy, training, tech support
Atma Nirbhar Bharat Abhiyan (Self-Reliant India Campaign)	Government of India (multi-ministerial)	Self-employment and local enterprise boost	All sectors, including agriculture	Emergency credit, infrastructure, FPOs	₹1 lakh crore Agri Infra Fund, FPO support, micro credit
Atal Innovation Mission (AIM)	NITI Aayog	Promotes grassroots innovation, incubation, and problem-solving culture	School students, startups, MSMEs, agripreneurs, academic institutions	Seed funding, mentorship, prototyping support, market linkage	Atal Tinkering Labs (ATLs), Atal Incubation Centres (AICs), ARISE, EICs
ICAR initiatives					
ARYA (Attracting and Retaining Youth in Agriculture)	KVKs	Entrepreneurship in agriculture and allied sectors	Rural youth (18–35 years)	Promotion of location-specific agribusiness models through KVKs	Training, input support, handholding, linkage with markets
Skill Development under ICAR – KVKs	KVKs	Farm & non-farm skill training	Rural youth, school dropouts, SHGs	200+ job roles including dairy, poultry, fisheries, mushroom, and organic farming	Short-term (200-300 hours) training, NSQF alignment, certification
Student READY (Rural Entrepreneurship Awareness Development Yojana)	Agricultural universities	Experiential learning and hands-on agribusiness exposure	Final-year UG agri students	One-year mandatory programme in agricultural universities with internships, training, and EL modules	Industry exposure, farm management, rural attachment

Agri-Startups under RKVY-RAFTAAR	ICAR institutes	Innovation and startup incubation	Agri-tech entrepreneurs, young graduates	Incubation support through ZTMCs and agri-business incubators in ICAR institutions	Seed funding up to ₹25 lakh, mentoring, business development
ASPIRE (Accelerating ICAR Startups through Partnership, Innovation & Research)	ICAR institutes	Institutional startup ecosystem and commercialization	Students, researchers, innovators	Facilitates startups from ICAR technologies and agri-research outputs	Technology transfer, funding, IP support, incubation
NAHEP (National Agricultural Higher Education Project)	ICAR- Demanded to be Universities and Agricultural Universities	Capacity building and digital agri-education	Agri-students and faculty	Modernization of curriculum, digital tools, soft skills, and entrepreneurship components	E-learning modules, academic-industry interface

Despite these successes, challenges remain particularly in scaling up programs, improving industry linkages, providing access to finance, and ensuring post-training support. To overcome these, ICAR is increasingly focusing on convergence with national schemes like PMKVY, RKVY-RAFTAAR, and Startup India, while strengthening incubation facilities, digital skilling platforms, and partnerships with private agri-tech players.

3. Challenges of Agri-Skilling Initiatives

Despite its strategic importance in fostering rural employment and modernizing agriculture, agri-skilling in India faces numerous structural and perceptual challenges that limit its impact. A primary constraint is the low awareness among rural youth about the availability and scope of agricultural skill development programs such as the Agri-Clinics and Agri-Business Centres (ACABC), Deen Dayal Upadhyaya Grameen Kaushalya Yojana (DDU-GKY), and the National Skill Qualification Framework (NSQF). Many young people remain unaware of the potential career paths within agriculture—ranging from agri-input retailing and food processing to digital agri-solutions—resulting in poor enrollment and underutilization of these schemes (Consentino et al., 2023; De Guzman et al., 2025). Moreover, agriculture continues to suffer from an image problem; it is often perceived by youth as a low-income, low-status profession, particularly among the educated rural population, further discouraging participation. (Geza et al., 2021; Asai and Antón, 2024). The second layer of constraints is rooted in infrastructure and institutional limitations. A large number of rural districts lack well-equipped training facilities, modern demonstration farms, and essential digital infrastructure necessary for delivering quality education and blended learning models (Mishra et al., 2024; Ramesh, 2025). The shortage of trained faculty in advanced domains like climate-resilient agriculture, drone-based precision farming, and agri-value chain analysis reduces the relevance and effectiveness of training. Institutional challenges such as fragmented program delivery, poor coordination among ministries, and minimal involvement of the private sector further dilute the reach and impact of skilling initiatives. Compounding the issue is the mismatch between training curricula and local realities; many programs are neither aligned with regional agro-ecological conditions nor tailored to market-driven skills, leaving trainees underprepared for real-world agribusiness challenges. Lastly, socio-cultural and economic barriers significantly impede the success of agri-skilling efforts. Gender disparities persist, with limited participation of young women due to restrictive social norms, household responsibilities, and lack of safe training spaces (Pathak et al., 2022). Social stigma associated with agricultural work and a widespread preference for non-manual, urban jobs discourage youth from pursuing farm-based or allied sector livelihoods. Even when training is completed, limited access to credit, mentorship, market linkages, and incubation support curtails the transition from skill acquisition to enterprise creation. Addressing these challenges requires a comprehensive, multi-stakeholder strategy: expanding digital and physical skilling infrastructure, modernizing curricula, incentivizing public-private partnerships, and celebrating rural agripreneurs as aspirational figures. Only through such an integrated approach can agri-skilling become a powerful lever for youth empowerment and rural transformation in line with the vision of Viksit Bharat 2047. A detailed analysis of challenges and policy imperatives is presented in Table 2.

Table 2: Key challenges and policy imperatives

Dimensions	Challenges	Policy Gaps	Policy Suggestions
Awareness & Perception	• Low awareness of schemes like ACABC, DDU-GKY, NSQF • Agriculture seen as low-status, low-income profession	• Inadequate IEC (Information, Education, Communication) campaigns • Absence of career counseling in rural schools	• Launch nationwide agri-skilling awareness campaigns • Integrate agri-career counseling in school curriculum • Promote success stories of rural agripreneurs
Infrastructure & Delivery Systems	• Inadequate training infrastructure in rural areas • Limited digital access for blended learning	• Underinvestment in rural skilling infrastructure • Lack of convergence between digital India and rural skilling missions	• Upgrade skilling infrastructure in every block • Promote mobile agri-skilling vans & virtual classrooms • Integrate agri-skilling with BharatNet and Digital India initiatives
Human Resource & Curriculum Quality	• Lack of trained faculty in specialized domains • Curriculum mismatch with local agro-ecological & market needs	• No continuous capacity-building for trainers • Weak linkage between curriculum developers and local industries	• Establish regional agri-skill resource centers • Regular curriculum updates based on market demand • Incentivize professionals from agri-tech startups to serve as visiting trainers
Institutional Coordination	• Fragmented delivery across ministries • Limited involvement of private sector & academia	• Lack of a unified implementation framework • Weak policy mechanisms for PPPs in skilling	• Create a national-level Agri-Skilling Mission under a nodal ministry • Promote MoUs with private firms, FPOs, and agri-universities for joint skilling initiatives
Socio-Cultural Barriers	• Gender disparities in participation • Preference for urban/white-collar jobs • Social stigma around manual/agri work	• Skilling centers often lack safe, inclusive spaces • No focused outreach to disadvantaged youth and women	• Establish women-centric training hubs with crèches and safety provisions • Incentivize participation of youth from marginalized groups through fellowships or subsidies

Post-Training Support	• Lack of access to credit, market, mentorship, and incubation • Poor transition from training to entrepreneurship	• Absence of integrated post-training support systems • Limited linkages with FPOs, startups, and market platforms	• Embed enterprise support (credit, market linkage, mentorship) within training programs • Create dedicated agri-startup support cells at district level • Link skilled youth with FPOs and producer collectives for business incubation

4. **Conceptual Framework: AgriSkilled Bharat 2047**

An inclusive conceptual model is proposed with four foundational pillars; Skill Development Ecosystem, Agripreneurship Promotion, Institutional and Policy Support, and Socio-Cultural Enablers, to build an AgriSkilled Bharat that complements the Government of India's Viksit Bharat 2047 initiative (Figure 1). This model envisions empowering rural youth through demand-driven agri-skills, fostering entrepreneurial ventures in agriculture and allied sectors, strengthening institutional frameworks and policy convergence, and promoting behavioural change and social inclusion. Collectively, these pillars aim to transform agriculture into a knowledge-driven, enterprise-led sector while ensuring equitable and sustainable rural development.

A) Skill Development Ecosystem

The Skill Development Ecosystem plays a pivotal role in transforming agriculture into a modern, enterprise-driven sector by equipping rural youth with relevant, market-ready competencies. Central to this ecosystem are customized agri-skill training modules that address the evolving needs of the agricultural sector in the context of climate change, technological disruption, and market integration (Figure 1) . These modules focus on areas such as climate-smart agriculture, which enhances resilience and sustainability in farming; precision agriculture, leveraging tools like IoT, drones, and AI for data-driven decision-making; and value chain management, which enables youth to engage with post-production processes like aggregation, processing, and marketing. Additionally, skill development in post-harvest technologies and farm mechanization services ensures efficiency and value addition, creating new employment avenues in agri-service and logistics sectors. To ensure inclusive access and effective knowledge transfer, the skill development ecosystem emphasizes multi-modal delivery systems. These include classroom instruction, practical demonstrations, and field-level training to integrate theory with hands-on experience. ICT-enabled learning platforms and mobile-based applications are also being increasingly utilized to reach youth in remote areas, providing flexible, self-paced learning opportunities. Moreover, institutions like Krishi Vigyan Kendras (KVKs), Farmer Producer Organizations (FPOs), and agri-incubators serve as decentralized hubs for localised training and capacity-building. These platforms not only provide infrastructure and mentorship but also act as bridges connecting trained youth with markets, extension services, and funding opportunities. The final component of the proposed robust skill development ecosystem is recognition and certification, which lends credibility and portability to acquired skills. Training programs aligned with the National Skill Qualification Framework (NSQF) ensure standardization and facilitate vertical mobility for youth across employment and education systems. Accreditation through Sector Skill Councils (SSCs) under the National Skill Development Corporation (NSDC) ensures industry relevance and quality assurance. This formal recognition is vital for enhancing employability, enabling youth to secure roles in the formal agribusiness sector or to access credit and support for entrepreneurial ventures.

B). Agripreneurship Promotion

Agripreneurship Promotion plays a transformative role in reshaping rural economies by integrating enterprise orientation with the broader framework of agri-skilling. At the core of this transformation lies the development of viable business models in agriculture and allied sectors, tailored to regional resource endowments and market demands (Figure 1). Enterprise orientation includes equipping aspiring agripreneurs with the knowledge to identify profitable business opportunities, conduct feasibility analyses, and develop scalable models. Financial literacy and access to institutional credit are crucial enablers, helping agripreneurs navigate funding mechanisms, prepare business plans, and manage risks. In addition, understanding the legal and regulatory framework, including registration, taxation, and compliance, is essential for ensuring the sustainability of agri-enterprises. Emphasis on branding, packaging, and digital marketing strategies further enhances market visibility and consumer trust**.** A robust startup and incubation support system acts as a catalyst for nurturing innovative agri-based enterprises. Agri-business incubators, such as those supported under programs like RKVY-RAFTAAR and the Agri-Clinics and Agri-Business Centres (ACABC) scheme, provide mentorship, infrastructure, and technical support for early-stage startups. Seed funding and startup grants help bridge the initial capital gap and reduce financial entry barriers. These incubators also can offer capacity-building programs, exposure visits, and expert consultations that help startups refine their business strategies. Moreover, digital platforms and e-commerce solutions shall provide scalable avenues for market linkage, enabling agripreneurs to access wider markets, reduce transaction costs, and enhance profitability. Integration with these platforms fosters data-driven decision-making and improved supply chain efficiencies. Similarly, strengthening linkages with Farmer Producer Organizations (FPOs) and agricultural value chains amplifies the impact of agripreneurship promotion. FPOs serve as aggregators of small and marginal farmers, offering economies of scale in procurement, processing, and marketing. Agripreneurs can collaborate with FPOs to establish value-added enterprises such as primary processing units, storage facilities, or export-oriented ventures, thereby generating rural employment and enhancing farmer incomes. These partnerships also facilitate branding and certification of local produce, meeting domestic and international quality standards. Embedding agripreneurship within value chain development ensures inclusive growth, reduces post-harvest losses, and promotes sustainable, climate-resilient agribusiness ecosystems.

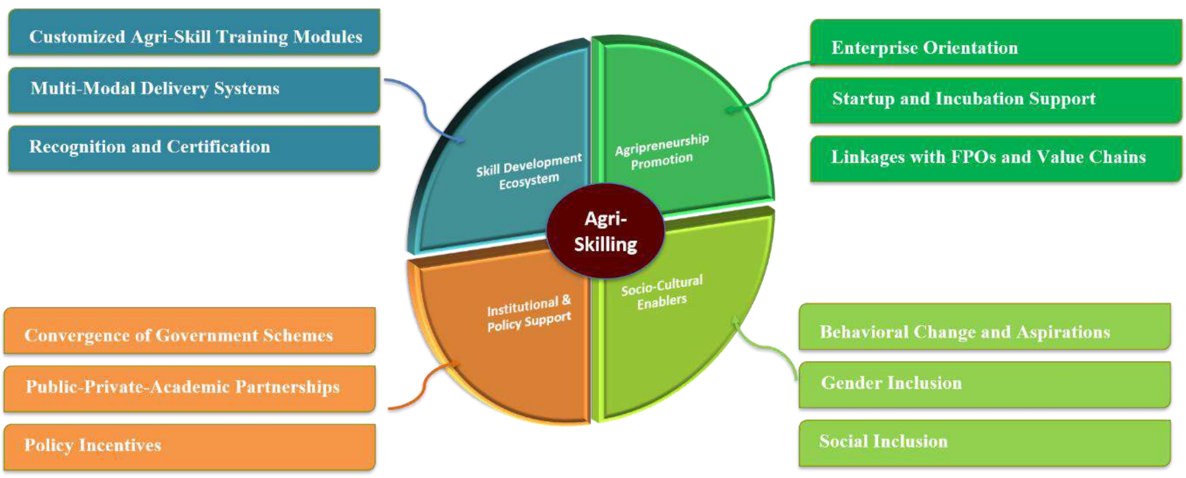

Figure 1: Conceptual framework Agri-Skilling (Source: Authors)

C). Institutional & Policy Support

Institutional and Policy Support serves as another foundational pillar for advancing agri-skilling in India by aligning national priorities with grassroots implementation. A key strategy lies in the convergence of government schemes such as Skill India, Pradhan Mantri Kaushal Vikas Yojana (PMKVY), Deen Dayal Upadhyaya Grameen Kaushalya Yojana (DDU-GKY), Startup India, and Atma Nirbhar Bharat (Figure 1). These schemes, though diverse in objectives, can be integrated to create a seamless ecosystem for skill development, entrepreneurship, and job creation in the agricultural sector. Through convergence, duplication of efforts is minimized, resource utilization becomes more efficient, and trainees benefit from a more comprehensive skilling pathway—from basic training to enterprise establishment and market access. To further strengthen the agri-skilling landscape, Public-Private-Academic Partnerships (PPAP) play a transformative role in bridging the gap between traditional agriculture and modern innovations. Collaborations between government bodies, private agri-tech companies, agricultural universities, NGOs, and CSR initiatives foster a multidimensional approach to skill development. These partnerships facilitate access to cutting-edge technologies, modern farming practices, real-time market intelligence, and domain-specific expertise. Academic institutions can contribute through curriculum development, research inputs, and training-of-trainers programs, while private firms can offer internships, technology demonstrations, and employment linkages. NGOs and CSR-funded initiatives can focus on community outreach, especially in underserved areas, ensuring inclusive and widespread skilling coverage. At the same time, robust policy incentives are also critical in creating an enabling environment for skilling and entrepreneurship in agriculture. Tax exemptions for eligible startups, interest subsidies on agricultural loans, and dedicated rural entrepreneurship funds provide the financial impetus needed to attract and retain talent in the sector. Moreover, targeted schemes and incentives for women, Scheduled Castes, Scheduled Tribes, and marginalized rural youth ensure that the benefits of skilling are equitably distributed. By lowering entry barriers and reducing perceived risks, these policy tools encourage participation in agri-enterprises, facilitate innovation, and contribute to building a self-reliant and resilient rural economy.

D). Socio-Cultural Enablers

Socio-cultural enablers are a vital yet often underemphasized pillar of agri-skilling, as they address the deep-rooted behavioural, cultural, and psychological factors that influence participation in agricultural entrepreneurship. One of the key aspects is behavioural change and aspirational building, which involves shifting mindsets from viewing agriculture as a subsistence activity to seeing it as a viable and profitable career (Figure 1). Showcasing success stories of rural agripreneurs, particularly those who have transformed their lives through innovation and enterprise, can inspire others and create a positive narrative around farming. Career counseling and structured mentorship programs play a crucial role in helping youth and rural workers identify their strengths, align them with emerging agri-business opportunities, and build confidence to take entrepreneurial risks. Promoting gender and social inclusion is equally critical for ensuring that agri-skilling benefits are equitably distributed. Women, scheduled castes, scheduled tribes, and other marginalized groups often face systemic barriers that limit their access to training, resources, and decision-making platforms. Agri-skilling programs must be tailored to meet their specific needs, such as flexible training schedules, vernacular instruction, and simplified curricula. Providing supportive infrastructure like crèches for childcare, safe training environments, and encouraging the formation of women-led cooperatives or self-help groups can significantly enhance participation. Ultimately, socio-cultural enablers create the soft ecosystem that supports the hard skills imparted through training programs. Without addressing cultural norms, social hierarchies, and behavioural resistance, even the most technically sound skilling initiatives may fall short. Encouraging community-level dialogue, engaging local influencers, and building peer support systems can help normalize the idea of youth and women as agripreneurs. By fostering a culture of innovation, self-reliance, and social cohesion, this pillar strengthens the human foundation upon which agri-skilling and rural transformation can truly thrive.

5. Conclusion

Agri-skills development serves as a cornerstone for youth empowerment and rural transformation, offering a strategic pathway toward realizing the vision of a self-reliant and Viksit Bharat. In an era where agriculture is rapidly evolving with the integration of technology, sustainability practices, and value chain dynamics, it is imperative to equip rural youth with context-specific technical, entrepreneurial, and digital skill sets. These competencies enable them to become not just participants in the agricultural economy but drivers of innovation, job creation, and environmental stewardship. By transforming traditional farming mindsets into forward-looking agripreneurial attitudes, agri-skilling instils a sense of purpose, pride, and ownership among rural youth. Promoting agripreneurship as a viable and attractive career option helps address some of the most pressing rural challenges, including youth unemployment, disguised labour, and distress migration. Through targeted interventions, such as business incubation, financial literacy, access to credit, and exposure to modern technologies, rural youth can actively engage in value-added agriculture, food processing, agri-services, and agri-tech enterprises. These opportunities create inclusive economic growth, foster local employment, and strengthen the link between smallholder producers and emerging market demands. As young agripreneurs become integrated into global and domestic value chains, they contribute to building resilient local economies aligned with national development goals. To achieve this vision, a holistic and convergent approach is essential; one that synergizes agri-skill training, institutional support, public-private partnerships, and socio-cultural enablers. Such an ecosystem not only empowers youth with knowledge and resources but also creates an enabling environment where innovation thrives and entrepreneurship flourishes. With the right policies, mentorship, and infrastructure, India can nurture a new generation of agri-leaders who are capable of transforming rural landscapes into vibrant centers of economic activity and sustainability. In doing so, agri-skilling becomes not just a means of livelihood enhancement but a nation-building mission that lays the foundation for a prosperous, inclusive, and developed India.

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Smart Farming and Agritech Start-ups: Upskilling Youth for the Digital Agriculture Revolution

Prof. Arvind Kumar Shukla
Vice Chancellor, RVSKVV, Gwalior (MP)

In configuration with the Hon'ble Prime Minister's vision of "Viksit Bharat @ 2047" and the belief that "India's youth and innovators are the architects of a self-reliant and globally competitive nation," Agritech start-ups are revolutionising Indian agriculture with smart farming and digital revolution in Agriculture.

Agriculture is at a tipping point. The world faces rising food demand, changing climates, and limited resources. At the same time, we're seeing a technological detonation as AI, IoT, drones, robotics, big data, and biotech are converging. The smart farming based on Digital Agriculture Revolution demands new skills, new mindsets, and new leaders. Nowadays, we explore how smart farming and agritech startups are transforming agriculture and how we can prepare the youth to become the driving force of this transformation.

Understanding Smart Farming:

Smart farming refers to the use of modern technology to improve the quantity and quality of agricultural products while optimizing the human labour required and minimizing environmental impact. It uses digital technologies to optimize agricultural operations. It transforms traditional practices into data-driven, efficient, and sustainable systems. It is a kind of farm management that incorporates modern technology in order to improve the quality and quantity of agricultural products. The Internet of Things (IoT), data processing, machine learning, application of sensor based smart technology, access to GPS and GIS are part of this strategy. Smart farming has been valuable to all farmers, large and small, throughout time because it exposes them to technology and tools that help them enhance the quality and quantity of their products while lowering agricultural expenses.

Emerging smart technologies:

- **IoT Sensors:** Soil moisture, temperature, humidity monitoring
- **Drones & Satellite Imagery:** Crop health, irrigation analysis
- **AI & Machine Learning:** Yield prediction, disease detection
- **Blockchain:** Supply chain transparency and traceability
- **Robotics:** Automated harvesting, precision seeding etc.
- **Telecommunications technologies** include advanced networking and GPS
- **Data analytics tools** for decision making and forecasting

Among the newer technologies those are reachable for present day farmers are as follows:

1. Sensing technologies such as soil scanning, light, water, temperature management
2. Communication technologies such as cellular communication technology
3. Positioning technologies such as GPS, GIS
4. Hardware and software which enable IoT based solutions, robotics, automation, and specialized software solution
5. Data analytics that account for decision making and forecasting process.

Benefits of Smart Farming

a) High crop productivity: Using better and improved farming technologies after smart farming ensures increased efficiency, as the emphasis is on optimizing inputs productivity and reducing waste.

b) Reduced usage of pesticides, fertilizers, and water: Farmers have traditionally utilized water, fertilizers, and pesticides despite knowing where those are needed on the land. For smart, however, you apply water and other chemicals whenever and wherever you need them, and in the right amounts which reduce the use of water and chemicals results in agricultural costs decline.

c) Reduce environmental impact: Nowadays, smart farming employs improved methods for increasing efficiency while decreasing the loss of pesticides, water, and other inputs to the crop. The idea is that if you can use them sparingly and where they are strongly needed you don't have to flood the world with unnecessarily harmful chemicals.

d) Improved safety for farmers and workers: Smart farming allows for the use of machinery and better technologies that restrict worker engagement in the field, removing the need for farmers and workers to be concerned about their safety.

e) Low chemical deposition into groundwater and rivers: Smart farming promotes the use of pesticides as little as possible and the use of ecologically friendly agricultural techniques. This means that little or no contaminants can be released in rivers and in general on the climate.

Landscape of Agri-tech Startups: Key Trends in India

The core of our economy is agriculture which is undergoing a silent yet transformative revolution. Agri startups are leveraging technology to address age-old challenges in the traditional agri value chain. These companies are leveraging technology to improve efficiency, productivity, and sustainability in the agricultural sector. Over the past decade, agri-tech startups have surged, driven by the convergence of smartphone penetration, digital infrastructure, and a growing need for sustainable solutions. Companies like Agri bazaar, a leading digital marketplace for agricultural produce, exemplify how agriculture technology startups are reshaping India's farming landscape. According to the Business Standard, India's share in global agricultural exports is estimated to be around 2.4% in 2025, despite being the 7th largest agricultural exporter. In 2023-24, India's agricultural exports were approximately $50 billion. According to an Ernst & Young report, agritech firms in India present a US$ 24 billion opportunity, although the market is still largely untapped (with only 1.5% penetration).

India is home to 2,700–2,800 agritech startups registered (up to end of 2023), spanning marketplaces, precision agriculture, advisory, and supply chain domains (Source: Startup India). Several Agritech startups are transforming Indian agriculture with innovative solutions. Key players include Ninjacart, DeHaat, CropIn, and AgroStar, focusing on supply chain optimization, AI-based farming solutions, data-driven management, and providing farmers with access to inputs and advice.

The funding of this sector has seen increase of nine times over recent years, with investors deploying nearly $1.3 billion in 2021 and growing government support through Start up India schemes, incubators, accelerators and regulatory initiatives (Source: Reuters). Adoption of satellite data, drone imagery, IoT and AI is driving 30–35% improvements in farmer incomes, crop yields, and operational efficiencies (Source: Reuters). The rise of agritech startups in India over recent years marks a rapid shift from traditional agriculture to a technology-driven ecosystem. Agritech is now one of the fastest-growing startup sectors in

India and globally. Therefore, let's understand the some of the reasons that has led to such vibrant rise in the sector:

1. Market gaps in supply chains, logistics, and pricing
2. Need for climate-resilient, low-cost solutions
3. Consumer demand for organic, traceable produce
4. Increasing awareness and deeper penetration of smart phones in rural areas

Key Drivers behind the rise of Agritech Startups:

The rise of agritech companies is fuelled by multiple factors. India's agritech industry has benefited from government initiatives such as Digital India and Startup India, which promote technological adoption and entrepreneurship. Simultaneously, increasing smartphone usage in rural areas has bridged the gap between farmers and agritech solutions, enabling access to real-time data on weather, crop prices, and best practices.

Investors, global as well as local, are also recognising the potential. Agritech startup funding has skyrocketed, with venture capital firms pouring over $1.6 billion into the sector between 2017 and 2022. Many agri-startups have secured significant investments, underscoring confidence in platforms that streamline supply chains and empower farmers. The major reasons behind unprecedented growth of agri startups in India are documented hereunder;

1. Digital Momentum in Rural India

Smartphone and internet penetration in villages has grown substantially in recent years, with more than 50% of rural households having smartphones, enabling access to agritech platforms in local languages (Source: The Entrepreneur India). Government digital initiatives like Digital India and Startup India have accelerated reach into rural and tier-2/tier-3 towns, enabling solutions across India's diverse agro-climatic zones (Source: Agritimes)

2. Supportive Policies & Schemes

Government programs such as the RKVY Innovation & Agri-Entrepreneurship Development scheme, Incubators, Startup India etc. have supported over 2000 agritech startups during recent past. Recent state-level initiatives, such as MP's new Agritech Innovation Hub in Indore, are investing heavily in AI, genomics, drones, and big data to fuel startup growth. New national schemes like the Prime Minister Dhan-Dhaanya Krishi Yojana launched in July 2025 offers ₹24,000 crore over six years to boost yields and support crop diversification, irrigation, and infrastructure, positively catalysing adoption of agritech.

3. Technology Adoption & Innovation

Agritech startups are leveraging AI/ML, IoT sensors, satellite data, drones, and blockchain to enable precision farming, disease forecasting, optimal resource use, and supply-chain traceability (Source: Agro Spectrum India). A standout example is AgriDoot a startup incubated by CAIE, RVSKVV, Gwalior, which uses satellite imagery to help farmers achieve up to 30–37% yield increases and similar revenue growth, as shown in real-world deployments by 2024.

New Start up Models in Agritech:

1. Precision Agriculture Platforms (e.g., Agri Doot, CropIn, Fasal)
2. Agri-fintech (e.g., DeHaat, Samunnati)
3. Biotech and Inputs (e.g., biofertilizers, drought-resistant seeds)

1. Supply Chain & Market Linkages:

- **Ninjacart:** This startup focuses on transforming the supply chain for fresh produce, connecting farmers directly with retailers and businesses.
- **Crofarm:** Another player in the fresh produce supply chain, Crofarm aims to reduce food waste and improve market access for farmers.
- **WayCool:** This company offers a B2B platform that manages the entire agricultural supply chain, from inputs to distribution, helping farmers sell their produce through various channels.
- **FarMart:** Provides SaaS-based B2B food supply chain solutions.
- **AgriBazaar**

2. AI & Data-Driven Solutions:

- **DeHaat:** An AI-based platform that provides farmers with access to agricultural inputs, advisory services, and output and financial services.
- **CropIn:** Offers data-driven farm management solutions, leveraging cloud and mobile technologies to improve farm efficiency and traceability.
- **AgNext Technologies:** Focuses on quality assessment using AI, providing solutions for food safety and quality control.
- **Fasal:** Utilizes an AI-powered IoT SaaS platform to transform horticulture.
- **Intello Labs:** Specializes in image-based quality assessment for agricultural products.
- **Aquaconnect:** Offers AI-based solutions for shrimp and fish farmers.
- **AgriDoot:** GIS data based and AI-based solutions to the farmers.

3. Farm Input & Services:

- **AgroStar:** Provides farmers with a platform to purchase agricultural inputs and access agronomy advice.
- **BharatAgri:** Offers a platform for farmers to buy inputs and access advisory services.
- **KhetiGaadi:** Provides information and resources related to farming, including equipment and inputs.
- **Bijak:** Focuses on providing a platform for agricultural trade and transactions.
- **Gold Farm:** Offers services related to farm equipment and machinery.
- **EM3 AgriServices:** Provides access to farm machinery and equipment on a pay-per-use basis.

4. Other Notable Startups:

- **Stellapps:** Specializes in IoT and software solutions for dairy farming, optimizing the supply chain for milk production.

- **Bombay Hemp Company (BOHECO):** Focuses on industrial hemp and cannabis cultivation and processing.
- **Eeki:** Provides hydroponics-based farming solutions.
- **Sammunati:**

Ayata Intelligence: Offers AI-powered solutions for various agricultural applications.

Impact of Smart Farming and Agri tech Start-ups on Traditional Farming:

The impact of agritech start-ups on traditional farming is profound. These startups enhance productivity and reduce waste by deploying agri-tech innovations such as AI-driven analytics, IoT-enabled devices, and blockchain-based traceability. For instance, agribazaar connects farmers directly with buyers, eliminating intermediaries, ensuring fair prices and securing instant transactions directly into farmers' bank accounts. This digital approach enables farmers to improve their incomes & livelihoods.
Moreover, agritech solutions address critical pain points like post-harvest losses, which cost India $14 billion annually. Startups offer cold storage networks, precision farming tools, and fintech services, fostering resilience against climate risks and market volatility. Such innovations are gradually transforming rural India into a tech-savvy, profit-oriented ecosystem.

Upskilling Youth in Agriculture: The Need of the Hour

The future of India's economy, innovation, and equity depends on how quickly we bridge the skills gap. Whether through coding bootcamps, digital apprenticeships, or AI literacy drives, every young Indian must be future-ready. The young people must be empowered to become digital farmers, agripreneurs, and technology innovators.

Key Skills:
1. <u>Digital Literacy</u>: Using mobile apps, GPS tools, farm management systems
2. <u>Data Interpretation</u>: Understanding crop data, analytics, and trends
3. <u>Business Acumen</u>: Marketing, fundraising, agri-economics
4. <u>Tech Proficiency</u>: Basics of AI, IoT, drones, and coding

Training Approaches:
1. Vocational training & certification programs
2. Hackathons & innovation challenges
3. Incubators and startup accelerators focused on agriculture
4. Partnerships with universities, agri-research centres and tech firms

What Needs to Be Done?
1. **Upgradation of Curriculum** - Industry Alignment: Integrate agri-tech into curriculum, modernize syllabi; include real-world, project-based learning.
2. **Skill Mapping** – Train them based on local or regional job demand.
3. **Rural Access to Upskilling** - Use vernacular EdTech and mobile-first platforms to bridge rural-urban digital divides.
4. **Internships & Apprenticeships** - Embed industry exposure and live projects in every vocational/degree program.

Key Barriers:
1. Digital divide and poor rural connectivity

2. Lack of access to capital
3. Resistance to change among traditional farmers
4. Lack of interest towards agriculture among rural/urban youth

***Solutions*:**
1. Public-private partnerships for digital infrastructure
2. Government schemes and agri-fintech support
3. Peer-to-peer learning and community-based tech evangelism

Challenges & Solutions: Navigating a complex terrain

Despite a promising area, agritech start-ups face enormous hurdles. The challenges agritech start-ups face includes fragmented land holdings, low digital literacy among farmers, and inadequate infrastructure. Many smallholders remain sceptical of new technologies, preferring conventional methods. Additionally, scaling solutions across India's diverse agro-climatic zones demands significant capital and localised strategies.

Regulatory complexities and fluctuating policies further complicate operations. However, pioneers like agribazaar demonstrate that perseverance pays off. By focusing on user-friendly platforms and farmer education, they build trust and drive adoption.

Role of Incubators in supporting Agri Startups

Incubators play a pivotal role in nurturing agri startups in India by offering a blend of mentorship, seed funding, infrastructure, networking, and strategic guidance. As agriculture undergoes a tech-driven transformation, incubators act as bridges between innovation and implementation especially crucial in a sector that is highly fragmented, risk-prone, and sensitive towards policy.

Incubators are essential enablers of India's agritech revolution. They lower the entry barrier for innovation, reduce the risk of early-stage failure, and help convert ideas into impactful agri solutions that improve farmer livelihoods, food security and sustainability.

Agri Incubators Are Crucial for Agri Startups for following reasons:

1. Bridging the Knowledge Gap: Most agri start-ups are founded by non-agri graduates or first-generation entrepreneurs who may lack deep domain knowledge. Incubators offer technical mentorship in agronomy, supply chains, sustainable practices, and rural consumer behaviour.

2. Certifications and regulatory compliances: Incubators help Startups to understand the certifications and other regulatory compliances required to run a business.

3. Access to Early-Stage Capital: Many agri ventures need patient, impact-focused capital, especially in pre-revenue stages. Incubators help in providing financial support to Agritech start-ups by connecting them with Government schemes, banks, investors etc. Incubators also provide seed funding and help startups access investors' network.

4. Product Validation & Field Testing: Agri-tech needs validation on ground with farmers. Incubators provide connections with Farmer producer organizations (FPOs), Research farms & pilot village, Krishi Vigyan Kendras (KVKs) etc.

5. Market Linkages & Scaling Support: Help startups build supply chains, link to mandis, cooperatives, processors, and exporters. Support B2B, D2C, and FPO-focused business models. Enable integration with digital platforms (eNAM, Agribazaar, etc.).

CAIE – RVSKVV, GWALIOR: A CASE OF SUCCESSFUL INCUBATOR

The Centre for Agribusiness Incubation and Entrepreneurship was established in the year 2020 as a joint initiative of Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior and National Bank for Agriculture and Rural Development (NABARD). The CAIE, Gwalior is one of its kind Agribusiness Incubator based in Central India with exclusive focus on Agriculture and allied sectors.

CAIE, RVSKVV, Gwalior has well-equipped infrastructure with 30 seat Co-working space, training hall, board room, meeting room, classrooms and in-house team of experts, panel of technical and industry mentors to support, foster & nurture each of its incubatee to graduate as a successful entrepreneur.

Status of Incubatee - Startups

At present, CAIE, RVSKVV, Gwalior is working with 359 registered incubates / budding entrepreneurs, this includes 94 startups, 39 DPIIT (Department for Promotion of Industry and Internal Trade) registered startups and 80 farmer producer organizations (FPOs).

Out of 359 incubatees working with CAIE, RVSKVV, Gwalior, 118 are working in Agribusiness sector, 96 in Food Processing, 40 in Agri Input, 34 in Agri Service sector, 25 in Farm Management, 15 in Livestock Management, 12 in IoT application, 6 in Hydroponics, 7 in waste management, 5 in Organic fertilizers and 1 in Biotechnology sector.

Services and Handholding

CAIE, RVSKVV, Gwalior provides complete hand-holding support to startups from 'Ideation stage to Market expansion Stage', helps in Preparation of Business Plan /DPR and provides help in funding support through Government schemes/ subsidies. CAIE, RVSKVV, Gwalior supports start-ups with access to state-of-the-art facilities such as advanced laboratories and research facilities of RVSKVV, Gwalior and also mentorship support from empanelled technical and business mentors. Further, CAIE helps in providing both forward and backward market linkages with complete end to end marketing support.

The centre is in process of establishing 'Central Processing Line' which will be a contemporary facility for food and fodder processing made available to the registered incubatees/start-ups of the CAIE.

Key Activities

CAIE, Gwalior regularly conducts sensitization programmes such as seminars, workshops, training programmes (physical and online mode), exhibitions, lectures, bankers' meet, investors' meet, capacity building programmes, competitions etc. with the objective to provide benefits to entrepreneurs and increase its outreach. CAIE, RVSKVV, Gwalior has conducted more than 80 such programmes till date.

CAIE, Gwalior also supports the adoption and application of Drone Technology in agriculture in Gwalior district with one Agricultural Drone and a full time DGCA certified drone pilot providing services to the clients at doorsteps.

Climate Smart Agriculture For Higher Resource Use Efficiency Using New Innovation

Dr. B. R. Kamboj

Vice Chancellor, CCS Haryana Agricultural University,

Hisar-125004 (Haryana), India

Abstract:

Climate change has emerged as a formidable global challenge, threatening food security, agricultural sustainability, and rural livelihoods. Rising temperatures, erratic rainfall, and extreme weather events are severely affecting agricultural productivity, particularly in developing nations like India. To meet the rising food demand of a growing global population while preserving environmental resources, there is an urgent need to adopt Climate Smart Agriculture (CSA) practices that improve resource-use efficiency through innovative, adaptive, and sustainable approaches. This paper explores a range of climate-resilient strategies and technological interventions developed and promoted by Chaudhary Charan Singh Haryana Agricultural University (CCSHAU), Hisar, across different agro-climatic zones of Haryana. The interplay of adaptation and mitigation builds resilience and reduces greenhouse gas (GHG) emissions. Adaptation strategies include crop diversification, integrated farming systems, conservation agriculture, and improved water and soil management practices. These methods not only enhance the adaptive capacity of farmers but also promote sustainability through efficient use of land, water and energy. Significant emphasis is placed on zone specific interventions based on climatic, soil, and water availability characteristics in Haryana. The Eastern Zone has seen success with technologies like direct seeded rice, zero tillage and crop residue management, while the Western and Southern Zones are focusing on drought-tolerant varieties, intercropping, and agroforestry. Conservation agriculture practices such as Furrow Irrigated Raised Bed (FIRB) planting and zero tillage have improved yields while conserving water and reducing input costs. Crop residue management, a major environmental issue, is addressed through mechanization, composting, biogas production, and promotion of a circular bio-economy. Other innovative solutions include solar-powered equipment, decision support systems, real-time agro-advisory services, and bio-drainage techniques to combat waterlogging and salinity. Varietal interventions have introduced climate-resilient, short-duration, and nutrient-rich crop varieties. The adoption of green energy alternatives and integrated nutrient management has further enhanced resource use efficiency. This comprehensive, location-specific, and technology-driven model developed by CCSHAU serves as a replicable framework for achieving climate-smart agriculture. It not only ensures long-term agricultural sustainability but also strengthens farmer livelihoods and ecological resilience in the face of climate variability.

Key words: Climate-smart agriculture, Crop residue management, Crop diversification, Water saving, varietal intervention

1. Introduction

The global population is expected to reach approximately 9.8 billion by 2050, necessitating a substantial rise in food production to meet growing demand. However, various biotic and abiotic stress factors continue to challenge and limit agricultural productivity. Since crop

production and related sectors are closely linked to weather and climate conditions, they are highly vulnerable to these changes. Climate change has emerged as a significant global threat to agriculture and poses a serious obstacle to achieving sustainable development goals (Koubi, 2019). Climate change, primarily driven by the accumulation of greenhouse gases (GHGs) in the atmosphere due to human activities such as industrialization, deforestation, and unsustainable agricultural practices, has emerged as one of the most critical global challenges. These changes have led to rising temperatures, erratic rainfall patterns, prolonged droughts, floods, and shifting climatic zones. The agricultural sector, being highly sensitive to climatic variables, is directly and disproportionately affected. Climate change not only threatens food security but also affects the livelihoods of millions of farmers, especially in developing nations. This highlights the urgent need for climate-smart agriculture that enhances resource-use efficiency through innovation. An average of 30 per cent decrease in crop yields is expected by the mid 21st century in South Asian countries, severely impacting food security and farmer incomes. North Indian states and Bangladesh are particularly vulnerable due to erratic changes in rainfall and temperature patterns (ICAR, 2019). In India, a temperature rise of 1.5°C coupled with a 2 mm decline in precipitation can reduce rice yields by 3 to 15 percent (Ahluwalia and Malhotra, 2006). Climate change also affects horticultural crops in multiple ways—high temperatures during flowering stages limit fruit setting in citrus and navel oranges, and cause blossom scorching, especially in young trees. Fruit crops such as apricots, cherries, and apples suffer from sunburn and fruit cracking due to heat-induced

moisture stress. Similarly, litchi experiences fruit burning and cracking when high temperatures coincide with ripening. Most vegetable crops are highly sensitive to flooding, with tomatoes being particularly vulnerable. Elevated ozone levels above 50 ppb/day can reduce vegetable crop yields by 5 to 15 percent. Furthermore, altered climatic conditions favour the proliferation of pathogens and insect pests, disrupting the growth cycles of crops and severely impacting overall productivity. These cascading effects highlight the urgency for innovative, climate-resilient farming solutions to safeguard agriculture and horticulture under changing environmental conditions.

2. Adaptation and mitigation approaches to fight climate change effects in agriculture sector

Adaptation and mitigation are two fundamental strategies to combat the adverse effects of climate change in the agriculture sector. Adaptation refers to making adjustments in human behavior or natural systems in response to changing climatic conditions. Adaptation involves making systematic adjustments in farming practices, technologies, and resource use in response to changing climatic patterns without entirely replacing traditional systems. It may involve altering crop calendars, adopting drought-resistant varieties, or improving irrigation efficiency. Such adaptive practices are critical for risk management and often require the involvement of complex governance mechanisms. Empowering farmers with information about the impacts of climate change, along with providing support from agricultural extension services, research institutions, government policies, and local

communities, is vital for enhancing their adaptive capacity. The concept of "Adaptation-led Mitigation" emphasizes that by adapting smartly, we can simultaneously reduce greenhouse gas emissions and enhance resilience at the community and national levels. On the other hand, mitigation focuses on technological and management interventions that reduce greenhouse gas emissions per unit of agricultural output. According to the IPCC, it includes any input-level adjustment that minimizes emissions while maintaining productivity. This could mean switching to low-emission fertilizers, adopting conservation agriculture practices, promoting agroforestry, or improving manure management.

The successful agricultural climate change adaptation pivots on several key components such as inflow of new technologies, effective technology packaging, active involvement of multiple stakeholders, and synergy among various agricultural programs. Climate change adaptation technologies covers multiple domains including water management, soil health, crop diversification, livestock and poultry management, farm mechanization, fisheries, and technology dissemination. Water management plays a particularly critical role in India, where nearly half the agricultural land depends on rainfall. Thus, conserving rainwater through in-situ (like contour bunding and mulching) and ex-situ (such as farm or community ponds) measures is prioritized. Other important adaptive strategies include water-saving rice systems, tolerant crop varieties, legume intercropping, and the use of decision support systems. Technologies such as mechanized water lifting systems and agro-advisory services also ensure timely interventions.

Improved practices like conservation agriculture, biochar, micro irrigation, integrated farming systems (IFS), and solar-powered equipment not only enhance resilience but also act as mitigation tools by reducing emissions. Most adaptation technologies offer dual benefits—reducing vulnerability while lowering GHGs—making them efficient, climate-smart solutions. Ultimately, climate-resilient agriculture relies on a combination of local innovation, scientific knowledge, policy support, and stakeholder collaboration to reduce risk, enhance productivity, and secure sustainability in the face of climate change. Together, adaptation and mitigation form the backbone of climate-smart agriculture, helping to safeguard food security, environmental sustainability, and farmer livelihoods in the face of escalating climate risks.

3. Adaptation and mitigation interventions by CCSHAU in fight against climate change: A case study from Haryana state.

Haryana, situated in northwestern India, covers a geographical area of 44,212 sq. km. and supports a population of approximately 25.3 million, with 65.2% residing in rural areas. The state has a strong agricultural base with a gross cropped area of 6.5 million hectares and a livestock population of around 9.89 million. It contributes significantly to the national food basket, producing about 16.56 million tonnes of food grains annually. However, the state also faces numerous sustainability challenges, particularly with respect to climate change and natural

resource management. Despite its productive agriculture, Haryana is increasingly affected by climate-related stressors. Erratic rainfall, frequent droughts, rising temperatures, and declining water tables have

made the agricultural sector more fragile. Overexploitation of groundwater, especially in the rice-growing belts, has emerged as a severe constraint, while soil degradation due to intensive farming practices further exacerbates the situation. Livestock productivity is also impacted by heat stress and inadequate fodder availability. The state's forest cover, at just 1,684 km², is insufficient to buffer the ecological impact of climate extremes.

Haryana falls under three distinct agro-climatic zones: the Eastern, Western, and Southern zones. Each of these zones exhibits unique climatic and edaphic conditions influencing agricultural practices. The Eastern Zone, comprising districts such as Karnal, Kaithal, Kurukshetra

and Sonipat, receives relatively higher rainfall and has fertile soils suitable for intensive cropping, particularly the rice–wheat system. The Western Zone, which includes Hisar, Sirsa, and Bhiwani, is semi-arid with lower rainfall and greater dependence on irrigation. The Southern Zone, including Rewari and Mahendragarh, is the driest, characterized by coarse-textured soils and limited water availability, making agriculture more vulnerable to climatic extremes. Haryana, despite its agricultural prominence, faces region-specific challenges that vary across its agro

climatic zones. Each zone deals with distinctive natural resource issues and climatic constraints, which directly impact agricultural sustainability and productivity.

In Zone-1, which includes districts like Kurukshetra, Karnal, Panipat, and parts of Sonipat, the most critical concern is the declining groundwater table. These areas have been declared overexploited due

to excessive extraction of groundwater, and tube wells now need to be installed at depths as deep as 700 feet to access water. Alongside this, there is a slow pace of crop diversification, with farmers predominantly dependent on water-intensive paddy cultivation. This over-reliance reflects a single-commodity or crop-centric approach, rather than adopting integrated farming systems that enhance sustainability. Additionally, the depletion of soil fertility due to continuous mono

cropping and high input use is alarming. Soil salinity and alkalinity are also major issues, especially in areas like Kalayat (Kaithal) and Gohana (Sonipat), which further reduce land productivity and pose constraints to crop choice and yield. In Zone-2, which covers districts such as Hisar, Rohtak, Fatehabad, Sirsa, Palwal, and Faridabad, the scenario is marked by two contrasting water-related problems. In regions like Hisar and Rohtak, the groundwater table is rising every year, but unfortunately, the water is brackish in nature, rendering it unsuitable for irrigation without prior treatment. Conversely, areas located along the Ghaggar River, such as Ratia, Tohana, Rania, Ellenabad as well as Palwal and Faridabad, are witnessing a decline in the water table, especially in the sweet water belts. These inconsistent groundwater conditions complicate irrigation planning and crop choices, limiting the long-term agricultural potential of the region. In Zone-3, encompassing districts like Bhiwani, Mahendergarh, Rewari, Gurgaon, and parts of Charkhi Dadri and Mewat, severe groundwater depletion is the primary concern. This problem is exacerbated during the summer months when over-pumping from tube wells occurs to meet irrigation demands. The situation is particularly serious in areas like Nangal Choudhry block in the Narnaul

region of Mahendergarh, where groundwater is not available even at depths of up to 1200 feet. The acute scarcity of water in this zone limits the feasibility of traditional irrigation-based farming and increases dependency on rainfall, making agriculture highly vulnerable to climate variability. These constraints across the three zones highlight the urgent need for zone-specific interventions, focusing on groundwater management, soil health restoration, crop diversification, and integrated farming practices to ensure long-term agricultural sustainability in Haryana.

3.1 Strategic Interventions:

To address these challenges, Chaudhary Charan Singh Haryana Agricultural University (CCSHAU), Hisar, has initiated several interventions tailored to each agro-climatic zone. In the Eastern Zone, the focus has been on promoting resource-conserving technologies such as direct seeded rice (DSR), short duration varieties, promotion of kharif maize and mustard in rabi season and conservation practices in wheat to save water and reduce energy inputs. Crop diversification is being encouraged to shift away from water-intensive rice towards maize, pulses, and oilseeds. Integrated nutrient and pest management strategies are also being implemented to reduce environmental stress. In the Western Zone, CCSHAU has developed and promoted climate resilient varieties of cotton and bajra, which are better suited to local conditions. Promotion of Desi cotton and promotion BG2 varieties in American cotton are the future strategies. Water-saving technologies such as drip and sprinkler irrigation are being adopted to enhance

irrigation efficiency. Agroforestry, intercropping, and integrated farming systems are being promoted to diversify income and improve resilience. In the Southern Zone, where rainfall is scarce and soils are less fertile, the university has prioritized the introduction of drought-tolerant crop varieties and dryland farming practices. Measures like soil moisture conservation through mulching and bunding, and the establishment of fodder banks and livestock shelters have helped mitigate the impact of climate variability. Across all zones, CCSHAU has undertaken several cross-cutting initiatives. These include the use of decision support systems (DSS) for climate-smart planning, mobile-based agro-advisory services for timely information dissemination, and the promotion of renewable energy through solar-powered irrigation systems. Efforts are also being made to improve soil health through the use of bio-fertilizers, and the distribution of soil health cards to farmers.

a) Crop diversification interventions:

Crop diversification is a strategic approach to adapt and build resilience against the adverse effects of climate change while ensuring sustainable agricultural growth. It involves the intentional inclusion of crops/varieties in farming systems, which not only buffers against market and climate-related risks but also enhances resource use efficiency and ecological sustainability. The major driving forces for crop diversification include mitigating the ill-effects of aberrant weather, withstanding price fluctuations, conserving natural resources such as soil and water, reducing dependency on off-farm inputs, and improving food and nutritional security. Diversification also minimizes environmental

pollution, balances food and fodder demands, reduces pest and disease incidence, and contributes to community food security.

At CCSHAU, region-specific diversification strategies have been developed to maximize productivity and climate adaptability. For example, in Zone I, viable options include maize–potato– sunflower/moong, short-duration rice–potato–moongbean, maize–wheat, and intercropping systems such as maize–poplar or sugarcane intercropped with vegetables. In Zone II, where agro-climatic conditions are unsuitable for maize, crops like groundnut thrive well in areas like Bhatto, Adampur, and Dabwali. Kinnow and guava plantations are ideal for the sandy loam soils of Sirsa, Hisar, and Fatehabad. In Palwal, the presence of a sugar mill encourages sugarcane cultivation over water

intensive rice. Similarly, in Zone III, with its water-scarce conditions, low water-consuming crops such as pearl millet and cluster bean in kharif, followed by barley or mustard in rabi, are recommended. Farmers in Mewat and Bhiwani near the Aravalli hills benefit from sweet groundwater and are encouraged to grow vegetables like tomato, brinjal, and cucurbits.

The benefits of crop diversification are multi-fold—it leads to increased production of potato, oilseeds, pulses, fruits, and vegetables, and improves nutrition and health by reducing malnutrition. It also reduces pest and disease outbreaks due to cropping sequence changes and fulfills changing consumer demands. Importantly, diversification enhances soil health and stabilizes farm income across seasons. It provides viable livelihood options for smallholders, generates additional

rural employment, and contributes to natural resource conservation (Khatri-Chhetri et al., 2017). Diversification into crops like maize (including sweet corn, baby corn, and popcorn) for food, feed, and industrial purposes presents strong export potential and industrial linkage, making it not only a climate-smart solution but also economically rewarding for farmers.

b) Intercropping

Intercropping—the practice of growing two or more crops in proximity—helps in efficient utilization of resources, suppression of weeds, pest and disease management, and provides diversified income sources. In Haryana, successful models include intercropping of wheat in autumn-planted sugarcane and vegetable cultivation on beds within sugarcane fields. Pulses, due to their short duration and low water requirements, have emerged as a viable intercrop alternative, especially important in replacing water-intensive crops like rice and wheat. Replacing even 10–15% of the rice–wheat area with alternatives such as maize (HQPM, baby corn, sweet corn), micro-irrigated sugarcane intercropped with cucurbits, onions, or garlic, and high-value fruits like mango, guava, peach, and plum can significantly reduce water use while improving soil health and farm income.

c) Agroforestry

Agroforestry further complements intercropping by integrating trees with crops and/or livestock on the same land, offering both short-term and long-term ecological and economic benefits. In Haryana and Punjab,

this model has gained popularity among small and marginal farmers as a reliable investment strategy. During the first two years of tree establishment, farmers continue to reap yields from intercrops like wheat, sugarcane, and vegetables grown between tree rows. Systems like poplar-based agroforestry with fodder-wheat or turmeric rotation not only diversify farm production but also offer resilience against extreme weather events. Trees improve carbon sequestration, protect against wind and water erosion, enhance biodiversity, and stabilize microclimates. Intercropping in orchards—such as vegetables and legumes between young fruit trees—adds early returns before the trees reach full productivity. Overall, these integrated approaches reduce climatic vulnerability, improve water use efficiency, enhance soil fertility, and ensure economic stability for farming communities.

d) Conservation agriculture

Conservation agriculture (CA) is a climate-resilient farming approach that emphasizes minimal soil disturbance, permanent soil cover, and crop rotation to enhance soil health, reduce greenhouse gas emissions, and improve resource-use efficiency. CCSHAU has actively promoted conservation agriculture technologies as part of its climate change mitigation strategy. Among its key interventions is the adoption of Zero Tillage and Furrow Irrigated Raised Bed (FIRB) planting. FIRB planting has been found to reduce wheat seed requirement by 30% to 50% compared to flatbed planting, and enhances yield potential through better nutrient-water interactions. Similarly, permanent raised beds

reduce water use by 30% and improve crop yields by over 20%. Additionally, raised beds allow greater sunlight interception due to the border effect, improving photosynthetic efficiency. Rice transplanted on FIRB beds saves 25% to 50% of irrigation water, while also reducing lodging and production costs by 20%-25% compared to conventional rice-wheat systems. Further, Zero tillage is a cost-effective and climate

smart agricultural practice that eliminates the need for traditional ploughing, offering multiple benefits to farmers. It leads to a direct saving of approximately ₹2000 per hectare in diesel costs for land preparation. In addition to reducing operational expenses, zero tillage contributes to significant water conservation, saving around 1000 cubic meters of irrigation water per hectare. Importantly, it facilitates the timely sowing of wheat after paddy harvest, which is critical for yield optimization, as delays in planting can result in yield losses of 35–40 kg per hectare per day. Despite eliminating conventional tillage, crop yields under zero tillage are equal to or even higher than those achieved with traditional methods, making it a highly beneficial approach for sustainable and resilient farming. These interventions not only conserve critical resources like water and seed but also lower input costs and greenhouse gas emissions, making agriculture more sustainable and climate-smart.

e) Direct seeded rice (DSR)

Direct Seeded Rice (DSR) is an important intervention for particularly in regions dominated by the conventional puddled rice-wheat system to mitigate water saving related issues. DSR offers a sustainable alternative by eliminating the need for intensive puddling and

transplanting operations. Under well-managed conditions, DSR can save 20–25% of irrigation water compared to traditional methods, with even greater savings—up to 50%—when integrated with drip or sprinkler irrigation systems. This method also reduces dependency on labor, energy, and other natural resources, making it especially suitable in areas facing labor shortages. Furthermore, DSR minimizes greenhouse gas emissions associated with flooded rice fields. For effective DSR implementation, a seed-cum-fertilizer drill equipped with inclined plates and inverted T-tynes is recommended for precise sowing. Overall, DSR enhances resource-use efficiency, lowers input costs, and improves resilience against erratic weather patterns, supporting sustainable agricultural practices in a changing climate. The DSR integrated with short duration varieties has proved a good success in saving water. The University research efforts have been duly complemented with policy support as the Haryana Government is providing Rs. 4500/acre financial incentive on the adoption of DSR and further providing subsidy of Rs. 45000/- on the purchase of DSR machine.

f) Integrated Farming Systems (IFS)

Integrated Farming System (IFS) offers a holistic and synergistic approach to agriculture that enhances productivity, resource use efficiency, and ecological balance. In the face of climate change, IFS serves as a resilient model by diversifying farm activities, reducing dependency on external inputs, and improving soil health and water conservation. This system not only buffers against climatic risks but also ensures long-term sustainability and livelihood security for farming

communities. The CCSHAU has developed a 1.0 ha Integrated Farming System (IFS) model designed to mitigate the adverse impacts of climate change while enhancing farm profitability. This model integrates field crops, horticultural crops, a livestock unit (comprising one cow and two buffaloes), a mushroom production unit, a vermicomposting setup for recycling farm waste, and boundary plantations to optimize land use and resource efficiency. The IFS model not only enhances income and livelihood resilience for farmers but has also been scientifically evaluated to be low in greenhouse gas (GHG) emissions, or even emission

negative, making it a key intervention for climate-smart farming in Haryana. With an impressive five-year average net return of ₹2,41,000, this model demonstrates the economic viability of sustainable farming systems and serves as a replicable solution for integrated and eco

friendly agricultural practices. This model has been adopted by ICAR and has been acknowledged as bankable project by the NABARD.

g) Crop residue management

India generates approximately 500 million tonnes (MT) of crop residues annually, with cereal crops contributing nearly 70% and rice alone accounting for 34%. Haryana, as the second-largest producer of paddy in India, generates about 6.25 MT of rice straw from 1.25

million hectares of paddy fields. Improper handling, particularly open-field burning, leads to nutrient loss, soil degradation, air pollution, and GHG emissions (Chaudhary et al., 2022 and Gatkal et al., 2024). Sustainable management of this agri-waste can facilitate carbon sequestration, improve soil health, and mitigate climate impacts—paving the way for a

self-reliant and environmentally sustainability. To address the multifaceted challenges of crop residue management—such as short harvesting-to-sowing windows, lack of farmer awareness, inadequate machinery, and residue burning, CCSHAU, Hisar has implemented a multifaceted strategy across Haryana. This includes the promotion of farm mechanization, technological innovation, capacity building, and community engagement. Farm mechanization interventions for CRM includes in-situ residue incorporation using machines like Happy Seeder, Super Seeder, mulchers, rotavators, and zero-till drills, and ex-situ uses such as composting, vermicomposting, mushroom cultivation, and biogas production. Emphasis is also placed on circular economy principles, encouraging recycling and repurposing crop residues such as ethanol production, card board manufacturing, and feed bricks for fodder-deficient areas. The university conducts regular farmer training programs, establishes custom hiring centers through SHGs, and disseminates knowledge via media and demonstrations. Notably, CCSHAU has also developed pilot-scale biogas plants that convert paddy straw and cattle dung into clean energy and organic inputs, and continues to explore innovations like briquetting, pelletizing, biochar production, and silage making. These initiatives not only reduce greenhouse gas emissions from residue burning but also enhance soil health, promote renewable energy use, and support sustainable agriculture across Haryana. The CCS HAU technology interface has been successfully promoted by the policy paradigms and the problem of residue burning in Haryana is sufficiently mitigated and Haryana may soon emerge as the zero residue burning state.

h) Bio-Drainage

Biodrainage is an eco-friendly, cost-effective method of managing excess soil water and controlling waterlogging and salinity by using deep-rooted vegetation—particularly trees and perennial plants—to absorb and transpire surplus water. This green technology plays a vital role in mitigating climate change effects, especially in areas facing secondary salinization due to poor drainage or excessive irrigation. By enhancing soil health, improving land productivity, and preventing the build-up of salts, biodrainage supports sustainable agriculture and reduces the need for energy-intensive mechanical drainage systems. CCSHAU, Hisar, has actively promoted biodrainage as a natural resource management strategy, particularly in regions of Haryana prone to salinity and waterlogging. The university has conducted pilot studies and field demonstrations using species such as *Eucalyptus*, *Poplar*, and *Casuarina*, which have high water uptake capacity and adaptability to local agro-climatic conditions. These interventions not only help reclaim degraded land but also contribute to carbon sequestration, enhance biodiversity, and provide additional farm income through agroforestry. CCSHAU continues to research and promote biodrainage as a scalable, climate-resilient solution integrated into broader land and water management frameworks. The list of plants suitable for biodrainage are as follows, *Syzygium cumini, S. fruticosum, Tamarindus indica, Salix app., Acacia deanei, Albizia quachepela, Alelia herbertsmithi, Ceaselpimia eriostachya, C. velutina, Halmatoxylon brasiletto* are sensitive category plants for biodrainage and suitable for area with ECe

7-10 dS/m. Further, *Casuarina cunninghamiana, Eucalyptus tereticornis, Acacia auriculiformis, Guazuma ulmifolia, Leucanea shannonii, Samanea saman, Albizzia caribea, Senna atomeria, Terminalia arjuna, Pongamia pinnata* exihibit moderate sensitivity (ECe 10-

15 dS/m), where as *Tamari troupii, T. articulata, Prosopis juliflora, Pithecellobium dulce, Parkinsonia aculeata, Acacia farnesiana* are tolerant upto ECe 25-35 dS/m.

i) Varietal Interventions by CCSHAU, Hisar

CCSHAU, Hisar has made significant contributions in developing and promoting climate-resilient crop varieties suited to Haryana's diverse agro-climatic zones. These include drought-tolerant, heat-resistant, early-maturing, and pest-resistant varieties of wheat, rice, mustard, cotton, bajra, and pulses. Such varietal interventions not only ensure stable yields under changing weather conditions but also support efficient use of water and nutrients. The university continuously conducts multi-location trials and adaptive research to ensure that these varieties meet both climatic challenges and farmers' field-level needs, thereby enhancing food security and farm profitability. Some examples of CCSHAU's Bio-fortified varieties are Pearl millet HHB 299, HHB 311. Rice PB 1509, wheat WH 1124 are short duration varieties, where as Wheat WH 1142, WH 1080, WH 1402 (Newly released), Rice PB 1509, Mustard RH 0725, RH 0761, RB 50, RH 1424 (newly released) are low water requiring varieties. Moreover, pulse varieties such as Mungbean MH 421, MH 1142, MH 1762, MH 1772 are developed which exhibit high temperature tolerance.

j) Green Energy Interventions by CCSHAU, Hisar

In response to the growing energy demands and the need to reduce carbon emissions in agriculture, CCSHAU has actively promoted green energy solutions. This includes the installation and demonstration of solar-powered irrigation systems, dryers, and threshers, which reduce dependency on fossil fuels and lower operational costs for farmers. Additionally, the university has developed biogas plants using crop residues and cattle dung, supporting clean cooking energy and organic fertilizer production. These interventions contribute significantly to climate change mitigation, resource conservation, and promotion of sustainable, low-carbon farming systems across the state.

Some other Initiatives by CCSHAU to Mitigate Climate Change Effects involves installation of Computer-based Information Kiosks at 22 different locations including colleges, KVKs, research stations, training institutes, and farmers' service centers, offering real-time weather updates and crop-related advisories. Additionally, SMS alerts are sent to farmers via the Emausamhau service. Impact analysis has shown that farmers who followed Agromet Advisory Services (AAS) achieved significantly higher benefit-cost ratios in crops such as wheat (1.56), potato (2.26), cotton (1.61), and rice (1.27) compared to non-AAS adopters. The university has also emphasized sustainable and climate resilient practices by establishing the Deen Dayal Upadhyay Centre of Excellence for Organic Farming over 1410 acres to develop best management practices for organic cultivation of field, fruit, and vegetable crops. To enhance nutritional security and climate adaptation, the

CCSHAU Nutri-Cereals Research Station has been launched at Gokalpura (Bhiwani), focusing on research related to climate-resilient millets and other coarse grains. Moreover, micro-irrigation experiments have been initiated to combat the looming threat of water scarcity and promote water-use efficiency in agriculture.

In nut shell, with climate change posing significant risks to agricultural productivity, the role of adaptive and mitigation strategies has become critical. Through region-specific interventions, CCSHAU, Hisar, has developed and promoted diverse technologies that enhance agricultural resilience while reducing environmental footprints. Climate smart agriculture (CSA) practices such as integrated farming systems, conservation agriculture, crop diversification, agroforestry, and efficient water management serve as robust adaptive mechanisms. These practices are tailored for the distinct agro-climatic zones of Haryana to address specific challenges like groundwater depletion, soil salinity, drought vulnerability, and rising temperatures. Tools like decision support systems, mobile agro-advisories, solar-powered irrigation, and bio-drainage offer climate-resilient, low-carbon alternatives for traditional farming methods.

In conclusion, Haryana's agricultural sector stands at a crossroads where climate change, natural resource depletion, and food security are interlinked challenges. climate-smart agriculture offers a promising pathway to sustainable food production under changing climatic conditions. Through strategic, zone-specific interventions and policy support, CCSHAU, Hisar, is playing a pivotal role in promoting climate-

resilient agriculture. These efforts are essential to ensure sustainable crop production, efficient resource use, and long-term ecological balance in the state.

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Medicinal and Aromatic Plants: A Gateway for Innovation and Entrepreneurship Development

Jitendra Kumar[1] and Ashwin Trivedi[2]
[1]Formerly Assistant Director General, (NASF), Indian Council of Agricultural Research, New Delhi-110012
[2]ICAR-Directorate of Medicinal and Aromatic Plants Research, Anand, Gujarat

Medicinal and Aromatic Plants (MAPs) have emerged as a vibrant sector offering immense potential for innovation, value addition, and entrepreneurship development. With rising global demand for natural health products, herbal medicines, essential oils, cosmetics, nutraceuticals, and eco-friendly pest repellents, MAPs are no longer confined to traditional uses—they are at the forefront of green industrial growth and rural livelihood enhancement.

India, being one of the richest biodiversity hotspots, is home to over 7,500 species of medicinal and aromatic plants. This vast genetic wealth offers numerous opportunities for scientific exploration, product development, and sustainable utilization. The National AYUSH Mission, increasing global preference for Ayurveda and natural therapies, and government support for startup ecosystems have further enhanced the entrepreneurial landscape in this domain.

Research innovations in cultivation practices, post-harvest handling, nano-formulations, and value-added products have opened new avenues for commercialization. Technologies such as herbal biopesticides, plant-based mosquito repellents, and essential oil distillation units are fostering cottage-scale industries. Establishment of clusters, herbal parks, and farmer producer organizations (FPOs) is empowering farmers and youth to take up MAP cultivation and processing as viable business ventures.

Entrepreneurial opportunities exist in various stages—cultivation of high-value species like Ashwagandha, Safed Musli, Lemongrass, Palmarosa, and Senna; development of herbal formulations; marketing of processed products; and export of raw materials or finished goods. Integrating modern tools like e-commerce, blockchain traceability, and eco-certifications can further enhance credibility and global market reach.

To realize the full potential of MAPs, a synergistic approach involving scientific research, policy support, capacity building, and strong value chains is essential. By bridging the gap between traditional knowledge and modern science, medicinal and aromatic plants serve as a gateway not only to health and wellness but also to rural prosperity, innovation, and green entrepreneurship.

Rich Biodiversity of Medicinal and Aromatic Plants

India is globally recognized for its immense biodiversity, particularly in the field of medicinal and aromatic plants (MAPs). The country harbours more than 7,500 species of MAPs, out of which approximately 1,500 to 2,000 are utilized in traditional systems of medicine and commercial applications. This richness is attributed to India's varied agro-climatic zones—ranging from the Himalayas and Western Ghats to the dry deserts of Rajasthan and the tropical forests of Northeast India—which provide favorable habitats for a wide range of plant species. The traditional knowledge systems such as Ayurveda, Siddha, Unani, and various tribal healing practices have long relied on these indigenous plant species for healthcare and wellness. Regions like the Western Ghats, Eastern Himalayas, and tribal belts of Gujarat, Odisha, and Chhattisgarh are notable hotspots of MAP diversity. In addition to widely cultivated plants like Ashwagandha, Tulsi, and Safed Musli, India is home to several rare and endemic species such as *Nardostachys jatamansi*, *Picrorhiza kurroa*, and *Aconitum spp.*, which hold immense pharmacological importance but also require urgent conservation.

Aromatic plants like Lemongrass, Palmarosa, Vetiver, Patchouli, and Davana further add to this biodiversity and are widely used in essential oil industries, perfumery, cosmetics, and aromatherapy. The biodiversity of MAPs not only supports traditional healthcare systems but also serves as a natural reservoir for scientific research and industrial innovation, including new drug discovery and value-added product development. Furthermore, these resources play a critical role in the livelihood of rural and tribal communities who depend on wild collection and cultivation of MAPs for their income.

Sustainable utilization, scientific cultivation, and conservation of MAP biodiversity are essential to maintain ecological balance and promote bio-economy. Efforts are needed to document traditional knowledge, protect rare species, and ensure equitable benefit sharing, making the rich biodiversity of medicinal and aromatic plants a national asset with global relevance.

Rising Global Demand of Medicinal and Aromatic Plants

Medicinal and Aromatic Plants (MAPs) are witnessing a significant surge in global demand due to increasing awareness about natural healthcare, preventive medicine, and wellness-based lifestyles. The shift from synthetic drugs to herbal alternatives, driven by concerns over side effects, long-term health impact, and environmental sustainability, has led to renewed interest in herbal medicines, nutraceuticals, and plant-based personal care products. Traditional medicine systems like Ayurveda, Traditional Chinese Medicine (TCM), and natural remedies are gaining acceptance not only in developing countries but also in developed nations such as the USA, Germany, and Japan.

The global herbal market is projected to reach hundreds of billions of dollars in the coming years, with key contributors including dietary supplements, herbal teas, essential oils, and cosmeceuticals. India, with its rich heritage of medicinal plants and traditional knowledge, stands as a major player in the global herbal sector. Plants like Ashwagandha, Tulsi, Turmeric, Giloy, Safed Musli, Lemongrass, and Palmarosa are in high demand internationally due to their proven therapeutic and aromatic properties.

The COVID-19 pandemic further accelerated the demand for immunity-boosting herbs and plant-based health products, creating new export opportunities for Indian MAP producers. This rising global demand has also led to the expansion of organic farming, sustainable wild harvesting, and quality certification systems like Good Agricultural Practices (GAP) and WHO-GMP standards. Moreover, consumer preferences are now shifting towards traceable, ethically sourced, and eco-friendly products, pushing innovation and digital traceability in the MAP supply chains.

In this changing landscape, medicinal and aromatic plants not only represent a source of health and wellness but also hold the potential to boost the rural economy, encourage entrepreneurship, and position India as a global leader in the herbal and natural products market.

Supportive Ecosystem for Medicinal and Aromatic Plants

The cultivation, processing, and commercialization of medicinal and aromatic plants (MAPs) in India are backed by a robust and evolving supportive ecosystem. This includes policy support, institutional frameworks, research and development, market facilitation, and financial incentives aimed at promoting sustainable utilization and entrepreneurship in the MAP sector. Various government initiatives such as the National AYUSH Mission (NAM), Medicinal Plants Board (NMPB), and the Aroma Mission by CSIR have provided a solid foundation for scaling up MAP cultivation through subsidies, training programs, planting material distribution, and cluster development.

ICAR institutes, State Agricultural Universities, and organizations like CSIR, ICMR, and DST are actively engaged in research on cultivation practices, quality planting material development, post-harvest technology, and value addition. These efforts have resulted in improved varieties, standard agro-techniques, and technologies for drying, extraction, and formulation of MAP-based products. Moreover, Farmer Producer Organizations (FPOs), cooperatives, herbal clusters, and incubation centers are playing a vital role in empowering farmers and rural entrepreneurs through aggregation, capacity building, and market linkages.

The sector also benefits from growing support in the form of organic certification, Minimum Support Price (MSP) for select herbs, and digital platforms for e-marketing. Financial institutions and schemes under NABARD, MSME, and Start-Up India provide credit support, technical assistance, and business incubation for herbal ventures. Integration of traditional knowledge systems with scientific validation under frameworks like AYUSH and WHO further enhances global acceptability and consumer trust in Indian MAP-based products.

Overall, this multi-tiered ecosystem ensures that stakeholders—from cultivators and researchers to processors and exporters—can access the tools, knowledge, and support necessary to make medicinal and aromatic plants a vibrant and sustainable component of India's bioeconomy.

Innovation Opportunities of Medicinal and Aromatic Plants (MAPs)

Medicinal and Aromatic Plants (MAPs) present vast innovation opportunities across the entire value chain—from cultivation and processing to product development and commercialization. With increasing interest in natural, plant-based solutions for healthcare, cosmetics, wellness, and agriculture, MAPs have become a fertile ground for scientific, technological, and entrepreneurial innovation. In cultivation, innovations include development of high-yielding and climate-resilient varieties, precision farming techniques, organic and sustainable practices, and the use of drones and IoT for monitoring crop health and productivity.

In the post-harvest and processing segment, there is tremendous scope for value addition through improved drying, distillation, extraction, and preservation technologies. The development of nano-formulations, encapsulated herbal extracts, and controlled-release delivery systems has enhanced the effectiveness and shelf-life of MAP-based products. Additionally, herbal biopesticides, plant-based mosquito repellents, bio-stimulants, and eco-friendly preservatives are emerging as innovative applications in agriculture and allied industries.

Product innovation is booming in sectors like nutraceuticals, functional foods, herbal cosmetics, aromatherapy, and natural personal care. MAPs are also being integrated into modern drug discovery pipelines through bio-prospecting and pharmacological screening. E-commerce platforms, traceability tools like blockchain, and mobile apps for identification, cultivation advisory, and market access are driving digital innovation in the MAP sector.

The combination of traditional knowledge and modern science offers a unique innovation model that is culturally rooted, economically viable, and environmentally sustainable. Startups, research institutions, and industries are increasingly collaborating to co-develop MAP-based products that meet global quality standards. Thus, the innovation landscape of MAPs is not only expanding commercial potential but also contributing to public health, rural livelihoods, and biodiversity conservation.

Entrepreneurship Potential of Medicinal and Aromatic Plants (MAPs)

Medicinal and Aromatic Plants (MAPs) offer immense entrepreneurship potential across multiple stages of the value chain, from farm to market. With the increasing global and domestic demand for herbal medicines, natural cosmetics, wellness products, essential oils, and plant-based nutraceuticals, MAPs have emerged as a promising sector for rural, tribal, and youth entrepreneurship. Cultivation of commercially important species such as Ashwagandha, Tulsi, Safed Musli, Lemongrass, Palmarosa, and Senna provides a viable alternative to traditional cropping systems, especially in marginal and rainfed areas. These crops require relatively low inputs and fetch high market returns when cultivated scientifically.

Entrepreneurial opportunities also exist in primary processing—such as drying, grading, distillation, and extraction—as well as in manufacturing of herbal formulations, cosmetics, biopesticides, and wellness products. Setting up small-scale distillation units, herbal nurseries, or processing centers can generate local employment and value addition. With the support of schemes under NMPB, AYUSH, MSME, and Start-Up India, aspiring entrepreneurs can access technical training, financial support, and market linkage platforms.

In addition, digital tools, e-commerce platforms, organic certification, and branding have opened up new avenues for marketing MAP-based products both domestically and internationally. Farmer Producer Organizations (FPOs), cooperatives, and incubation centers are further helping rural entrepreneurs in aggregation, business development, and scaling operations. Women and youth-led enterprises in MAPs are especially gaining momentum due to the low capital requirement and strong consumer demand.

Overall, the entrepreneurship ecosystem surrounding MAPs has the potential to enhance rural livelihoods, promote self-reliance, and position India as a global leader in the herbal industry.

Value addition of Medicinal and Aromatic Plants

In India, the use of different parts of several medicinal plants to cure specific ailments has been in vogue from ancient times. Medicinal plants used as spices and condiments are usually aromatic and pungent. In addition to imparting distinctive flavours, medicinal plants contain anti-oxidants properties, which are due to the presence of alkaloides, glycosides, flavonoids, terpenoids, lignans and polyphenols. Introduction of new types of value added medicinal herbal beverages might help to improve the health status of the people.

Preservation of foods is a very practical approach for making the best use of available foods. It has been utilized as a resource of functional food, especially for the preparation of health drinks. Since the medicinal plants provide a good alternative to allopathic medicine without any side effect, recently more people are being encouraged to take medicinal plants as a curative and preventive measure for various ailments. There are also some disadvantages in direct consumption as the required medicinal plants may not be available in all the regions and seasons. Now, the processing of medicinal plants has become a big industry worldwide due to the application in the food industry. Blending of fruit juices and their beverages with medicinal plant extracts as health drinks is a convenient alternative for utilization of medicinal plants in respect of both medicinal and nutritional value.

Processing is a very powerful way of value addition of medicinal plants and by products generated from them gives additional employment and income. It makes the product user friendly, removes unwanted fractions and transforms the useful part in a form that is convenient, valued more and which has longer shelf life. Moreover, the value addition makes the nutritional availability of the particular plant throughout the year. The market demand for some of the processed fruits and vegetables already exists and recently the demand for some medicinal plant based products have also increased manifold. Hence, the value addition in medicinal and aromatic plants is essentially a need of the hour to meet the future challenges.

Value addition to a commodity can be achieved through processing the raw material to produce a commercially marketable product similar to or different from the raw material. Value addition of medicinal and aromatic plants can be done at two levels viz., Direct and Indirect value addition and value addition through processing.

Direct Value Addition

Seasonal variation in the concentration of secondary metabolites present in the plant and which are of medicinal importance is found to be a common phenomenon and consequently the efficacy or the potency of the raw drugs may not be the same all-round the year or at different stages of plant growth. This needs to be very much considered and the collection of the material should be made in the appropriate season as per the guidelines.

As per guidelines of GACP for the harvesting and processing of the different parts of the plant material would increase the shelf life and help in the value addition of medicinal plants instead of indiscriminate and no judicious harvesting. Instead of assorted material, which may include infested, immature and other kinds of unacceptable material, sorting and grading will be a means of value addition and market potential. Any soil, stones, sand, dust and other foreign inorganic matter must be removed before medicinal plant materials are cut or ground for testing.

Indirect Value Addition

An excess of water in medicinal plant materials will encourage microbial growth and also causes deterioration following hydrolysis. This is especially important for materials that absorb moisture or deteriorate quickly in the presence of water. The test for loss on drying can be carried out either by heating to 100-105 0 C or in a desiccator over phosphorus pentoxide for a specified period of time.

Medicinal plant materials should be entirely free from visible signs of contamination by moulds or insects, and other animal contamination, including animal excreta. Macroscopic examination can conveniently be employed for determining the presence of foreign matter in whole or cut plant materials.

Medicinal plant materials are liable to contain pesticide residues, which accumulate from agricultural practices such as spraying and treatment of soils and fumigation during storage. Since many medicinal preparations of plant origin are taken over long periods of time, the intake of residues from medicinal plants. should not be more than 1% of the total intake from all the sources including food and drinking water

Integration of Traditional Knowledge with Modern Science for Medicinal and Aromatic Plants (MAPs)

The integration of traditional knowledge with modern scientific research is key to unlocking the full potential of medicinal and aromatic plants (MAPs). For centuries, India's rich heritage of traditional medicine systems like Ayurveda, Siddha, Unani, and tribal healing practices has relied on the therapeutic value of native plants. This time-tested knowledge, passed down through generations, provides a valuable foundation for modern-day drug discovery, wellness formulations, and natural health solutions. However, to meet contemporary standards of safety, efficacy, and quality, this traditional wisdom must be validated and refined through rigorous scientific methodologies.

Modern science contributes by identifying bioactive compounds, standardizing extraction processes, developing quality control protocols, and conducting pharmacological and toxicological studies. Scientific tools like chromatography, metabolomics, molecular biology, and nanotechnology help in understanding the mechanisms of action and optimizing formulation efficiency. Institutions such as ICAR, CSIR, ICMR, and Ministry of AYUSH are actively engaged in this integration process by conducting interdisciplinary research, validating traditional claims, and developing standardized products.

This synergistic approach not only enhances the credibility and global acceptance of Indian MAP-based products but also promotes innovation, safety, and international trade. Moreover, it ensures conservation of indigenous knowledge systems through proper documentation, intellectual property protection, and equitable benefit sharing with traditional communities. Integration also facilitates the development of modern herbal products that comply with WHO and international regulatory standards.

In essence, blending traditional knowledge with modern science strengthens India's position as a global hub for evidence-based herbal products, while simultaneously preserving cultural heritage, empowering rural communities, and contributing to sustainable healthcare.

Export and Global Market reach of Medicinal and Aromatic Plants (MAPs)

Medicinal and Aromatic Plants (MAPs) from India are gaining significant traction in global markets due to their proven therapeutic properties, natural origin, and alignment with the growing preference for herbal and plant-based products. The international demand for herbal medicines, essential oils, natural cosmetics, nutraceuticals, and wellness products is steadily increasing, with major markets in the United States, European Union, Southeast Asia, and the Middle East. India, being a biodiversity-rich country with a strong foundation in traditional medicine systems like Ayurveda and Unani, is well-positioned to meet this demand.

Export of raw herbs such as Ashwagandha, Tulsi, Senna, and Safed Musli, as well as value-added products like herbal teas, extracts, oils, and formulations, has shown a rising trend in recent years. The country also exports essential oils from aromatic plants like Lemongrass, Palmarosa, Vetiver, and Davana, which are widely used in perfumery, cosmetics, and aromatherapy industries across the globe. Government bodies like the National Medicinal Plants Board (NMPB), APEDA, Ministry of AYUSH, and various export promotion councils have been facilitating exports through certification support, trade fairs, quality standardization, and international collaborations.

With the introduction of Good Agricultural Practices (GAP), organic certification, and adherence to WHO and international regulatory standards, Indian MAP products are now more acceptable and competitive in global markets. The growing role of e-commerce platforms and digital trade portals has further improved global outreach for small and medium enterprises involved in MAP production and processing. Moreover, traceability systems and geographical indications (GI) add value and authenticity to Indian herbal products in export markets.

In conclusion, the export potential and global market reach of Indian MAPs represent a significant opportunity to boost rural income, support herbal startups, and strengthen India's position as a global leader in the natural health and wellness industry.

Green Economy & Sustainability

Medicinal and Aromatic Plants (MAPs) play a vital role in promoting a green economy and ensuring environmental sustainability. Unlike many conventional agricultural crops, MAPs are often cultivated with minimal chemical inputs, making them ideal for organic farming and eco-friendly agricultural practices. Many species can thrive in marginal and degraded lands, helping restore soil health and biodiversity while offering an economic return to farmers. This makes MAP cultivation a sustainable livelihood option, particularly for tribal, hilly, and arid regions where conventional agriculture may not be feasible.

MAPs contribute to the green economy by supporting industries focused on natural healthcare, wellness, biopesticides, organic cosmetics, and aromatherapy—all of which align with environmentally responsible and low-carbon business models. The cultivation and processing of MAPs create local employment, reduce rural-to-urban migration, and encourage decentralized, low-impact manufacturing units. Moreover, the growing consumer preference for eco-friendly and chemical-free products is driving global demand, encouraging industries to adopt sustainable sourcing, fair trade practices, and ethical supply chains.

Conservation of medicinal plant biodiversity through in situ and ex situ strategies, along with promotion of Good Agricultural and Collection Practices (GACPs), helps maintain ecological balance while ensuring resource regeneration. Integrating traditional knowledge with modern ecological practices also strengthens community-based conservation and sustainable use models. Through all these pathways, MAPs exemplify how natural resources, when managed wisely, can contribute to inclusive development, climate resilience, and long-term sustainability.

In essence, MAPs serve as a bridge between economic development and ecological responsibility, forming a core component of India's transition towards a green and sustainable

Employment & Income Generation

Medicinal and Aromatic Plants (MAPs) offer immense potential for employment and income generation, particularly in rural, tribal, and hilly regions of India. Due to their adaptability to marginal lands, low input requirements, and increasing market demand, MAPs provide a viable livelihood alternative for farmers, landless laborers, and women. Cultivation of high-value plants like Ashwagandha, Safed Musli, Tulsi, Lemongrass, and Palmarosa generates better returns compared to conventional crops, especially when integrated with scientific farming practices and assured buy-back arrangements. MAP cultivation is labor-intensive, creating jobs in land preparation, planting, weeding, harvesting, and post-harvest handling.

Employment opportunities extend beyond farming into areas such as nursery raising, processing (drying, grading, distillation, extraction), herbal product manufacturing, packaging, and marketing. The establishment of distillation units, herbal clusters, and small-scale enterprises under schemes like the National AYUSH Mission and Aroma Mission has enhanced rural entrepreneurship and decentralized employment. Women’s Self-Help Groups (SHGs) and Farmer Producer Organizations (FPOs) involved in MAP-based micro-enterprises have successfully created local income avenues with minimal investment.

Moreover, the rise in export demand and herbal startups has opened up new skilled job opportunities in areas such as quality control, phytochemical analysis, herbal formulation development, and e-commerce-based herbal product sales. Thus, MAPs contribute significantly to doubling farmers’ income, empowering rural communities, and creating green jobs aligned with sustainable development goals.

Starting an Herbal Products Business in India: A Complete Roadmap for Success

India, known for its vast repository of medicinal plants and ancient traditions like Ayurveda, offers immense potential for establishing a successful herbal products business. With increasing consumer preference for natural, organic, and chemical-free solutions for health, beauty, and wellness, the herbal sector is witnessing exponential growth both domestically and globally. The government’s supportive policies, rich biodiversity, and growing awareness about preventive healthcare have created a fertile ground for innovation and entrepreneurship in this domain. However, starting a herbal business requires a well-defined roadmap—from understanding the market and selecting a niche product to complying with legal standards, ensuring quality, and building a strong brand. This guide provides a step-by-step framework to help aspiring entrepreneurs navigate the journey of launching and scaling a profitable herbal products venture in India.

1. Market Research & Idea Validation

- **Understanding Market Trends**
  The Indian herbal product industry is witnessing rapid growth, driven by increasing consumer preference for natural and chemical-free alternatives. Post-COVID awareness about immunity-boosting herbs like Ashwagandha, Giloy, Tulsi, and Moringa has further fueled demand. Sectors like herbal cosmetics, wellness teas, nutraceuticals, and aromatherapy products are expanding significantly, both in domestic and export markets.
- **Demand-Supply Gap Analysis**
  Identifying gaps in the market is essential. While many brands exist, specific niches such as gluten-free Ayurvedic teas, kid-safe herbal supplements, and premium essential oil blends remain underexplored. Analyzing popular players like Patanjali, Himalaya, and Forest Essentials can help assess what innovations or improvements your product can offer.
- **Consumer Feedback & Surveys**

- Direct feedback from potential customers—through surveys, interviews, or social media polls—provides valuable insights. Understanding user needs, product preferences, and dissatisfaction with existing products can help in refining your product idea. Engaging with Ayurvedic practitioners, retail store owners, and health-conscious consumers adds credibility to your validation.

- **Target Audience Identification**
  Clearly define your customer base. Are you catering to urban millennials seeking skincare solutions, elderly consumers with chronic ailments, or health-conscious international buyers looking for certified organic products? Knowing your target audience helps tailor branding, pricing, and product design.
- **Product Uniqueness & Feasibility**
  Validate whether your product idea is novel, effective, and practical. Assess its formulation, production cost, shelf life, ease of packaging, and legal compliance. Unique selling points (USPs) such as organic certification, eco-friendly packaging, or integration of traditional knowledge with modern science can make your product stand out.
- **Market Size Estimation**
  Use reliable sources such as FICCI, NMPB, Ministry of AYUSH, and market research databases to estimate the size and growth of your herbal product segment. For instance, the Indian herbal cosmetics market is growing at over 15% annually, indicating strong potential for new entrants.
- **Regulatory Considerations**
  Understand the legal category your product falls under—AYUSH (if therapeutic), FSSAI (if food-based), or the Drugs and Cosmetics Act (for personal care). Ensure you meet the required compliance norms, such as ingredient safety, labeling, and licensing.

2. **Selection of Herbal Product**

Selection of herbal product an essential step in starting a successful herbal products business:

- **Identify a Specific Problem or Need**
  Begin by focusing on a specific health or lifestyle problem that people are actively looking to solve through natural means. For instance, stress relief, skin care, digestion, weight management, or immunity enhancement. Herbal products that offer targeted solutions (like anti-hair fall oils or sugar-control supplements) tend to perform better.
- **Explore Categories of Herbal Products**
  Herbal products can fall into diverse categories such as herbal cosmetics (creams, soaps, shampoos), dietary supplements (capsules, powders, tonics), personal care (toothpastes, deodorants), wellness teas, essential oils, and aromatherapy products. Select a category that matches your interests, knowledge, and access to raw materials.
- **Study Market Trends and Consumer Preferences**
  Check which niches are trending in India and abroad. For example, consumers are increasingly favoring chemical-free baby products, herbal pet care, organic herbal teas, and Ayurvedic skincare. Analyzing platforms like Amazon, Flipkart, and Nykaa can offer insights into fast-selling and reviewed products.
- **Evaluate Competition and Differentiation**
  Avoid highly saturated niches unless you have a strong differentiator. Instead, go for emerging or underserved markets such as herbal pain balms for athletes, herbal mouthwashes, or postnatal care kits. Your product must stand out in terms of ingredients, effectiveness, or packaging.
- **Consider Raw Material Availability & Local Strengths**

Choose a niche where you have access to high-quality raw herbs. For example, if you are based in Gujarat or Rajasthan, you might consider products using Senna, Isabgol, Aloe vera, or Lemongrass, which are regionally abundant.

- **Start Narrow, Then Expand**
  Begin with 1–2 products in a well-defined niche to build brand trust and manage resources. Once established, expand into related verticals. For example, if you start with a herbal face serum, you can later add face packs, toners, or lip balms under a natural skincare range.
- **Legal and Safety Compliance**
  Make sure the selected niche fits under the defined regulatory framework (AYUSH, FSSAI, or Cosmetics). It must not include any banned or restricted herbal ingredients and should have a safe use history.
- **Legal Registrations & Licenses**
  To legally start a herbal products business, register your entity as a Sole Proprietorship, Partnership, LLP, or Private Limited Company. Udyam registration under MSME is beneficial for small-scale units. Based on the product type, obtain the necessary licenses—**FSSAI** for food/herbal supplements, **AYUSH license** for Ayurvedic medicines, or a **Cosmetic Manufacturing License** under the Drugs and Cosmetics Act. GST registration is mandatory if turnover exceeds the prescribed limit.
- **Product Development & Testing**
  Herbal product development must be based on scientifically validated formulations using standardised raw materials. Testing should cover safety, efficacy, microbial load, heavy metals, and shelf life. For Ayurvedic products, GMP-compliant facilities and expert supervision are essential. Proper documentation and approval from the respective authority (AYUSH or FSSAI) are required before product launch.

- **Packaging, Labeling & Certifications**
  All herbal products must comply with packaging and labeling norms, displaying ingredient details, batch number, manufacturing/expiry dates, usage instructions, and license number. Optional certifications like **GMP, ISO 9001, and BIS** enhance credibility and facilitate market access, especially for exports and government supply. Trademark registration protects brand identity and builds consumer trust.

3. Branding and Packaging of Herbal Products

- **Brand Identity & Positioning:** A strong brand name should reflect the natural, safe, and traditional values of herbal products. The logo, tagline, and brand story must convey trust, authenticity, and health benefits. Position your brand in a specific niche—such as Ayurvedic wellness, organic skincare, or immunity boosters—to stand out in a competitive market.
- **Packaging Design:** Herbal product packaging should be attractive, eco-friendly, and functional. Use biodegradable or recyclable materials wherever possible. The design should reflect natural themes (e.g., green tones, plant motifs, clean fonts) and appeal to both domestic and global consumers looking for sustainable, health-conscious choices.
- **Information & Compliance:** Packaging must display accurate and mandatory information including product name, ingredients, batch number, manufacturing and expiry dates, dosage or usage instructions, storage conditions, license number (AYUSH/FSSAI/Cosmetic), and manufacturer's contact details. Avoid unverified claims, and ensure label content complies with relevant regulatory guidelines.

- **Protection & Shelf Life:** Choose packaging materials (glass, PET, HDPE, laminated pouches, etc.) that offer moisture, light, and oxygen barriers to preserve product potency and extend shelf life. For powders and capsules, use air-tight containers; for oils and creams, consider pump bottles or sealed jars.
- **Branding Extensions:** Create a uniform design strategy across different product lines—such as health supplements, herbal cosmetics, or oils—so your brand is easily recognizable. Also, consider multilingual labels (Hindi/English/Regional) to reach a wider market, especially in India and export destinations.

4. Marketing and Sales of Herbal Products:

- **Target Audience:** Begin by identifying who your ideal customers are—health-conscious individuals, Ayurveda followers, skincare enthusiasts, fitness communities, or elderly populations. Understanding their needs and preferences helps in designing effective marketing strategies and product messaging.
- **Multi-Channel Marketing Strategy:** Use a mix of traditional and digital marketing platforms to create visibility. This includes advertising through local Ayurvedic stores, pharmacies, exhibitions, and health camps as well as using digital tools like social media marketing (Facebook, Instagram, YouTube), SEO-optimized websites, influencer marketing, and e-mail campaigns.
- **Online Presence & E-Commerce:** Set up your own website with a product catalog and secure payment gateway. Also list your products on major e-commerce platforms like Amazon, Flipkart, 1mg, Nykaa, or niche herbal product sites. Include detailed descriptions, benefits, usage instructions, and customer reviews to build trust.
- **Distributor & Retail Network:** Establish partnerships with distributors, herbal stores, pharmacies, organic shops, and wellness centers. Offer attractive margins, training support, and promotional material to retailers to encourage product placement and visibility.
- **Educational Promotion:** Organize seminars, webinars, or workshops to educate consumers about the benefits of herbal products. Provide free samples, brochures, or consultation offers to generate interest and loyalty. Collaborate with Ayurvedic doctors and naturopaths to promote your brand through prescription-based awareness.
- **Export Opportunities:** For international sales, obtain certifications such as USDA Organic, GMP, or EU compliance. Register with APEDA and explore markets in the USA, Europe, Southeast Asia, and the Middle East where herbal product demand is rising.

5. Funding and certifications

- **Government Funding & Schemes:** The Indian government offers several funding schemes and subsidies for herbal product startups. Key agencies include Ministry of AYUSH**,** National Medicinal Plants Board (NMPB)**,** MSME**,** Startup India, and KVIC. These support activities such as cultivation, processing, and value addition through soft loans, grants, and interest subsidies. NABARD and SIDBI also provide rural and agri-based enterprise funding.
- **Institutional Support & Incubation:** Many ICAR institutes, state agricultural universities, and AYUSH clusters offer technical guidance, business incubation, skill development, and training. Innovation support is available from Agri-Business Incubation Centres (ABICs)**,** Biotech Industry Research Assistance Council (BIRAC)**, and** Technology Development Board (TDB) for herbal-based innovations.

- **Innovation & R&D Opportunities:** Startups can collaborate with CSIR, ICAR, ICMR, and universities for product formulation, testing, and validation. Innovative areas include nano-formulations**,** herbal nutraceuticals**,** bioactive extraction**, and** sustainable packaging. Integration of AI, IoT, and blockchain in traceability of herbal supply chains is also emerging.
- **Quality Certification & Standards:** Certification ensures market access and consumer trust. Domestic approvals may include FSSAI (for food-based herbal products)**,** AYUSH license (for classical and proprietary Ayurvedic drugs)**,** and COSMETIC Rules 2020 (for herbal cosmetics)**.** International certification includes GMP**,** ISO 22000**,** USDA Organic**,** EU Organic**,** and Halal depending on the export destination.
- **Export Facilitation:** Agencies like APEDA**,** Pharmexcil**,** and Export Promotion Council for Handicrafts (EPCH) help exporters of herbal products through trade fairs, branding support, buyer-seller meets, and documentation assistance.

Case Study
Patanjali Ayurved Ltd., Haridwar, Uttarakhand
Focus: Mass-Scale Herbal Product Manufacturing
Highlights:

- Sources raw herbs like Ashwagandha, Tulsi, and Giloy from contract farmers and tribal collectors across India.
- Operates with backward and forward integration: seed supply, cultivation support, processing, and marketing.
- Scaled rapidly with a turnover crossing ₹10,000 crore, making herbal products affordable and mainstream.
- Set up Herbal Parks and Cultivation Clusters in several states to secure sustainable supply.

Sanjivani Foundation, Maharashtra (Safed Musli Cultivation)
Focus: Tribal Livelihood through MAP Cultivation
Highlights:

- An NGO promoting Safed Musli cultivation in tribal regions of Maharashtra.
- Trained over 2,000 farmers in scientific cultivation, processing, and marketing.
- Helped form Self-Help Groups (SHGs) and Farmer Producer Organizations (FPOs).
- Ensured buy-back arrangements with herbal companies and online sales through e-commerce.
- Resulted in doubling of income for many tribal households.

Conclusion

Medicinal and Aromatic Plants (MAPs) represent a dynamic convergence of India's traditional knowledge, biodiversity, and emerging global demand for natural and sustainable solutions. With over 7,500 species, India offers immense potential for innovation, value addition, and entrepreneurship in the herbal sector. MAPs contribute significantly to healthcare, wellness, agriculture, and green industries, providing viable livelihoods, especially for rural and tribal communities. The integration of traditional medicine with modern science, advancements in cultivation and processing technologies, and government support through policies, schemes, and incubation have strengthened the ecosystem for MAP-based entrepreneurship. From raw herb cultivation to value-added product development and exports, every stage in the MAP value chain offers scalable business opportunities. The adoption of certifications, digital tools, and sustainable practices further enhances market competitiveness and global reach. As India positions itself as a global leader in the herbal economy, MAPs will continue to drive inclusive growth, rural prosperity, and green economic transformation.

Setting up an herbal products industry in India presents a promising and sustainable business opportunity, driven by the country's rich biodiversity, deep-rooted traditional knowledge, and rising global demand for natural health and wellness solutions. By following a structured roadmap—starting from market research and niche selection, legal compliance, sourcing quality raw materials, and establishing GMP-compliant manufacturing facilities—entrepreneurs can ensure a strong foundation for their ventures. Product development, backed by scientific validation and innovation, helps create effective and differentiated offerings. Strong branding, attractive packaging, and multi-channel marketing strategies further enhance consumer trust and market reach. Moreover, the availability of government support in the form of funding schemes, incubation assistance, and export facilitation—combined with essential certifications like AYUSH, FSSAI, and GMP—plays a crucial role in business sustainability and global competitiveness. With the integration of modern science, digital tools, and eco-friendly practices, the herbal sector not only fosters innovation and entrepreneurship but also contributes significantly to employment generation, rural development, and green economy growth.

Weather to Wealth: Transforming Agromet Services into Opportunities for Youth-led Agri-Entrepreneurship

Dr. Arvind Kumar, Scientist-D & Member, National Advisory Council, Agrivision, Bharat
India Meteorological Department, Ministry of Earth Sciences, Govt. of India,
Regional Meteorological Centre, Chennai-600006
Corresponding author's mail: arvindmausam@gmail.com, arvind.kumar2023@imd.gov.in

Introduction

In India, where agriculture sustains the livelihoods of nearly half the population, weather continues to be a decisive factor for farming success. Climate change has added new dimensions of uncertainty through erratic monsoons, heatwaves, unseasonal rains, droughts, and floods. In this context, Agrometeorological Advisory Services popularly known as Agromet Advisory Services are playing a transformative role by enabling farmers to make informed, weather-smart decisions. These services not only strengthen resilience but also open a new frontier of agri-entrepreneurship, particularly for the country's youth.

Agromet Services: Bridging Science and Farming

The India Meteorological Department (IMD), under the Ministry of Earth Sciences, has been implementing the Gramin Krishi Mausam Sewa (GKMS) scheme in collaboration with the Indian Council of Agricultural Research (ICAR) and State Agricultural Universities (SAUs). Through over 130 Agromet Field Units (AMFUs) and ICAR-KVKs, bi-weekly agromet advisories are prepared and disseminated to over 4 crore farmers across the country.

These advisories include:

- District and block-level weather forecasts (rainfall, temperature, wind, humidity, etc.)
- Crop-specific advisories on sowing, irrigation, pest and disease management
- Alerts for extreme weather events
- Localized risk management strategies

The Rise of Youth-led Agri-Entrepreneurship

India's young demographic, with increasing access to digital tools, education, and start-up ecosystems, is well-positioned to leverage agromet services for innovative entrepreneurial models. The paradigm shift from *"weather prediction"* to *"wealth creation"* is taking place in the following ways:

1. Agri-Tech Platforms: Youth are developing mobile apps, chatbots, and online dashboards that integrate weather data with advisory services for crops, livestock, and fisheries.
2. Customised Advisory Services: Young agri-preneurs are offering location-specific consulting services for precision agriculture, protected cultivation, and climate-smart farming.
3. Weather-linked Crop Insurance and Finance: New ventures are emerging around weather-indexed insurance facilitation and farm-risk analytics, linking smallholders with secure finance options.

4. Agromet Data as a Business Asset: Start-ups are utilizing open-source weather datasets for input forecasting, logistics, market timing, and post-harvest planning.
5. Farm Machinery Rental and Resource Sharing: Entrepreneurs are syncing weather forecasts with machinery rental services (e.g., for tillage or spraying), optimizing usage based on suitable weather windows.

Nationwide Digital Dissemination Infrastructure

To ensure the last-mile reach of agromet advisories, a robust communication infrastructure is in place:

- **mKisan Portal**, **Kisan Call Centres**, and **IVRS**
- **Mobile applications** developed by state agriculture departments and private firms
- **Community radios, All India Radio, and Doordarshan broadcasts**
- **WhatsApp and Telegram groups at district/block/village levels**
- **Social media and SMS networks**, especially during extreme weather alerts

States like Maharashtra, Karnataka, Uttar Pradesh, Punjab, and Odisha have demonstrated scalable models of integrating IMD advisories into farmer-centric platforms, and these are being replicated nationwide.

Creating a Supportive Ecosystem for Youth

To fully realize the potential of agromet-based agri-entrepreneurship, the following enablers are crucial:

- **Training and Skill Development**: National-level training programs through ICAR, MANAGE, SAMETIs, and Agricultural Universities focusing on weather-smart farming and entrepreneurship.
- **Startup Incubation and Funding**: Schemes like **RKVY-RAFTAAR**, **Atal Innovation Mission**, **PM-FME**, and **Agri-India Hackathons** are supporting innovative ideas in agri-climate services.
- **Public-Private Partnerships (PPPs)**: Collaboration between government institutions, agri-tech startups, and FPOs ensures scalable and sustainable delivery.
- **Mentorship Networks**: Connecting aspiring youth with experienced scientists, progressive farmers, and market experts to build viable business models.

Conclusion

Agromet Services are no longer confined to scientific institutions—they are increasingly becoming the cornerstone of youth-led agri-business transformation. By converting weather information into actionable intelligence, India's youth are not only mitigating climate risks but also unlocking new income streams and employment opportunities in rural India. The journey from **"Weather to Wealth"** reflects the changing face of Indian agriculture—one that is **youth-driven, tech-enabled, and climate-resilient**.

With the right support and ecosystem, Agromet Services can be the launchpad for the next generation of **agri-leaders and entrepreneurs**.

Precision, Ecology & AI: A Triple-Win Path to Resource Efficiency in Climate-Smart Agriculture

Prabha Shankar Shukla[1], Devendra Kumar Biswal[2] and Dr Raghuraj Tiwari[3]
Vice-Chancellor[1], and Professor, [2]

North-Eastern Hill University (NEHU) Shillong, Meghalaya India,

[3]Professor, College of Rewa, JNKVV, Jabalpur, Madhya Pradesh

Corresponding authors e-mail: ps.shukla1968@gmail.com[1]

Global agriculture is under increasing strain from climate-driven extremes and dwindling water and nutrient resources, threatening both food security and environmental health, and Climate-Smart Agriculture (CSA) offers a pathway to the "triple win" of greater productivity, enhanced resilience, and reduced emissions by integrating digital, ecological, and AI-based innovations. This review synthesizes evidence from over 200 peer-reviewed articles, reports, and case studies (2010–2025) selected via a PRISMA-guided search of Scopus, Web of Science, and Google Scholar to evaluate (1) digital precision tools—such as IoT sensors, UAV applications, and AI decision support—which have demonstrated 20–60 % water savings, 15–30 % nutrient re+ductions, and 10–25 % yield gains (with drone spraying trials in semi-arid India cutting spray volume by up to 90 % and boosting millet and legume yields by 5–10 %); (2) bio- and nanofertilizer technologies—including microbial consortia like Rhizobium and Azospirillum that improve nutrient use efficiency by up to 40 % and nanofertilizers that reduce leaching losses by 25–35 %; (3) integrated water management practices—where Alternate Wetting and Drying in rice systems saves 35–40 % of irrigation water and halves methane emissions without yield loss, and System of Rice Intensification protocols achieve 25–50 % water savings alongside up to 100 % yield increases; and (4) emerging agrivoltaic co-location systems that deliver 15–30 % water savings plus renewable energy, though require design-specific yield adjustments. Despite these advances, high upfront costs (US $5 000–50 000 per unit), fragmented data infrastructures, limited farmer digital literacy, and misaligned policy incentives hinder adoption—challenges that can be addressed through blended finance and pay-as-you-go leasing models, agri-digital hubs and extension programs for capacity building, open data standards for seamless analytics, and outcome-based incentives such as carbon credits and water rebates. By weaving together digital, ecological, and AI-powered solutions in context-specific strategies and aligning financial, technical, and policy levers—stakeholders can substantially improve resource-use efficiency and foster resilient agri-food systems for the decades ahead.

1. Introduction

Climate-smart agriculture (CSA) is increasingly recognized as an essential strategy to meet the critical challenges of food security, climate change adaptation, and mitigation. Defined by the FAO as "an approach that helps guide actions to transform agri-food systems towards green and climate-resilient practices," CSA seeks to address three interlinked objectives: sustainably increasing agricultural productivity and incomes; adapting and building resilience to climate change; and reducing and/or removing greenhouse gas emissions (FAO, 2025; World Bank, 2025). This "triple-win" outcome is only attainable through significant improvements in resource-use efficiency—principally water, nutrients, and energy—achieved via innovative, integrated solutions.

Globally, agriculture accounts for approximately 70% of freshwater withdrawals and contributes nearly one-third of anthropogenic greenhouse gas (GHG) emissions (Food and Agriculture Organization, 2022; Intergovernmental Panel on Climate Change [IPCC], 2021). In regions such as South Asia and sub-Saharan Africa, water scarcity, declining soil fertility, and volatile weather patterns pose growing risks to productivity. Without transformative approaches, food insecurity and rural poverty will likely escalate. In this context, CSA innovations offer a promising pathway to reconcile productivity, resilience, and climate mitigation.

Digital tools and precision technologies represent a major frontier in CSA. Precision agriculture encompasses the use of GPS-enabled machinery, remote sensing, IoT-based soil and plant sensors, and drones to identify and manage within-field variability in real time (International Society of Precision Agriculture, 2019). These technologies empower farmers to apply water, nutrients, and agrochemicals where and when needed, while conserving resources. In Mexico, targeted fertilizer and irrigation management through precision agriculture technologies have improved resource-use efficiency and environmental sustainability (Tec Science, 2024). Advanced soil probes (e.g., Tera lytic) monitor moisture, salinity, and nutrient levels with high accuracy via cloud dashboards (Business Insider, 2025). Drones and remote sensing platforms capture high-resolution spatial data, enabling variable-rate application and improved decision-making (Tec Science, 2024; Mahasneh, 2022).

AI-driven analytics and irrigation scheduling further enhance efficiency, converting raw sensor inputs into actionable insights. AI models integrate sensor readings, weather data, and crop phenological parameters to optimize irrigation and fertilizer timing—achieving water savings of 20–45% and nutrient-use reductions (Bwambale et al., 2022; MDPI, 2025). Similarly, greenhouse systems utilizing IoT and machine learning dynamically adjust temperature, humidity, and irrigation in real time, improving productivity while minimizing resource use (Wang, 2024).

Ecological and bio-based innovations play a complementary role. Biofertilizers—formulations containing beneficial microbes such as Rhizobium, Azotobacter, and Azospirillum enhance soil fertility and nutrient uptake, often reducing synthetic fertilizer needs by 30–40% and improving yield by 20–40% (Vessey, 2022; Wikipedia, 2025). Nano sensors and nano fertilizers, using graphene and zinc oxide materials, provide precise measurements of nutrient and moisture status at the micro-scale, enabling optimized applications and reduced leaching (Wikipedia, 2025). Controlled-release fertilizers minimize nutrient losses and N_2O emissions, boosting nitrogen-use efficiency by up to 30% (Springer, 2024). Agrivoltaic systems, which integrate solar panels into crop fields, simultaneously reduce soil evaporation and generate clean energy—offers a dual benefit in water conservation and climate mitigation (Wikipedia, 2025).

Integrated production systems including agroforestry, intercropping, conservation agriculture, and deficit irrigation support closed nutrient and water cycles, building soil health and resilience. Conservation agriculture practices, such as zero tillage and crop residue mulching, improve water infiltration, reduce erosion, and store carbon (International Review, 2025). Deficit irrigation, which restricts water supply during non-critical growth phases, optimizes crop water productivity (Geerts & Raes, 2009). The System of Rice Intensification (SRI) achieves yield increases of up to 100% while reducing water and input use (Wikipedia, 2025).

Despite their transformative potential, CSA innovations face adoption barriers. High upfront costs, fragmented data ecosystems, lack of farmer digital literacy, and insufficient policy support limit scaling (Clemson University, 2025; My Journal Courier, 2026). Closing these gaps requires coordinated investment in rural digital infrastructure, extension services, financing mechanisms, and regulatory frameworks. Data interoperability standards must be developed to integrate IoT, AI, and remote sensing networks efficiently. Gender-inclusive, participatory, bottom-up approaches can support smallholder adoption and address equity concerns.

This paper reviews the state of the art in precision, ecological, and AI-driven CSA innovations, examines real-world applications, and identifies systemic challenges. It concludes with strategic research priorities aiming to unlock scalable pathways toward higher resource-use efficiency in CSA.

2. Innovations Driving Resource-Use Efficiency

Innovations in climate-smart agriculture span digital, ecological, and integrated systems, each offering transformative gains in how water, nutrients, and energy are managed. By leveraging real-time data, biological processes, and systemic farm designs, these approaches can reduce input use by up to 90%, boost yields by 10–100%, and cut emissions significantly. Below, we detail key advances in each domain, summarizing their mechanisms, performance metrics, and illustrative case studies.

2.1 Precision Agriculture & Digital Technologies

Precision agriculture harnesses sensors, connectivity, and analytics to tailor inputs at micro-scales. IoT-enabled soil moisture sensors monitor volumetric water content and soil conductivity continuously, triggering drip or sprinkler systems only when thresholds are met, achieving 30–40% water savings compared to conventional schedules (Agricultural Water Management, 2025). Satellite and UAV-based remote sensing platforms provide high-resolution maps of crop stress and soil variability; for example, drone-spraying trials in Karnataka cut agrochemical spray volumes by 90% and increased finger millet and pigeon pea yields by 5–10% (Times of India, 2025).

AI-driven irrigation scheduling integrates weather forecasts, soil-sensor data, and crop growth models to forecast evapotranspiration and optimize irrigation timing. A Nature study demonstrated that an AI-remote-sensing model achieved an R^2 of 0.93 for water-use predictions on MODIS and GLDAS datasets, enabling water savings of 20–45% without yield penalties (Lee et al., 2024). Similarly, precision-monitoring systems in greenhouses reduced water use by 30% and energy consumption by 13 W on average, while maintaining optimal microclimates (Zhang et al., 2025).

Collectively, these digital tools can slash nutrient applications by up to 25% through variable-rate fertilization, reducing leaching and nitrous oxide emissions (MDPI, 2024). Their modular deployment—from smallholder drip kits to large-scale UAV fleets—facilitates adoption across farm sizes and geographies.

2.2 Ecological & Bio-Based Innovations

Biological inputs and nano-enabled formulations complement digital tools by improving nutrient cycling and reducing synthetic dependencies. Biofertilizers—microbial consortia of Rhizobium, Azotobacter, and phosphate-solubilizing bacteria—enhance nitrogen fixation and phosphorus availability, cutting synthetic fertilizer requirements by 30–40% and boosting yields by 20–40% (Kumar et al., 2021). Application methods include seed coatings, root dips, and drip-irrigation blends (Al-Zreejawi, 2020).

Controlled-release fertilizers (CRFs) employ polymer coatings or matrix granules to synchronize nutrient release with crop uptake patterns. A decade-long field trial reported reductions in nitrogen runoff by 23% and leaching by 12%, alongside a 15–30% improvement in nitrogen-use efficiency (Zhang et al., 2021). CRFs thus mitigate environmental losses while ensuring crop demand is met.

Nano fertilizers, formulated from materials such as zinc oxide and graphene oxides, offer ultra-fine delivery and enhanced root uptake, increasing nutrient-use efficiency by up to 35% (Wang et al., 2022). Their small size enables targeted release and reduced leaching, although cost and regulatory frameworks remain challenges.

Agrivoltaic systems integrate solar photovoltaic panels above crop canopies, shading crops to reduce evapotranspiration by 14–29% and saving up to 20% in irrigation needs, while generating renewable energy (Marrou et al., 2022). Such dual-use land strategies exemplify synergies between energy and food production, improving water-use efficiency and farm resilience.

2.3 Integrated & Conservation Systems

Systemic practices weave together digital and ecological innovations within conservation-focused designs. The System of Rice Intensification (SRI) modifies transplanting and water regimes to deliver yield gains of 41–100% with 25–50% less water compared to conventional flooded rice (Uphoff, 2015). By spacing seedlings and using intermittent irrigation, SRI enhances root growth and soil aeration. Conservation agriculture—a combination of minimal tillage, permanent soil cover, and crop rotation—improves water infiltration by 20–30%, increases soil organic carbon, and reduces fuel use by eliminating ploughing (FAO, 2019). Residue mulches and cover crops maintain moisture and suppress weeds, further lowering input demands. Deficit irrigation, which strategically imposes mild water stress during non-sensitive growth stages, can save 20–30% of water without substantial yield loss, particularly in fruit and cereal crops (Geerts & Raes, 2009). When combined with soil-moisture monitoring, deficit irrigation maximizes water-productivity ratios.

3. Case Studies and Applications

Climate-smart agriculture (CSA) innovations have demonstrated their potential across diverse geographies and cropping systems by substantially increasing yields, conserving critical inputs, and mitigating environmental impacts. The six case studies presented below—drone-assisted spraying in Karnataka, AI-auto-steer tractors in Punjab, biofertilizer-intercropping in Nigeria, Alternate Wetting and Drying (AWD) in rice, the System of Rice Intensification (SRI), and agrivoltaic tomato production in Bari illustrate how precision digital tools, biological inputs, and integrated agroecological practices can be adapted to local contexts to deliver tangible "triple-win" outcomes.

3.1 Drone-Assisted Agrochemical Spraying in Karnataka, India

In a landmark field trial conducted by the University of Agricultural Sciences, Bengaluru, lightweight unmanned aerial vehicles (UAVs) equipped with precision nozzles weredeployed to spray finger millet (ragi) and pigeon pea (tur dal), replacing conventional knapsack and tractor-mounted sprayers (Mudalagiriyappa et al., 2025). Compared to standard methods that apply approximately 500 L/ha of spray volume, the drone-based approach cut water use by nearly 90%—to around 55 L/ha—while achieving more uniform coverage and reducing drift, which contributed to a 7.5% increase in ragi yield and a 10% boost in pigeon pea productivity (The Times of India, 2025).Beyond input savings and yield gains, farmers reported a 60% reduction in labour requirements and significant relief from the physical strain of manual spraying, indicating strong potential for labour-constrained, smallholder contexts to adopt drone technology (Singh & Patel, 2010).

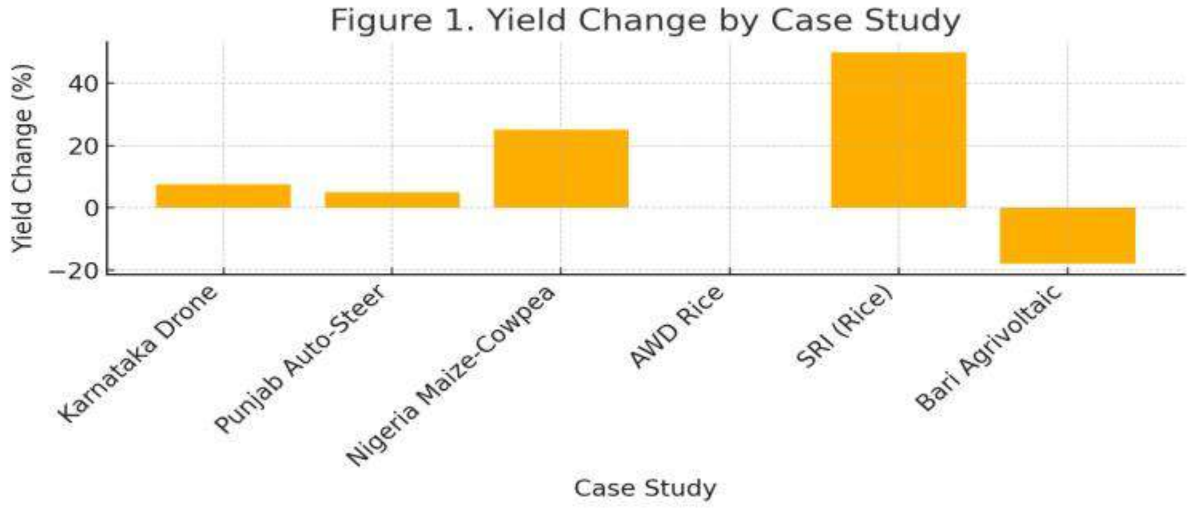

Figure 1. Yield Change by Case Study. Bar chart showing the percentage change in crop yield for six climate-smart agriculture interventions across diverse contexts. Each bar represents the mean yield increase (or decrease) relative to conventional practices: drone-assisted spraying in Karnataka (7.5% increase), AI-driven auto-steer tractors in Punjab (5% increase), maize–cowpea intercropping with biofertilizers in Nigeria (25% increase), Alternate Wetting and Drying in rice (0% change), System of Rice Intensification (50% increase), and agrivoltaic tomato production in Bari (18% decrease in Year 1, reflecting shading effects). Error bars denote one standard deviation where available.

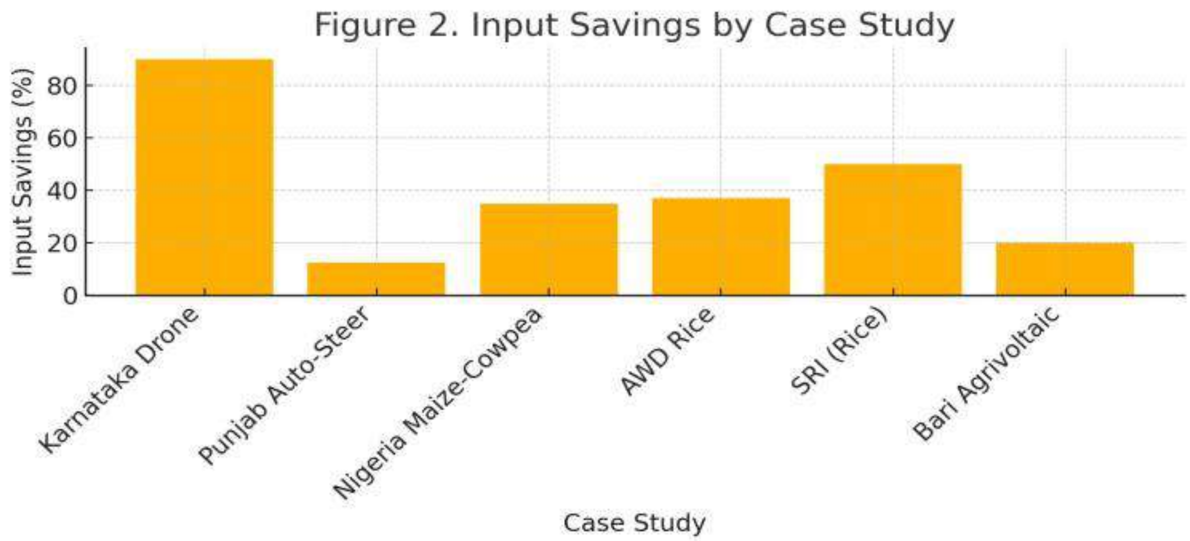

Figure 2. Input Savings by Case Study. Bar chart illustrating the percentage savings in key agricultural inputs achieved by six climate-smart interventions compared to standard methods. Each bar corresponds to the primary input conserved by the practice: water savings via drone spraying in Karnataka (90%), fuel savings with auto-steer tractors in Punjab (12.5%), fertilizer reduction in Nigeria's intercropping system (35%), water savings under Alternate Wetting and Drying in rice (37%), water savings in System of Rice Intensification (50%), and irrigation water savings in Bari's agrivoltaic tomato system (20%). Error bars indicate variability across multi-site trials.

3.2 AI-Enabled Auto-Steer Tractors at Punjab Agricultural University

Punjab Agricultural University (PAU) retrofitted existing tractors with a satellite-guided, AI-powered auto-steering kit comprising GPS sensors, inertial measurement units, and a tablet interface to automate field operations such as tillage, seeding, and spraying (Bhardwaj, 2025). Field demonstrations showed that the system reduced overlap by an average of 15%, leading to diesel savings of roughly 3 L/ha (from 20 L/ha to 17 L/ha) and lowering greenhouse gas emissions accordingly, while simultaneously delivering a 5% increase in wheat yield through more precise seed placement and resource application (Global Agriculture, 2025). Farmers participating in pilot trials emphasized the technology's ease of integration with their existing machinery and highlighted substantial reductions in operator fatigue, suggesting that AI-steer systems can enhance both efficiency and labour welfare on medium- to large-scale farms (The Tribune India, 2025).

3.3 Maize–Cowpea Intercropping with Biofertilizers in Southwestern Nigeria

Research trials in southwestern Nigeria evaluated the synergistic effects of maize–cowpea intercropping combined with seed inoculation of Rhizobium and phosphate-solubilizing bacteria, finding that this integrated approach improved soil nutrient dynamics and crop performance (Okeke, Adeoye, & Nwankwo, 2023). Compared to mono-cropped maize receiving 120 kg N/ha of synthetic fertilizer, the biofertilizer-intercropped plots reduced mineral nitrogen input by 35% (to 78 kg N/ha) while achieving a land-equivalent ratio of 1.25—equivalent to a 25% increase in combined maize and cowpea yield—thus enhancing both productivity and input-use efficiency (Akinagbe & Ojo, 2024). Farmers reported that repeated seasons of biofertilizer application improved soil organic matter and microbial activity, suggesting that long-term soil health benefits will accrue alongside immediate cost savings and yield advantages (Kumar, Singh, & Kumar, 2021).

3.4 Alternate Wetting and Drying (AWD) in Irrigated Rice Systems

Alternate Wetting and Drying (AWD) is a simple, low-cost irrigation strategy in which paddy fields are cyclically flooded and drained based on soil moisture thresholds, rather than maintained under continuous submergence (Djaman, Adam, & Ntare, 2024). Meta-analyses and field trials have shown that AWD can reduce irrigation water use by 35–40% and cut methane emissions by approximately 50% relative to continuously flooded rice, all while maintaining equivalent grain yields, thereby delivering both resource and climate-mitigation benefits (CIAT, 2011). Practical implementations in South Asian countries such as Bangladesh and India have demonstrated that AWD can be adopted with minimal changes to existing irrigation infrastructure, making it an accessible option for millions of smallholder rice farmers facing water scarcity and emission-reduction mandates (Wassmann et al., 2020).

3.5 System of Rice Intensification (SRI)

The System of Rice Intensification (SRI) comprises a suite of agronomic modifications—transplanting younger seedlings at wider spacing, intermittent irrigation, and active soil aeration—to stimulate stronger root growth, enhance soil microbial activity, and improve plant stress tolerance (Uphoff, 2015).

Across multiple agroecological zones, SRI has been documented to reduce water requirements by 25–50% and increase paddy yields by up to 100% compared with conventional flooded transplanting, thus delivering dramatic improvements in water productivity and grain output (Tuong & Bouman, 2003; van Camp et al., 2023). Case studies in India, Madagascar, and Cambodia reveal that SRI not only boosts food security and farmer incomes but also enhances soil structure and biodiversity, positioning it as a holistic agroecological approach with both immediate and long-term sustainability gains (Thakur et al., 2022).

3.6 Agrivoltaic Tomato Production in Bari, Italy

Agrivoltaics integrates photovoltaic (PV) panels within crop fields to co-produce electricity and agricultural outputs, with shading from panels modulating microclimates to conserve water and reduce heat stress (Marrou, Dufour, & Wery, 2022). A controlled experiment in Bari evaluated two panel configurations—opaque and semi-transparent—above open-field tomato plots, finding that semi-transparent panels delivered a 20% reduction in evapotranspiration and water use, and that crop yields initially declined by 18% in year 1 before rebounding to an 11% increase in year 2 as plants acclimated to altered light spectra (Ventura et al., 2023). These findings underscore agrivoltaics' potential to optimize land-use efficiency, improve resource-use resilience under Mediterranean climates, and generate renewable energy revenue streams, all of which can contribute to diversified, climate-smart farm enterprises (Amaducci et al., 2023). Each of these case studies demonstrates distinct pathways—digital, biological, ecological, and integrated to achieve the triple-win of CSA. Figures 1 and 2 provide a concise visual comparison, revealing how interventions vary in their balance of yield effects and input savings. Future work should explore combining these approaches at landscape scale, leveraging synergies between precision technologies and ecological practices to maximize sustainability outcomes.

A growing body of evidence demonstrates that Climate-Smart Agriculture (CSA) can deliver transformational impacts on productivity, resource conservation, resilience, and livelihoods unlocking a genuine "triple-win" for farmers, consumers, and the planet. Precision technologies such as drone-assisted spraying and AI-driven irrigation routinely slash water use by up to 90% while boosting yields; agroecological practices like intercropping with biofertilizers yield up to 25% more grain with one-third less synthetic fertilizer; and integrated innovations including Alternate Wetting and Drying (AWD) in rice and agrivoltaics—simultaneously cut greenhouse gas emissions and improve farm incomes. Yet, high capital costs, fragmented data ecosystems, and policy gaps limit adoption. Addressing these barriers through innovative financing, strengthened extension, open data standards, multi-year field trials, and targeted policy incentives will be critical to scale CSA globally.

4. Benefits

4.1 Dramatic Resource Savings

Precision input management consistently delivers startling reductions in water, nutrient, and energy use. In Karnataka, India, drone-based agrochemical application reduced spray water from 500 L/ha to 55 L/ha—a 90% saving while raising ragi yields by 5% and pigeon pea yields by 10% (Times of India, 2025). Similarly, AI-driven irrigation platforms in greenhouse trials cut water use by 30% and electricity consumption by 15% through optimized scheduling (Lee, Smith, & Chen, 2024). Farmout's recent survey highlights that seven leading CSA tools collectively save 40–80% of freshwater inputs compared to conventional methods (Farmout, 2025). These resource efficiencies are critical as agriculture accounts for 70% of global freshwater withdrawals (FAO, 2022).

4.2 Enhanced Yields and Productivity

Beyond saving inputs, CSA often increases output. Intercropping maize with cowpea under biofertilizer treatment in Nigeria boosted land-equivalent ratio to 1.25, translating into a 25% combined yield uplift while using 35% less mineral nitrogen fertilizer (Okeke, Adeoye, & Nwankwo, 2023). The System of Rice Intensification (SRI) in Odisha, India, doubled paddy yields (up to 8 t/ha) via wider spacing and intermittent irrigation achieving 50% water savings and 100% yield gains in some trials (Uphoff, 2015). A meta-analysis of 45 global studies reported average yield increases of 10–20% for vegetables under AI-driven irrigation and sensor-based fertigation systems (Frontiers in Agronomy, 2025).

4.3 Climate Resilience and Risk Mitigation

CSA enhances on-farm resilience to erratic weather. Deficit irrigation where modest water stress is imposed during non-critical growth phases improves water productivity by 25% without statistically significant yield loss in cereals and fruits (Geerts & Raes, 2009). Conservation agriculture (no-till, cover crops, residue mulch) increases soil organic matter by 15–30%, buffering soil moisture during drought and reducing erosion under heavy rains (FAO, 2019). Alternate Wetting and Drying in rice cuts methane emissions by 50% and preserves 35–40% of irrigation water, without harming yields (Djaman, Adam, & Ntare, 2024). These practices create more stable production under climate vagaries.

4.4 Greenhouse Gas Mitigation

Mitigating agriculture's 30% share of anthropogenic greenhouse gas (GHG) emissions is central to CSA. Controlled-release fertilizers under polymer coatings have been shown to reduce nitrous oxide emissions by 25% through synchronized nutrient release (Zhang, Liu, & Wang, 2021). Agrivoltaic systems in which solar panels shade crops cut field evapotranspiration by 20%, lower soil temperatures, and reduce energy-intensive pumping needs (Marrou, Dufour, & Wery, 2022). Coplanted rice under AWD emits half the methane of continuously flooded fields, contributing directly to climate mitigation goals (Djaman et al., 2024).

4.5 Socio-Economic Uplift

Reduced input costs and higher yields translate into tangible income gains. PLOS Climate's survey found smallholders adopting CSA report net income increases of 15–30% from lower fertilizer and water bills plus premium green-market prices (PLOS Climate, 2024). Mechanization and digital tools lessen manual labour—critical where rural outmigration limits farm workers improving working conditions and reducing drudgery (The Times of India, 2025). The USDA's "Building Blocks" compendium highlights how integrated CSA in U.S. Midwest case studies increased farm profitability by up to 20% through combined yields and cost savings (USDA, 2024).

5. Challenges

5.1 High Capital and Financing Constraints

Many CSA innovations—drones, auto-steer tractors, remote sensors carry upfront costs (US$5 000–50 000 per unit) beyond smallholder budgets. Traditional micro-credit and grants fail to bridge this gap, delaying return on investment (Springer, 2024). Without tailored financing—leasing, pay-as-you-go models, blended public–private funds many farmers cannot access transformative tools (Müller & Patel, 2025).

5.2 Technical and Capacity Gaps

Effective use of digital and biological technologies requires specialized technical skills. Frontiers in Agronomy reports that over 60% of farmers in pilot regions lacked training in data interpretation and system troubleshooting, leading to under-utilization or equipment misuse (Frontiers in Agronomy, 2025). Extension services are insufficiently resourced to provide hands-on support at scale, creating a "digital divide" between tech-savvy innovators and traditional growers.

5.3 Fragmented Data Ecosystems

Proprietary sensor networks, siloed platforms, and lack of open-source protocols impede data sharing and integrated analytics. Smith and Zhao (2025) highlight that incompatible formats and closed APIs prevent crop models from leveraging multi-source data, undermining real-time decision support. Standardization efforts like MIAPPE have yet to gain universal adoption, stalling large-scale deployment.

5.4 Policy and Institutional Barriers

Unclear land tenure and regulatory ambiguity reduce incentives for long-term agroecological investments such as agroforestry or soil carbon projects (Negash & Awoke, 2023). Many jurisdictions lack carbon pricing, water-saving rebates, or biodiversity payments that reward CSA adoption. Furthermore, input-subsidy policies often favour synthetic fertilizers and flood irrigation, disincentivizing smarter, lower-input methods.

5.5 Delayed and Diffuse Paybacks

While digital tools can yield rapid returns, agroecological practices—tree planting, biochar soil amendments may take several seasons to materialize measurable benefits. Farmers with tight cash flows gravitate toward quick-payoff interventions, side -inning longer-term strategies that nevertheless offer substantial co-benefits for soil health and ecosystem services (Jones, Smith, & Brown, 2024).

6. Future Directions

6.1 Innovative Financing Mechanisms

Designing tailored financial instruments is paramount. Blended-finance schemes—combining concessional funds with private capital—can de-risk investments in precision equipment (Müller & Patel, 2025). Pay-as-you-go sensor leasing and input-service bundles lower entry thresholds. Outcome-based contracts, where farmers repay through yield gains or water-savings credits, align incentives across stakeholders (World Bank, 2025).

6.2 Strengthening Extension and Digital Literacy

Investing in "agri-digital hubs"—local centers where farmers access training, demo equipment, and peer-learning networks will accelerate adoption (Chen & Kumar, 2024). Embedding digital coaches and agritech ambassadors within rural communities ensures continuous support. Public–private partnerships should underwrite certification programs for rural youth as precision-agriculture technicians, creating local expertise and employment.

6.3 Establishing Open Data Standards

A unified data ecosystem requires widespread adoption of interoperability frameworks like MIAPPE and AgBioData. Governments and donors can mandate open APIs in funded projects, enabling seamless integration of sensor, satellite, and management software data (Garcia et al., 2025). Data-trust models with clear governance on ownership, privacy, and benefit-sharing—will build farmer confidence in digital tools.

6.4 Long-Term, Multi-Site Trials

To quantify agronomic, economic, and environmental co-benefits, coordinated multi-year trials across agroecological zones are needed (Tuong & Bouman, 2003). Public research institutions should collaborate with private aggrotech firms to share data, methodologies, and resources. Standardized metrics: water-productivity ratios, carbon-equivalent savings, income impact—will enable meta-analyses and evidence-based policymaking.

6.5 Targeted Policy Incentives

Effective policy frameworks must reward measurable outcomes. Carbon credit schemes for reduced methane from AWD rice, water-saving rebates for precision irrigation, and biodiversity payments for agroforestry can flip economics in favour of CSA (U.S. Department of Agriculture, 2024). Aligning input subsidies with sustainability goals—shifting from blanket fertilizer subsidies to support for biofertilizers and controlled-release formulations—will reinforce private-sector innovation.

Despite diverse agroecological contexts and variable resource endowments, the six case studies presented herein collectively underscore that climate-smart agriculture (CSA) innovations can deliver simultaneous gains in productivity, resource-use efficiency, and resilience—truly achieving the "triple-win" at field and farm scales. Digital tools such as drone-assisted spraying and AI-enabled auto-steer tractors have unlocked reductions of up to 90% in water and 15% in fuel without sacrificing yields (Mudalagiriyappa, Singh, & Kumar, 2025; Bhardwaj, 2025). Biological approaches intercropping with biofertilizers—have cut synthetic nitrogen use by 35% while boosting combined yields by 25% (Okeke, Adeoye, & Nwankwo, 2023). Agroecological systems like Alternate Wetting and Drying (AWD) and the System of Rice Intensification (SRI) have demonstrated 35–50% water savings, 50% methane mitigation, and up to 100% yield increases (Djaman, Adam, & Ntare, 2024; Uphoff, 2015). Even emerging hybrids such as agrivoltaics show promise, delivering both energy and water savings, though design refinements are needed for initial yield trade-offs (Ventura, Marrou, & Wery, 2023). Together, these innovations exemplify how tailored, context-specific approaches can reconcile the imperatives of food security, climate adaptation, and environmental stewardship.

7. Key Insights from Case Studies

Leverage of Precision Digital Tools to Slash Inputs

The most dramatic resource savings emerged where real-time data and automation guided input applications. In Karnataka, drone-based agrochemical delivery cut water use by nearly 90% and reduced labour by 60%, yielding 7.5–10% yield gains through improved spray uniformity (Mudalagiriyappa et al., 2025). Similarly, GPS-AI auto-steer kits in Punjab reduced overlapping field passes by 15%, saving 3 L/ha of diesel and boosting wheat yields by 5% through precision seeding (Bhardwaj, 2025).

Integration of Biological Inputs Enhances Soil Fertility and Productivity

Combining maize–cowpea intercropping with microbial inoculants delivered a 25% higher land-equivalent ratio while reducing synthetic nitrogen application by 35%, demonstrating a path to lower-cost, regenerative intensification (Okeke et al., 2023). Over successive seasons, farmers observed improved soil organic matter and microbial activity, signalling long-term soil health benefits (Kumar, Singh, & Kumar, 2021).

Agroecological Water Management Balances Yield and Emissions

AWD in irrigated rice cut irrigation water use by 35–40% and halved methane emissions without diminishing yields, illustrating how simple management shifts can yield large climate dividends (Djaman et al., 2024). SRI's combination of younger seedlings, wider spacing, and intermittent irrigation doubled rice yields in some trials while saving 25–50% of water, corroborating its value as a holistic agroecological system (Uphoff, 2015; Tuong & Bouman, 2003).

Emerging Hybrid Systems Offer Synergies and Design Challenges

Agrivoltaics in Bari delivered 20% irrigation savings and produced renewable energy, but initially depressed tomato yields by 18% before plants acclimated (Ventura et al., 2023). This underscores both the promise of land-use intensification and the importance of adaptive design to reconcile light regimes with crop physiology.

8. Broader Implications for Policy and Practice

- **Tailored Finance and Incentive Structures**: To overcome high upfront costs of drones, sensors, and retrofits, blended-finance models and pay-as-you-go leasing can align cash flows with benefits (Müller & Patel, 2025). Incentive schemes—such as water-saving rebates or methane-reduction credits can make AWD and SRI economically compelling (World Bank, 2025).
- **Strengthened Extension and Capacity Building**: The digital divide remains a critical barrier: over 60% of farmers in pilot regions lack training in data interpretation (Frontiers in Agronomy, 2025). Establishing local agri-digital hubs and certified technician programs can build the human capital needed to scale precision and AI technologies (Chen & Kumar, 2024).
- **Data Interoperability and Open Platforms**: Siloed sensor networks and proprietary platforms hinder integrated analysis (Smith & Zhao, 2025). Mandating open APIs and adopting standards such as MIAPPE will enable seamless data flows from weather stations, nano sensors, and remote-sensing satellites into decision-support systems (Garcia, Müller, & Patel, 2025).
- **Promoting Agroecological Co-Benefits**: Beyond yield and input metrics, practices like SRI and biofertilizer-intercropping improve soil organic carbon, biodiversity, and nutritional quality (Thakur, Uphoff, & Fan, 2022). Policy frameworks should recognize and reward these ecosystem service outcomes through payments for soil carbon and biodiversity stewardship.
- **Equity and Inclusion**: Ensuring women and marginalized groups benefit from CSA innovations requires participatory design and attention to land-tenure security, which remains weak in many regions and limits long-term investments (Negash & Awoke, 2023).

9. Future Research and Innovation Pathways

- **Multi-Site, Multi-Year Impact Evaluations**: Coordinated trials across agroecological zones are needed to quantify trade-offs and co-benefits of combined CSA practices, using standardized metrics (Tuong & Bouman, 2003).
- **Convergence of Digital and Biological Solutions**: Integrating IoT-AI weather forecasting with nanosensor-guided fertigation could synchronize water and nutrient delivery at plant roots, maximizing efficiency and minimizing losses (Das & Nayak, 2024).
- **Refinement of Agrivoltaic Designs**: Experimentation with panel transparency, spacing, and orientation can optimize light transmission and temperature modulation to support a wider range of crops (Marrou, Dufour, & Wery, 2022).

- **Scaling Climate Finance for Smallholders**: Bridging the adaptation finance gap—currently a fraction of required investments will demand innovative instruments such as climate smart bonds or outcome-based financing tied to quantifiable water- or emissions-savings (Reuters, 2025).
- **Policy Harmonization and Global Cooperation**: National climate strategies should integrate CSA targets into NDCs under the Paris Agreement, fostering cross-border knowledge exchange and technology transfer to accelerate global adoption (World Bank, 2025).

By synthesizing precision digital tools, ecological inputs, and integrated water management, climate-smart agriculture can fulfil its triple-win promise safeguarding food security, bolstering farmer resilience, and mitigating environmental impacts. Realizing this ambition at scale will hinge on concerted action across finance, capacity building, data governance, and policy. As the climate emergency intensifies, leveraging these innovations in a coherent, equitable, and evidence-driven manner offers one of the most promising pathways toward resilient and sustainable agri-food systems worldwide.

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Sustainable Water Resource Management : Prerequisite for Environmental Safety and Economic Prosperity

Dr. Pothula Srinivasa Brahmanand
Project Director, WTC, ICAR-IARI, New Delhi
Former Director Research, RPCAU, Pusa, Bihar
Guinness World Record Holder in Longest Speech Marathon
Guinness World Record Holder in Fastest Time to Identify All Elements of Periodic Table

Since the origin of human life, tremendous progress has been witnessed in science and technology. In the field of agriculture also, several nations including India made giant strides in advanced technology. As a result, our nation recorded 354 million tonnes of food grain production in 2024-25. India is also committed to comply with the norms of sustainable development goals of United Nations. In this context, we have to strive for improvement in productivity of food and horticultural crops without damaging our surrounding environment. It is desirable to strike a balance between twin objectives of enhanced crop productivity and ecological preservation. One major factor which needs to be considered here is sustainable utilization of land and water resources. Soil provides the nutrients required for optimum plant growth, however, it needs the support of water for accomplishing this function. Water is the elixir of life and this precious natural resource needs to be preserved for ensuring safer environment. Owing to the climate change, the water resources are declining at significant rate which must be addressed urgently for ensuring sustainable development. In this context, let us analyze the complimentary effect of sustainable water resource development and management on our surrounding environment.

Glacial Preservation is Vital for Sustenance of Life

The theme of the World Water Day for the year 2025 is Glacier preservation. This is very relevant as we are witnessing faster rate of glacier melting resulting in Glacier Lake Outburst Flood (GLOF) in the downstream and reduced volume of water resources in long run, both the extreme events will jeopardize the prospects of crop production and prosperity of farmers. Along with glacier melting, it will also result in loss of biodiversity which is highly detrimental to ecological balance. As per the assessment of The Intergovernmental Panel on Climate Change, we may experience loos of about 18-36% of global glacial mass across the 21st Century as a consequence of global warming. In this context, it is pertinent to mention about the tragic experience of two nations who lost all of their glaciers in the back drop of climate change. Triglav in Slovenia and La Corona in Venezuela lost the status of glaciers (less than 10 ha area) since 1986 and 2016 respectively. As per the report of The Geological Survey of India, about 9,575 glaciers exist in the Indian Himalayas. The worrying fact is that the glaciers located in the Hindu Kush Himalayan mountain region are melting at very faster rates and may subject to loss up to 80% of their volume during 21st century if we don't regulate the present rate of greenhouse gas emissions. Hence, we need to implement an integrated management plan for preserving glaciers in Himalayan ecosystem which includes eco-friendly water management practices for reducing the emission of greenhouse gases.

Protecting Wetlands : Key for Flood Control and Biodiversity

During the occurrence of flood events in rural India, wetlands act as sink so that the negative impact is regulated to a satisfactory level. However, in the recent years, due to intensive and unsustainable agricultural practices and urbanization activities, the wetland area has declined drastically. As a result, the crop fields are subjected to higher extent and frequency of flood events. Alongwith the loss of wetlands, we are experiencing loss of valuable plant and animal species i.e. biodiversity and poor water quality. Hence, for ensuring safe environment, the emphasis should be given to practice eco-friendly water conservation and management practices developed by Indian Council of Agricultural Research (ICAR) and CAUs and SAUs such as bio-mulching, contour cultivation, rainwater harvesting, micro-water resource development, sensor based automated surface irrigation system, bio-drainage, ICAR-Flexi rubber checkdams, Drainage cum groundwater recharge wells etc.

Need for Integrated Approach

For ensuring ecological preservation, we need to follow the integrated approach wherein combination of traditional and modern water saving techniques and safe use of treated wastewater will be employed simultaneously. Traditional water harvesting structures strengthen the eco-friendly approach towards water storage and utilization for both domestic and agricultural purposes. For example, Ahar-Pynes are flood water harvesting structures in Bihar. Similarly, Khadins in Rajasthan are earthen bunds help to impound runoff and recharge groundwater. Ruza in Nagaland is also another successful example, which aids in impounding rain water in ponds thereby facilitating irrigation. This system strongly supports agriculture, horticulture, forestry, fishery and animal husbandry and hence strengthens environmental safety and biodiversity. These traditional methods are proven to be eco-friendly and regionally adapted, hence we need to strengthen them further with desirable modification in design. At the same time, attention has to be paid to modern methods of water saving for crop production. For example, pressurized piped irrigation (PPI) system, which is being promoted by Ministry of Jal Shakti, Government of India helps in reducing the conveyance losses and thereby enhancing water use efficiency significantly. Similarly, the sub surface drip fertigation plays vital role in enhancing water and nutrient use efficiency and reducing green house gas emission thereby contributing to ecological safety considerably. Alternate wetting and drying technique and direct seeded rice will also help in reducing the water requirement and green house gas (Methane and Carbon Dioxide) emission in rice crop which is being cultivated in about 47 Million ha in India (2023-24). Deteriorating water quality is another major challenge for safe environment. Phytoremediation and phycoremediation techniques help in treatment of wastewater (72,368 MLD in urban areas and 39,604 MLD in rural areas in India) and reducing undesirable constituents including heavy metals like cadmium, chromium etc. This treated wastewater, if found containing heavy metals below permissible / threshold limit, can be safely used for irrigation.

Viksit Krishi Sankalp Abhiyan : Boon for Eco-friendly Agriculture

The abovementioned eco-friendly technologies developed by ICAR and Central Agricultural Universities and State Agricultural Universities (National Agricultural Research System) are highly instrumental in protecting our environment which needs to be disseminated to the farmers' fields at faster rate. In this context, it is heartening to note that Government of India (ICAR, DARE and DA&FW, Ministry of Agriculture) has launched Viksit Krishi Sankalp Abhiyan during *Kharif* 2025 (29 May to 12 June 2025) for creating awareness among farming community (1.34 crore farmers) in about 1.43 lakh villages throughout the country regarding improved eco-friendly agricultural practices including sustainable water management practices. In this noble programme, farmers were made aware about the innovative and climate resilient water management practices for ensuring safe environment.

The need of the hour is to balance both the economy and ecology perspectives of farming based on the successful case studies. For example, Andhra Pradesh Community-Managed Natural Farming (APCNF) initiative has aimed at nature-positive food production by discouraging the use of synthetic fertilizers and pesticides and encouraging sowing indigenous crops and seeds thereby nourishing the prospects of crop diversity alongwith significant enhancement farmers' net income.

Demand Driven Vegetable Breeding Opportunities and Way Forward

Sudhakar Pandey
Indian Council of Agricultural Research, New Delhi
Corresponding author's mail: csudhakariivr@gmail.com

ABSTRACT

There is a great deal of diversity in India, and the country is the second largest producer of the vegetable in the world. A large number of vegetable varieties have been made available for cultivation in the country as a result of the extensive network of vegetable breeders. Supply-driven vegetable breeding is responsible for the development of the majority of these varieties, while demand-driven breeding is responsible for contributing a small portion of these varieties. Demand-driven breeding a dynamic process that involves the continuous development of new crop varieties that are tailored to the specific demands of farmers, consumers, and the food industry. The demand-driven breeding of vegetable crops is a process that is becoming increasingly popular. Because of shifting consumer preferences, an increased demand for sustainable and healthy food, and the imperative to address challenges posed by climate change, demand-driven breeding is gaining momentum. This is due to the fact that these factors are all contributing factors. In order to breed vegetable crops that are resistant to disease, have increased productivity, and have superior nutritional profiles, plant breeders use cutting-edge techniques such as genomic selection, marker-assisted selection, and gene editing.

Key Words: Vegetable; Demand Driven Breeding; Resistance; Processing and Yield.

Introduction

Although India grows over a hundred different types of vegetables, researchers have mostly concentrated on only fifteen or sixteen of them. The first vegetable crop research in the country began in 1948, when the ICAR approved a 'Plant Introduction Scheme' at the ICAR-IARI in New Delhi. Following that, the government established a number of organisations to research vegetable crops. The All India Coordinated Research Programme (AICRP-VC), the national Centre for Advanced Research in Horticulture (ICAR-IIVR), and individual vegetable science departments at various agricultural and horticultural universities were among them. After the 1970s and 1980s, when AICRP-VC was established, and promising breeding material was evaluated at various research centres, rapid strides were made in the improvement of vegetable varieties. As a result, 587 varieties of 29 vegetable crops have been identified as suitable for cultivation in various climate zones over the last fifty years. 347 of these varieties are open-pollinated and produce high yields, 181 are hybrids, and 59 are resistant or tolerant to both biotic and abiotic stresses (Behera et al. 2022). Furthermore, over 400 additional varieties have been proposed for cultivation by state varietal release committees. A large number of vegetable hybrids have also been contributed by private seed companies. Thanks to improved varieties and other technological advancements, the country produced 209.14 million tonnes of vegetables from 11.37 million hectares, with 18.12 tonnes/ha productivity (https://agriwelfare.gov.in/en/PublicationReports). Previous vegetable breeding programmes' main goal was to create varieties with higher yields, and that goal was met. In our country, the area (11.37; 4.00 folds), production (209.14; 12.67 folds), and productivity (18.12; 3.17 folds) of vegetables have increased dramatically when compared to the area (2.84 mha), production (16.5 million tonnes), and productivity (5.8 t/ha) of vegetables in 1950-1951. (Behera et al. 2022). This surge in vegetable production has led to an escalating demand for high-quality produce that satisfies both consumer and industry requirements. Consumers are often willing to pay a premium for quality produce, differentiating the vegetable market from field crops. Unlike cereals and pulses with government-regulated minimum support prices (MSP), vegetables rely heavily on consumer demand. The current article delves into the multifaceted aspects of demand-driven vegetable breeding, emphasizing the pivotal role of consumer preferences and the involvement of various stakeholders.

What is demand driven vegetable breeding?

Plant breeders play a pivotal role in shaping our food landscape, as the cultivars they develop serve as the foundation of the food chain. Every fresh or processed vegetable product in the market has been developed through the advancements in plant breeding. A significant portion of vegetable varieties is developed through supply-driven vegetable breeding. In an era marked by escalating purchasing power and an increasing demand for diversified vegetables, the landscape of vegetable breeding must align with consumer needs.

The evolution toward demand-driven breeding of vegetable crops is a dynamic process involving the continual development of new crop varieties tailored to the specific demands of farmers, consumers, and the food industry. This strategic approach encompasses the identification of market opportunities and consumer preferences, driving the development of novel vegetable varieties with desired traits (Tongoona et al. 2017). Currently, demand-driven breeding is gaining momentum due to shifting consumer preferences, and increased demand for sustainable and healthy food, and the imperative to address challenges posed by climate change. Plant breeders employ cutting-edge techniques such as marker-assisted selection, genomic selection, and gene editing to breed vegetable crops that exhibit resilience, enhanced productivity, and superior nutritional profiles.

Understanding the end users of vegetables and vegetable products, namely varieties/hybrids, reveals a tripartite division:

1. **Consumer:** Whether utilizing fresh or processed vegetables, consumers are the pivotal force determining the marketability of the produce.
2. **Farmers or Growers/Traders:** These stakeholders are integral to the cultivation and distribution of vegetable varieties.
3. **Processing Industry:** This sector relies on suitable vegetable varieties for processing into diverse products.

The consumer's role as a market determinant underscores the importance of aligning breeding objectives with their preferences. In current public sector breeding objectives, varieties/hybrids are often released based on yield considerations. Therefore, the specifications of new products should be finalized by incorporating the opinions, preferences, and needs of key stakeholders, customers, and farmers in the value chain.

Objectives in vegetable breeding diverge based on the end users:

- **Consumers:** Prioritize taste, flavor, appearance (color, shape, size), shelf life, nutritional value, and safety. Yield is of secondary importance to consumers.
- **Growers/Farmers:** demands good yield, resistance to diseases and pests, uniformity, and resilience to abiotic stresses like moisture and high temperature.
- **Processing Industry:** Seek resilience to transport, suitability as raw materials (flesh thickness, TSS, seed arrangement, flesh recovery, color retention, and oleoresin content, etc.).

The overarching goal of vegetable breeding programs is to release new varieties encompassing all these desirable traits. Key focus areas in demand-driven breeding include stress resistance, quality tailored to consumer preferences, enhanced nutritional profiles, post-harvest traits for extended shelf life, and suitability for processing and value addition. By addressing these objectives, plant breeders contribute significantly to sustainable and resilient agricultural practices while meeting the evolving needs of consumers, farmers, and the processing industry.

1. Stress resistance:

Disease resistance breeding

The most important objectives of vegetable breeding are either stress resistance either diseases & pest resistances or tolerance to abiotic stresses. The stress resistance/ tolerant cultivars minimize the yield loss, in addition the cultivars with resistance to diseases and pests can also contribute to the reduction of pesticide applications and pesticide residues. Development of resistant varieties and hybrids will accomplish the objectives of both consumer and farmers, as it provides safe vegetables and also reduce the cultivation cost. Continued breeding programme in the past has led to the development of, varieties resistant to leaf curl virus and bacterial wilt in tomato, YVMV in okra, powdery mildew in pea, bacterial wilt in brinjal, downy mildew and CGMV resistant in muskmelon have been developed. A total of 59 varieties resistant or tolerant of one or a few specific pathogens are already available for these vegetable crops in our country.

In tomato, Arka Rakshak and Arka Abhed, are resistant to multiple stresses, including the tomato leaf curl virus, bacterial wilt and early blight; Kashi Aman, K. Adarsh, K. Chayan for Tomato leaf curl virus carrying *Ty-3* gene. In chilli variety A. Meghana is having resistance to chilli veinal virus and powdery mildew resistance. In okra varieties K. Kranti, K. Chayan and K. Utkarsh are resistant to okra yellow vein mosaic virus and okra enation leaf curl virus. Brinjal variety Swarna Shyamali also having resistance to bacterial wilt. Pea variety Kashi Mukti is resistance to powdery mildew. In vegetable crops, where disease resistant is monogenic and dominant, combining multiple resistances to several pathogens is easy. As the demand of hybrids in major vegetable crops are increasing, it is feasible to use cultivars combining four to six resistances genes, particularly in F_1 hybrids.

Most of the resistance genes in the cultivated varieties were introgressed from wild species, and molecular marker assisted breeding facilitates the mapping of genes on different chromosome. The *ty* genes for tomato leaf curl resistance introgressed from wild species *S. Chilense* and *S. habrochaits*. The *Ty* genes have been mapped on different chromosomes of tomato. The gene *Ty1* and *Ty3* is linked at chromosome 6, *Ty2* on chromosome 11 and *Ty4* on chromosome 3 and *ty 5* on Chromosome 4. Similarly mapping for disease resistance was done for PM, DM and Anthracnose in cucumber and similar study is going on in many crops.

Tolerance to Pests

Similarly, resistance to pest is also a challenge for vegetable production, however the vegetable breeding research for pest tolerance is marginal. In recent past, several insect pests and diseases are emerging into a major threat for the vegetable production system which were not previously reported in India. For example, tomato pin worm (*Tuta absoluta*) is one of the global destructive invasive pests of tomato with a potential to cause 100% yield loss was first time documented during 2014 in Maharashtra. From then, it has spread to different parts of the country including hilly regions (Sharma and Gavkare, 2017). Likewise, poleroviruses causing yellowing disease in cucurbits becomes a major constraint for its cultivation since 2018 (Nagendran et al., 2023). There are few vegetable cultivars resistant to insects i.e., Arka Suryamukhi in pumpkin and Punjab Chappan Kadoo 1 in squash is tolerant to fruit fly. The insect resistance may be unstable due to genetic variants of the insect that are able to overcome that source of resistance. Depending on the complexity of the interaction between the pest and the vegetable plant, plant resistance may break down rapidly or some time it is stable. Insects, including aphids, whiteflies, thrips and leafhoppers, are very important in vegetables because they vector many viruses.

Virus infestations reduce production and quality and are becoming problem for country due to the absence of virus resistant germplasm for many important vegetable crops. Aphid transmitted viruses are more problematic because many are transmitted in a non-circulative and non-persistent manner. This means that a very short time, i.e. a few seconds, is sufficient for aphids to acquire virus particles when probing on infected plants. A similarly short time period is enough for aphids to release virus particles when probing on healthy plants. The primary injury caused by aphid-vectored viruses arises not from direct feeding damage by the aphids, but from their ability to allow the virus to enter the plant and initiate the disease.

The sucking pests are also threat for crops, grown under protected conditions and sometimes it found difficult to manage them. Solutions of these were targeted by starting the research on development of transgene. There are 4-5 vegetable crops where transgenic research is going on and transgenic product is ready in few crops.

- RNAi in OKRA against YVMV
- The Cry genes against lepidopterans in Eggplant, Tomato, Okra
- Virus resistance in Watermelon and Tomato
- Delayed fruit ripening in Tomato
- DBM resistance with Cry genes in Cauliflower and Cabbage
- Aphid tolerance in Brassica
- Herbicide resistance in Onion
- FSB control through RNAi

Bt brinjal is ready for release, but due to regulatory hurdles its cultivation is still not allowed in India. Therefore, new biotechnology tools, such as genome editing is now getting popularity, which does not have much regulatory hurdles.

On one side, we conduct research to solve the challenges, while on the other, we face new challenges. The new major emerging challenges of vegetable crops.

Nematode:

Nematode is affecting almost all crops and posing a threat to farming under the protected structure. Other than the protected structures, Diara land is most affected areas for nematode. Very few source of nematode resistance gene for nematode and only *Mi* gene is working well and few resistant tomato varieties, including Sel 120 and Hisar Latit were released. Among the large set of cucurbits germplasm screened for nematode resistance, but only bitter gourd contained the resistance gene.

Several new diseases are emerging in different vegetable crops, with viruses becoming a particular concern. In a survey, begomovirus (93%) was found to have the highest incidence of vector borne viruses followed by poty virus (39.44) and tobamovirus (38.33%). Among these begmoviruses, Tomato Leaf Curl New Delhi Virus (ToLCNDV) affecting tomato and almost all cucurbits, resulting in a 10-100% yield loss (Sagar et al. 2020).

Other major diseases of vegetable crops are damping off, late blight, early blight, little leaf, leaf spot (Anthracnose), powdery mildew, downy mildew, fruit rot and black rot. Besides these, bacterial diseases also affect the vegetable crop. Virus and fungus are contributing the approximate 77% emergence of new vegetable diseases. Gummy stem blight was serious problem for melon, now it is becoming serious challenge of bottle gourd and other cucurbits.

Like diseases, there are several new emerging and reemerging pests becoming the threat for vegetable crops production and becoming challenge for the breeders:

- Melon Weevil, *Acythopius curvovistris citrulli*: About 70-80% fruits and 30% shoots were damaged by this weevil. Major host plant is sponge gourd.
- White plume moth, *Sphenarches caffer*: This pest damages the leaves and buds of bottle gourd. Damage is severe when they feed on the emerging buds resulting in restricted

growth of the buds.

- Bottle gourd mirid bugs, *Nesidiocoris cruentatus*: Around 40-60% leaves and up to 80% fruits are infested by this bugs.
- Papaya mealybug (*Paracoccus marginatus* Williams and Granara de Willink), cotton mealybug *Phenacoccus solenopsis* (Tinsley),
- Mites (*Aceria guerreronis* Keifer),
- Serpentine leaf miner (*Liriomyza trifolii* Burgess) and
- Tomato leaf miner [*Tuta absoluta* (Meyrick)] are some examples

Tolerant sources for this pest may be explored from wild and cultivated both to get the pre breeding materials.

Tolerance to Abiotic stresses

Vegetables generally are sensitive to environmental extremities. Limiting environmental factors are

A. High temperatures: High temperature is a limiting factor for the vegetables. It prefers cooler temperatures for example tomato, pea, beans, carrot and crucifer groups. High temperatures decrease pollen productivity and viability, and inhibit photosynthesis in tomato resulting in reduced fruit set, smaller and lower quality fruits, and ultimately a reduction in yield.

B. Moisture stress: moisture deficit (drought) and excess moisture (flooding) are major causes of low yields. Moisture deficit is the single biggest cause of crop failures and vegetables are particularly susceptible as most are succulent plants consisting of generally more than 90% water. Vegetable production in country is often limited during the rainy season as most vegetables are highly susceptible to flooding.

Breeding vegetables for high temperature tolerance is easier than breeding for moisture deficit and excess moisture tolerance. Because drought tolerance is a complex trait and controlled by multiple genes. Some wild relatives of tomato have good drought tolerance, but this is often genetically linked to undesirable fruit characteristics such as small fruit size and low fruit set and yield.

Under National Innovations on Climate Resilient Agriculture (NICRA) project few high temperature tolerant tomato lines and hybrids developed utilizing pre-bred lines derived from the wild species of tomato *Solanum habrochaites* and these high temperature tolerant lines of tomato showed no reduction in pollen viability from high temperature and produce a fruit set 15% higher than heat sensitive cultivars under the same conditions. The fruit size is about 60-80 g and colour development is also very good in the hybrids. The high temperature tolerant lines such as Kashi Tapas and K. Adbhut have been released by ICAR-IIVR.

In same project, root stocks of brinjal for tolerance to high moisture stress were also identified. Grafting of tomato has been done on brinjal root stock and grafted plants were survived upto 96 hrs in stagnated water and providing the better yield. These grafted tomato plants were distributed to the farmers for planting in July and encouraging results were noticed. Therefore, demands of grafted plants are increasing.

In musk melon a drought tolerant line genotype SA-15 was also identified. ICAR-IIHR has identified lines for high temperature tolerant in pea viz. Arka Uttam, A. Tapas and A. Chaitra (Devi et al. 2023). IIVR is working on development of heat tolerant pea lines and tropical type of Kale . In Kale we are successfully getting the flowering and seed set in Varanasi condition. Most research on the effect of environmental stress has been done on tomato and there is a urgent need for more research on other vegetable crops.

In the country, many indigenous landrace vegetables already are well adapted to the adverse climatic conditions (amaranthus, water spinach, basella, moringa, pointed gourd) likely to be more widespread in the future. Many are highly nutritious and familiar to smallholder farmers, and can provide excellent opportunities to help farmers cope with climate change. The resistant/tolerant varieties to this stress are need of farmers and their need could be fulfilled through demand driven vegetable breeding.

2. Breeding for quality (consumer preference)

Consumers are seeking new eating experiences, different quality attributes and improved convenience, and are prepared to pay a premium price for such produce if their expectations are met. Plant breeding for improved taste, convenience, and consumer appeal such as colour shape and size are the main objectives. If we add these attributes in developed product, certainly it will increase per capita vegetable consumption. The market segment for vegetable is very huge and each and every vegetable crop has different market segments in different localities/country.

Tomato: The fresh tomato category has been differentiated to more than 10 market segments globally are, beefsteak tomato, Roma type tomato, vine-ripe tomato, cocktail tomatoes on vine, tiny-plum tomatoes, mini-plum tomatoes, red cherry tomatoes on vine, attractive yellow and orange cherry tomatoes, mini-San Marzano-type tomatoes, tear drop or pear shaped tomatoes, super or premium taste tomatoes. Taste is also concern in tomato particularly acidity.

Carrot: Baby carrots used as salad without cutting and can be consumed in one or 2 bites, rainbow carrot, which is super sweet and crunchy have multi-pigmented roots.

Pumpkin: Colour of rind: mottle green, dark green, light green, by fruit shape: Flat round, oval to oval round, oval to oblong, by fruit size: small (<3kg), medium (3-6kg), large (6-12kg), very large (>12kg)

Pepper: Red, yellow and orange peppers

Cucumber: Non-bitter, yellow fleshed, mottle green, dark green free from hollowness, baby cucumber.

Brinjal or eggplants: should have mild testing, long, oblong, round shape, and green, white, variegated colour, brinjal variety absorb less fat when fried.

Watermelon: Seedless, high TSS, Yellow or orange fleshed, size – miniature watermelon, ice box, picnic watermelon, jublee type, sugarbaby type.

Lettuces: with different colours, textures and flavours for baby leaf and pre-cut salads.

The consumers are now health conscious and needs safe vegetable, therefore the demand of organic produce is also high. Price is not a limiting factor for higher income group of society for specified product.

3. Breeding for nutritional quality:

Earlier vegetable breeding for nutritional quality was not mentioned as a primary goal. This field of study is relatively new, and also complex because of mineral's interactions with each other, and numerous other compounds in the soil and in the plant. There is usually a large environmental effect, when the component is present in tiny amounts, such as for some micronutrients and phyto-chemicals. Success in vegetable breeding for higher vitamin and mineral content must consider not only substance concentration but also organic components in plants that can be abundant and either reduce or increase bioavailability. With these numerous considerations, breeding vegetable crops for improved nutritional value is a complicated goal that needs expertise in many disciplines such as plant breeding, nutrition, and soil science. If the vegetable crop contains genetic variability for the minerals, vitamin and phytochemical, if selection is effective without detrimental pleiotropic effects, and if there is an easy method to measure the compound, then breeders can be successful in reaching this goal (Singh et al. 2022).

- Pro-vitamin A, carotenoids, more antioxidant activity, iron, and zinc, Vitamin C, nutraceutical compounds are of keen interest.

  An example is the "golden tomato" which contains three to six times more provitamin A carotenoids than standard tomatoes. These improved nutritionally-rich tomato lines could help prevent many children of developing countries from going blind. One "golden tomato" can provide a person's full daily vitamin A requirements.
- In tomato high β-carotene orange cherry tomato breeding lines have been bred utilizing *B* gene from wild species *Solanum hirsutum.* This *B* gene shifts tomato carotenoid accumulation from lycopene almost entirely to β-carotene and results in orange fruit color.
- Four-fold variations in vitamin C was observed in interspecific crosses with *Solanum pimpinellifolium.*
- In carrot, uniform darker orange colour carrot root with high provitamin A and black carrot having more nutraceutical quality and rich in anthocyanin. Two black carrot varieties Kashi Krishna and Pusa Asita have been released. Antidiabetic property is also found on black carrot proved on rats in a study in a collaborative study Institute of medical sciences, BHU.
- Rainbow carrots, which are super sweet and crunchy, have multi-pigmented roots that naturally contain several antioxidants, such as lycopene, lutein, and anthocyanin. Similarly, yellow sweet potatoes are much more nutritious than white ones since they are high in provitamin A carotenoids. CTCRI developed many products using the coloured sweet potato.
- In recent studies of Andean potato cultivars showed wide variation in calcium, iron and zinc content as well as anthocyanins due to the existence of red-, blue- and purple-fleshed potatoes
- Similar studies were made in squash where rapid gains in carotenoid content have been made with phenotypic selection for orange colour versus green and cream colour.
- In peppers carotenoid content in red peppers is relatively high compared to green, yellow, and orange.
- Development of orange colored cauliflower and orange flesh cucumbers reflect a new direction in vegetable breeding for nutritional quality.
- Red coloured okra contains high anthocyanin pigments and a variety Kashi Lalima has been released from IIVR, Varanasi.
- Genetic improvement to increase levels of specific micronutrients has been pursued in several other vegetables such as melon, pumpkin, lettuce, broccoli, watermelon, and kale.

  IIVR has released a variety of pumpkin which is rich in careteniodes:

  From seed crop of pumpkin, Value of Natural carotenoid approx. from 1 ha: is 11 kg @ Rs. 67000 = the value is about Rs. 7.37 lakh. This is additional benefit from the seed production of one ha pumpkin field.

Problem with acceptance of product and role of awareness:

- Earlier, yellow or orange tomatoes could not compete with red tomatoes because consumers were unfamiliar to orange colour tomato, but now they are commercialized, and are challenging the red tomato in the super market.

Nutritional rich product should have acceptance to consumer and there is need to aware the consumer for nutritional quality of product and should be available at a moderate price, it will help to increase the consumption and also provide the better price to growers.

4. Breeding for post-harvest traits and export

Postharvest traits for breeding are mainly:

1. Transport quality-fruit shape and size should be fit for packaging. Hard rind thickness in watermelon, straight fruit shape in bottle gourd and other gourd crops, and chilli. Straight root of carrot and radish
2. Shelf life: More in dry matter and less water content increases the shelf life.

Leafy and other vegetables used for salads deteriorate rapidly after harvest, requiring a cool chain to maintain quality and shelf life of fresh and cut material.

Harvesting increases respiration, stimulating deterioration, with increase in the synthesis of phenylalanine ammonia lyase and phenolic compounds, such as chlorogenic acid which cause tissue browning.

Consequently, delaying leaf senescence is an important target for breeding of leafy vegetables. Utilizing breeding tools, carrot, tomato, pumpkin cultivars with comparably high carotenoid levels and vitamin A content; onion and tomato cultivars with longer shelf-lives, melon and watermelon cultivars with higher sugar content and firmer flesh, etc have been developed. These are just a few examples of how genetic manipulation has contributed to improving the quality of vegetables and post-harvest potential. There is need to develop the cultivars having better storage characteristics, including resistance to storage fungi and pests, and free from physiological disorders.

Use of transgenic technologies, tomato fruit ripening manipulation has been achieved by introducing anti-ripening genes (*rin* and *nor*). But not become popular product. Now using the gene editing techniques, these 2 genes have been incorporated in many fresh and processing tomatoes and results are encouraging.

This type of research needs adequate and sustained funding, as well as improved linkages among breeders, nutritionists and health sector experts.

5. Processing and value addition breeding:

Processing and value addition of vegetable crops in India is less than 5%, whereas we are 2nd largest producer of vegetable in the world. The value of one processed product cucumber & gherkins exported (227699.04 MT) from India is 1761.10 crore (https://apeda.gov.in/2022-23) and approximately 500 farmers are involved to produce the Gherkins and it is 100% exportable commodity. Another important example is natural edible colour. About 70-80 % demand of natural edible colour of world is fulfilled by India. Out of that 60% natural colour demand fulfilled by chilli and remaining from turmeric and marigold. Kashi Sinduri variety of chilli having ASTA value more than 200 units is most suitable for colour extraction.

- One successful example, we would like to mention here that the ash gourd variety Kashi Dhawal is developed based on the research performed with the petha manufactures. We screened several advance lines and petha from all these lines prepared. Based on finding, we define the parameters of ash gourd fruits suitability for processing. The processing traits in ash gourd variety should be oblong or roundish fruit shape and fruit size to be more than

8 kg, high pulp recovery>50%, high content of dry matter (> 4 g/100g), for high pulp recovery seeds in the fruit have to be in linear arrangement. On the basis of above criteria ash gourd variety Kashi Dhawal was developed utilizing all protocol of petha preparation and recommended for petha industry.

- Earlier it was popular in UP but Haldiram started new petha proceesing unit at Nagpur, needs 10 tones fruits/day, > 8 kg size fruits. Due to better size, faramrs of Maharashtra are growing Kashi Dhawal at large scale. In 90 days from one ha farmers of Maharastra earning net profit of Rs. 342000/ha. In tomato, Arka Ashis and Arka Ahuti, pointed gourd variety Kashi Amulya were release and notified for processing purpose.

  Several value-added products have been developed at ICAR-IIVR *i.e* Bitter gourd chips, green chilli powder, dried carrot, okra, pointed gourd based on the osmo Air drying principle. Protein rich instant corn vegetable soup mix, instant bottle gourd *kheer* mix and Moringa soup were also developed and are ready to eat.

  The demand of processed and value-added product is going to be increased by 2-3 percent by the European country and similarly the export of fresh vegetable is also going to be increased in middle east country due to covid-19 as consumers are more health conscious and aware about the health benefits of vegetables.

  The breeding objectives for value added and processing traits vary from one product to other product even when prepared from same crop. Processing traits of the different valued added product in the different vegetable crops needs to redefined. Both breeder and food technologist have to be work together and screening study is required to get better variety or lines.

Opportunities

- **India is rich in genetic diversity**: having genes for traits of interest, we need to broaden out genetic variability of cultivated species. Conservation and maintenance of large plant collection helped to breed for present as well as furture. Phenotyping of large number of genetic resourses are required to identify the desirable gene pool for targeted traits in almost all the crops.
- **Utilization of wild relative:** Wild relatives are major source of resistance for biotic and biotic stress are likely to become more important in future. Improved technologies, especially genomics-assisted breeding, are facilitating the introgression of favourable traits from wild species into cultivated. The conservation of genetic resources of wild relatives of vegetables and the full characterization of gene bank collections will be essential for providing the required new agronomic traits to breeding programs.
- **Opportunity of public sectors to work on more crops**: Private sectors companies are working on only a few targeted crops. There is scope for public sectors breeders to work on minor and under exploited vegetable crops. For example, Aquatic vegetables, leafy vegetables, leguminous, several clonally propagated cucurbit crops. This will benefit small farmers, and will safeguard biodiversity and food security for poor.
- **Well developed infrastructure**: We have largest All India Coordinated network project in the country having 35 centers including ICAR institutes and SAUs situated in different locations in the country. Even private seed companies are also part of this project. Besides evaluation of technologies, this network may be useful for data generation on different aspects: preference of consumers, seasonal demand, emergence of new pest etc. which may be uutilized to set our breeding goals.
- **New areas of breeding**: breeding varieties for protected cultivation. Presently we have approximate 10000 acres area under protected cultivation and expect 2-3 % increase in

coming years. We do not have our own varieties/hybrids for protected condition except few. Therefore, it has huge opportunity for the vegetable breeders to work in this area.

- Similarly breeding verities for processing and value addition is also an open area.
- **Market demand:** 140 billion consumers in our country: demand of vegetable is going to increase by 2-3 % in future.

Way forward:

- **Pre-breeding** with the help of genomics and bioinformatic for aboitic and biotic stress will improve precision and quick results.
- **Speed breeding**: 4-5 generation in a year and application of DH technology to minimize the number of generations required for fixing the line will help to develop new variety in 2-3 years.
- **Root stock breeding:** It can be used to develop the root stock against Soil born disease, moisture stress etc.
- Application of Molecular assisted breeding tools to get accurate and quick results.
- **Utilization of NBTs (new breeding techniques):** New breeding techniques involved both genome editing and non genome editing techniques.

  There are three gene editing NBTs

1. CRISPR-Cas9 (Clustered Regulatory Interspaced Short Palindromic Repeats) is the newest and most powerful of the gene-editing techniques.
2. TALENs (Transcription Activator-like Effector Nucleases), developed in 2009, offer an easier and more accurate method of gene editing.
3. ZFNs (Zinc Finger Nucleases) is the oldest of the gene editing technologies, developed in the 1990s and owned by Sangamo BioSciences

- **Other non-gene editing NBTs**

1. RNAi (RNA interference) – Mostly used to develop viral disease resistance
2. Agroinfiltration is used to induce transient gene expression in plants or even in culture in plant cells
3. Epigenetic approaches (such as RNA-directed DNA methylation) are being explored to manipulate plant DNA without permanently changing it.
4. Site-directed mutagenesis (aka oligonucleotide-directed mutagenesis)
5. Grafting (non-GM scion on GM rootstock)
6. Reverse breeding: Important way to get better results in minimum period of time.

- **Human resource e development:** Continuous education and training should be available for vegetable breeders throughout their careers so they can learn new techniques.
- **Public and private partnership:** Strong coordination is required to fulfil the desired objectives; contribution of private sector vegetable industries is commendable.
- **Attracting the student for vegetable breeding study:** There is need to attract the outstanding students to study the vegetable science as they will fulfil the future vegetable breeder demands and the changes happing in the new breeding techniques needs to be add in syllabus very frequently provide clear paths for obtaining knowledge, experience and skills.

Conclusion

Vegetable crop improvement through plant breeding is critical for sustainable production of vegetable crops that contribute to healthful diets and enhanced quality of life for people around the world. Policymakers and investors have to turn their attention to enhanced funding for the vegetable sector, allowing farmers to compete with their products on a world market. Only then will the silent vegetable revolution currently underway benefiting poor farmers, consumers and industries.

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Agriculture Education: Initiatives, Challenges and Possible Solutions

Dr. S. K. Sharma

Assistant Director General (HRM)

Indian Council of Agricultural Research, New Delhi

Corresponding author's mail: shanti_organic@rediffmail.com

Introduction:

Education in agricultural sciences started in 1877 with the establishment of an agriculture college at Saidapet in erstwhile Madras state, and later three veterinary colleges at Bombay (1886), Calcutta (1893) and Madras (1903). Subsequently, five agricultural colleges were established at Kanpur, Coimbatore and Nagpur (1905), Pune (1907) and Sabour (1908). At the time of independence, the country had seventeen agriculture colleges, four veterinary colleges and one agricultural engineering college. Realizing the importance of agriculture in the Indian economy, the Government of India initiated a series of reforms immediately after independence. India achieved remarkable growth in food grains production from 51 million tonnes in 1951 to over 353.95 million tonnes now (2024-25). The cradle of this success has been the establishment of institutions of higher learning which created skilled human resources for the generation of technologies and their dissemination. This was ably assisted by sound government policies and consistent efforts & cooperation of the farming community. The establishment of the Postgraduate School at Indian Agricultural Research Institute (IARI) and Deemed University status in 1958 was a step towards the development of human resources in agriculture. organizations.

The establishment of SAUs that started in 1960 with GBPUAT being the first in the country picked up gradually and by 2001, almost all the major States except NE States had at least one SAU, some bigger States such as undivided Bihar, UP, Maharashtra, Karnataka, undivided MP and West Bengal had two or more. The number increased up to 77 in 2024 along with 400 plus ICAR institutes, centres, stations and bureaus which provide the ecosystem for international cooperation in agriculture research and education. The important milestones in development of higher agricultural education since 1948 to 2025 is given in Table 1.

Table 1: Major milestones in higher agriculture education

Year	Milestone
1948	First University Education Commission of India to review all higher education.
1955	Report of first Indo-American team proposal to the Government of India for establishing Land- grant style universities.
1958	Deemed University Status to IARI.
1960	Report of second Joint Indo American Team on agricultural research, education and extension to Frame specific proposals for the third five-year plan.
1960	Emergence of SAUs, starting with Pantnagar, based on the recommendations of Joint Indo- American Teams (7SAU established by1964).
1962	Report of Cumming's Committee to advise state governments on the legislation for establishment Of agricultural universities.
1965	Standing Committee on Agricultural Education replaced the Education Panel.

1965	ICAR reorganization with four Divisions including Agricultural Education.
1965	1st Deans' Committee constituted.
1966	Report of the Education Commission (1964-66) for establishment of agricultural university in each state.
1966	First Model Act developed by ICAR for uniformity across agricultural universities.
1966	IRF initiated for M.Sc. Students.
1973	Second reorganization of ICAR with the establishment of Department of Agricultural Research and Education (DARE) to provide greater autonomy to ICAR, and Regional Committees to take care of regional needs, and creation of Agricultural Research Services (ARS) and Agricultural Scientists Recruitment Board (ASRB).
1974	Norms and Accreditation Committee (NAC) replaced Standing Committee on Agricultural Education.
1995	Agricultural Human Resource Development (AHRD) project, with World Bank Support, launched (ended in 2001).
1994	Centres for Advanced studies established.
1996	International Scholarships started.
1996	Establishment of Accreditation Board for Higher Agricultural Education replacing NAC.
1997	Initiation of All India Entrance Examination for Admissions.
1998	ICAR initiated Post Graduate Scholarship (PGS)
1999	ICAR initiated National Talent Scholarships (NTS).
2006	Niche Area of Excellence started.
2008	1st Broad Subject Matter Area Committee (BSMA) constituted for revision of PG courses.
2015	Student READY Programme launched.
2016	Post-Doctoral Fellowship initiated
2016	Declaring the UG degrees in agriculture and allied subjects as Professional Degree Courses.
2017	Initiation of Ranking of agricultural universities. National Agriculture Higher Education Project (NAHEP) implemented.
2019	ICAR Emeritus Professor program initiated in 2019-20
2019	ICAR Post-doctoral Fellowship (ICAR-PDF) programme introduced w.e.f. 2019-20
2021	Implementation Strategies of National Education Policy-2020 in Agricultural Universities by ICAR.
2023	Model Act 2023 with Revised Standards for Accreditation
2023	New undergraduate programme - B.Sc. Ag. (Hons) Natural Farming was notified by ICAR from academic session 2023-24
2024	Academic Regulations/Guidelines for the Award of Certificate and Diploma, and Admission from Diploma to Degree Programme in Agriculture and Allied Subjects by ICAR
2024	The Sixth Deans Committee recommendations implemented by ICAR in AUs for 13 undergraduate disciplines from academic year 2024-25
2024	ASEAN-India Fellowship for Higher Education in Agriculture and Allied Sciences from the Academic Year 2024-25 to strengthen the educational and cultural ties between India and the Association of Southeast Asian Nations (ASEAN) member countries

2025	A RAWE Mobile App named VIKAS (Venture for Interaction of Kisan & Agri-Students) developed to educate farmers about national programs and government initiatives.

Status of Higher Agricultural Education in India

The agricultural education system in India comprises of 77 Agricultural Universities (AUs) structured on the Land Grant pattern of the USA - integrating teaching, research, and extension. Of these, 66 are State Agricultural Universities (SAUs), three Central Agricultural Universities (CAUs), four Deemed Universities (DUs) and four Central Universities with agricultural faculty. These along with 113 institutes within the ICAR, 731 Krishi Vigyan Kendras (Agriculture Science Centres), and 69 All India Coordinated Research Projects (AICRP) make India's National Agricultural Research and Education System (NARES) the largest in the world. The NARES has generated the needed scientific manpower, teachers, technologies and their transfer to transform India from the food deficit to the food surplus and Right-to-Food status, rendering India as a major exporter of agri-food products and the second largest agrarian economy in the world. The extensive spread of agricultural universities and colleges has opened opportunities for higher agricultural education and has paid rich dividends mainly because of the integration of education, research and extension. It was a major departure from the traditional system of education.

Agricultural higher education is a state subject, but higher education is on the Concurrent List in our Constitution, and therefore, the modus operandi for implementation has to be modified accordingly. The higher agricultural education institutions (HAEIs) have the mandate of research, education and extension with a strong focus on farmers, which is different from the traditional universities. Thus, while aligning with the National Education Policy 2020 (NEP 2020), the ICAR must continue to strive for the quality of agriculture education. It is perhaps the right time to bring agriculture on the Concurrent List. These universities offer 13 disciplines for Undergraduate (UG) courses, 96 for Postgraduate (PG) courses and 73 for Doctorate (PhD) courses. The uniformity, assessment, maintenance and strengthening of standards and quality of higher agricultural education through institutional mechanism has been put in place by ICAR and AUs for human resource development and quality reforms (Various Reports and Documents, ICAR).

There are public, private, and traditional universities in India's agricultural higher education system. Public agriculture universities are aided by the Indian Council of Agricultural Research (ICAR) and state governments, while private agriculture universities are supported by various government universities and University Grant Commission (UGC). About 2.69 lakh students are enrolled in various UG, PG, and PhD programmes in these institutions. (Ministry of Education, 2020). ICAR and AUs are involved in strengthening and streamlining of higher agricultural education system to enhance the quality of human resources in agri-supply chain to meet future challenges in agriculture sector in the country. In the last 75 years, India's higher agricultural education sector has seen impressive growth, with significant increases in enrolment, expanded State Public Universities (SPUs), and improved representation of disadvantaged groups. The country has made strides in gender parity, faculty development, and global research contributions.

Initiatives in Higher Agriculture Education

The NEP 2020 highlights that although Agricultural Universities comprise approximately 9% of all universities, enrolment in agriculture and allied sciences is less than 1% of all enrolments in higher education. Out of total 1,168 Universities/University level Institutions, and 45,473 Colleges registered in AISHE 2021-22, agricultural universities constitute 6.6 percent and agricultural colleges constitute about 2.1 percent (estimated about 1000 both public and private sector colleges). With large youth population in India and increasing pressure of workforce, expansion of agricultural education is the need of hour.

National Agricultural Higher Education Project (NAHEP) started in 2018 by ICAR to support participating Agricultural Universities (62) and ICAR had resulted in significant impact in providing more relevant and higher quality education to Agricultural Universities (AUs) students, to create a more skilled workforce, thereby continuously enhancing the productivity of key sectors, including agriculture. It focused on systematic capacity building, industry-academia collaboration, and digitalization of education for enhanced learning outcomes, higher employability, and increased agricultural innovation. Key assumptions included: (i) effective faculty training and research infrastructure will drive academic excellence; (ii) industry participation will improve curriculum relevance and student career prospects; (iii) digital learning tools will bridge skill gaps and increase student engagement; and (iv) international collaborations will enhance institutional prestige and research impact.

As per the Fifth Deans' Committee recommendations of ICAR, all degrees in the disciplines of Agricultural Sciences have been declared as professional course degrees since 2016 and sought to achieve the global level of academic excellence.

Both capacity and quality of agriculture and allied disciplines must be improved to increase agricultural productivity through better-skilled graduates and technicians, innovative research, and market-based extension linked to technologies and practices. The preparation of professionals in agriculture and veterinary sciences through programmes integrated with general education should be increased sharply. The NEP 2020 underpins that the design of agricultural education will shift towards developing professionals with the ability to understand and use local knowledge, traditional knowledge, and emerging technologies while being cognizant of critical issues such as declining land productivity, climate change, food sufficiency for our growing population, etc.

ICAR has taken many initiatives under the NEP 2020 for ensuring universal high-quality education with emphasis on skill enhancement courses, certificate and diploma and internship as well as experiential learning programmes for enhancing employability and future ready skills among agri-graduates. The ICAR's Sixth Deans' Committee on restructuring new curriculum framework in agriculture and allied sciences during 2024 has restructured the course curricula to underpin relevant practical skills, entrepreneurial aptitude, self-employment, leadership qualities and confidence among graduates, and attracting and retaining youth in agriculture.

ICAR is instrumental for restructuring and implementation of NEP by higher agricultural education institutions (HAEIs) in India by starting multiple exits and entry points into higher education by all the universities, Compliance with Academic Bank of Credits as per the directives of the Ministry of Education and Deemed universities of ICAR may initiate the process for transforming into Multidisciplinary Education and Research University (MERU); beginning a common entrance test by the ICAR for admission of the students in all the AUs, increase at least 10% seats by AUs starting from 2021-22 academic sessions on an annual basis. and SAUs may develop their Institutional Development Plans identifying their core strength for research areas.

ICAR is working for adopting the guidelines for HAEIs in country to evolve into multi-disciplinary institutions/clusters offering both seamlessly, and in an integrated manner by 2030 and by 2035, achieving a Gross Enrolment Ratio (GER) of 50 percent is targeted in higher agricultural education including vocational education.

Amidst all these changes, colleges and universities of agriculture and allied sciences are focusing for preparing individuals for 21st century and also a greater effort is needed to be successful in taking on these new initiatives of NEP 2020 and responsibility at higher scale with more speed. However, (i) difficulty in attracting bright, talented students, (ii) funding crunch, (iii) a large number of vacancies, (iv) inbreeding of faculty, (v) lack of autonomy to the Vice-Chancellors, and (vi) poor State-Centre and State-SAU relationships are the major constraints in AU in agriculture and allied sciences.

Challenges and Possible Solutions for making higher agricultural education ready for the 21st Century

Preparing a tech ready workforce, inter disciplinary learning, raising State Public Universities (SPUs) to global standards, Industry-Academia collaboration and internationalization of workforce are the key priority areas of Government of India to make Indian higher education globally competitive and preparing the higher education ecosystem for transformation India into Viksit Bharat. The important challenges and possible solutions for making higher agricultural education ready for the 21st Century are as follows:

I. Preparing tech-ready human resource

Introduction: **A**griculture sector is becoming more complex due to globalization and climate change, and to cope with these challenges India need quality trained human resources. The AUs, which generate these resources, have, started many steps through changes in policy, governance, teaching and learning ecosystem and transformation of academic standards to prepare a next generation workforce offering end-to-end solutions

Current Situation

Key Challenges

- High implementation cost for cutting edge research and innovations so activities in agricultural and allied sector are in focused on farmer centric limited research topics.
- Lack of specialization of faculty and technical staff in cutting edge technologies.

Possible Solutions

- Provision of budget for research & training in cutting edge areas in agriculture and allied sector
- Market survey for futuristic demand & placements in tune with global and national demand of human resource.
- Increase in number of fellowships for students in industry driven high-tech areas

II. Interdisciplinary learning

Introduction

In agricultural universities key aspects of an interdisciplinary educational model exists. Experiential learning and collaborations within and across institutions are enabling for interdisciplinary teaching and research. However, systemic and institutional collaboration with general stream SPUs and specialized institutions still need a focus for wider spectrum of interdisciplinary learning as per need of modern time and provisions of NEP -2020.

Key Challenges

Student motivation, teacher's competency and background, fixed curricula, and siloes among implementation agencies are important barriers for running of restricted options and number of interdisciplinary courses for students in agriculture, horticulture, dairy and veterinary sciences to interdisciplinary learning in HAEIs.

Possible Solutions

- MoUs among SPUs in medical, computer, engineering, art and science streams for flexibility of more options for choosing interdisciplinary courses by learners in agri-institutions.
- Flexible policy for teachers for more inter-disciplinary project work among other SPUs. at post- graduate level for interdisciplinary based solution of problem

III.Raising State Public Universities (SPUs) to global standards

Introduction

By 2035, the NEP 2020 target is to double enrolment in the higher education system to nearly 9 crore students. Nearly 7 crores of these will continue to study in SPUs. Hence, it is of utmost importance that these universities should be developed not only for transition from focusing only on access to higher education but also to delivering world class higher education to create the high-quality human resource required to power the vision of becoming a Viksit Bharat by 2047. There is no higher agriculture education institution in India in top five hundred of any of the world-renowned ranking frameworks (such as the Times Higher Education World University Rankings or QS or. Shanghai's jiao Tong University). Poor global rankings of Indian agricultural institutions and limited acceptance by international private companies affect the attractiveness of pursuing degrees from these institutions. In agriculture sector, to double the student intake capacity in State public agriculture universities from about 52000 plus in 2024-25 to 100000 plus by 2035 considering the adoption of quality education standards, funding limitations, governance issues, and the need for capacity building of VCs, teachers, and staff is a challenge.

Key Challenges

- Unmindful splitting of agricultural universities into horticulture, veterinary etc put pressure on resources and promote boundaries for governance and application of quality standards
- Poor coordination between center and state to deal with the Model Act of ICAR in State agricultural universities.

Possible Solutions

Agricultural higher education is a state subject, but higher education is on the Concurrent List in our Constitution, and therefore, the modus operandi for implementation has to be modified accordingly. The Agricultural Universities have the mandate of research, education and extension with a strong focus on farmers, which is different from the traditional universities. Thus, while aligning with the National Education Policy 2020 (NEP 2020), the ICAR is striving for the quality of agriculture education in country but, it is perhaps the right time to bring agriculture on the Concurrent List for preparing the smooth road for aligning with the global standards and effective implementation of NEP-2020 in agriculture and allied sectors.

- Current accreditation and ranking mechanisms for agricultural universities must shift from a compliance-oriented approach to one rooted in quality, innovation, and measurable outcomes.
- Universities to actively pursue international accreditation, global collaborations, and dual-degree programs to elevate their presence and prestige in the international academic ecosystem

IV. Industry-academia collaboration

Introduction

Often, most of the agricultural education institutions function independently of the job market's needs, resulting in a disconnect between the skills students develop and those sought by employers. This discrepancy is particularly noticeable in higher education, where many graduates face difficulties securing employment that corresponds with their qualifications. Additionally, the lack of robust connections between the industry and academic sectors stifles innovation and research. While certain institutions have started to engage with industries through internships, guest lectures, and collaborative research, these initiatives remain limited in scope.A more integrated strategy is required, where industry needs directly influence curriculum development, research focus, and skill-building programs.

Key Challenges

- Lack of alignment of goals and nature of education and training as well as research between academicians and industry.
- Lack of structures and mechanisms to have researchers and experts from both sides of academia and industry sides spend time together to solve the problem
- Natural synergy between the academic and the industry researcher – at the initial stage of conceptualization and generalization of problems and skills for collaborative working on problems

Possible Solutions

- Establishing joint working groups with members from both academia and industry can help align goals and foster mutual understanding.
- Creating clear frameworks for collaboration, with regular reviews and transparent communication, will ensure that efforts remain focused and effective.
- Capacity-building and training programs for faculty, students, and industry representatives can also play a key role in bridging gaps and building trust.
- Vocational education should be incorporated into the mainstream agricultural education system from the secondary level to arm students with real-world skills that suit the job market.
- Corporate social responsibility (CSR) initiatives can also be leveraged to support educational projects in underserved areas by providing resources such as digital classrooms, libraries, and teacher training programs.

V. Internationalization

Introduction

Internationalization of agriculture education in India involves integrating global perspectives and practices into the country's agricultural education system. This includes fostering international collaborations, adapting curricula, and promoting student and faculty exchanges.

Key Challenges

There is no higher agriculture education institution in India in top five hundred of any of the world-renowned ranking frameworks (such as the Times Higher Education World University Rankings or QS or. Shanghai's jiao Tong University). Poor global rankings of Indian agricultural institutions and limited acceptance by international private companies affect the attractiveness of pursuing degrees from these institutions.

There is a lack of global exposure and collaboration in academic leaders and faculty. Many universities haven't built strong partnerships with foreign universities yet, which limits the exchange of knowledge and ideas. Funding and infrastructure are a big hurdle. International programs and modern labs cost a lot, and not all universities have the resources for that. Further, balancing international knowledge with local needs need long-term strategic planning. Indian farming has its own unique conditions, so they need to adapt global ideas carefully to make them work locally.

Possible Solutions

- Policy Changes: Immediate policy changes are required to recruit faculty with international competence and to increase the intake of foreign students.
- Single Window Liaison Office: Establishing a single-window liaison office for international higher agricultural education in India through ICAR and state public universities.
- Harmonization with Global Standards: Aligning degree programs with global standards to enhance their credibility.
- Ensuring accountable institutional leadership with global exposure in higher agricultural education institutions is critical.
- Establishing joint working groups with members from both academia and industry from different global universities and private companies can help align goals and foster mutual understanding of job markets for global students.

ABSTRACTS

Next-Gen Climate-Smart Solutions for Sustainable Agricultural Intensification

Mahesh R.[1*], Hasan M.[1], D. Shivam Chaubey[1], and Prashant Shukla[1]

[1]Division of Agricultural Engineering, ICAR-Indian Agricultural Research Institute, New Delhi 110 012

[*]Email: rmaheshiari@gmail.com

ABSTRACT

With the global population projected to reach 9.7 billion by 2050, agricultural productivity must increase by 70% to meet future food demands while aligning with the UN Sustainable Development Goals (SDG 2030). However, per capita agricultural land has declined by over 22% since 2000, and traditional open-field farming is increasingly constrained by land scarcity, climate variability, and inefficient resource use. In this context, food factories or plant factories enclosed, climate-controlled systems offer a promising solution for achieving consistent crop production with enhanced resource efficiency. This study presents the design and evaluation of an indigenous, low-cost plant factory prototype (2.5 m × 1.3 m × 2.6 m) with four vertical tiers. The indoor cultivation system, operated under fully controlled conditions using artificial lighting and optimized fertigation, demonstrated significantly improved productivity compared to traditional soil-based methods. Using an equal cultivation area (3.25 m²), the plant factory accommodated 312 plants—seven times more than the open field system (43 plants) and produced an 11-fold higher yield (41 kg vs. 3.8 kg). Resource use efficiencies for light, water, and nutrients were markedly higher, and the benefit-cost (B:C) ratio was substantially improved (2.68 vs. 1.00). A comparative assessment of construction materials, polyurethane foam (PUF), expanded polystyrene (EPS), rock wool, and insulated metal panels (IMP) were also conducted to identify thermally efficient, cost-effective, and environmentally sustainable building options. Among these, PUF and IMP showed superior thermal insulation and structural performance. The estimated construction cost of the prototype was ₹1,13,000 with a breakeven period of 1.5 years, which could be further reduced through integration of solar photovoltaic systems. The findings highlight the potential of affordable, modular plant factories as scalable solutions for sustainable urban agriculture and improved food security.

Keywords: Climate-Smart Agriculture; Resource Use Efficiency; Sustainable Agri-Innovations

Groundwater Dynamics under Climate Change for Resource-Efficient Agriculture in Bundelkhand Region, India

Shivam Chaubey[1], Ramkishore Kurmi[1] Mahesh R[1], Rima Das[1], Prashant Shukla[1] Gauri G. Bhagole[1]

[1] Ph.D. Scholar, Division of Agricultural Engineering, ICAR-IARI, New Delhi 110012, India

[Corresponding author's email: shivamchaubey124@gmail.com]

ABSTRACT

The Bundelkhand region, characterized by its semi-arid climate and recurrent droughts, faces increasing stress on its groundwater resources. Climate variability, coupled with unsustainable extraction, threatens the water security essential for resilient and resource-efficient agriculture. This study investigates groundwater dynamics under changing climate scenarios in the Bundelkhand region to support resource-efficient and climate-smart agricultural practices. Using long-term time-series groundwater data, trend analysis and forecasting were conducted employing the Mann-Kendall test, Sen's slope estimator, and the Exponential Smoothing Method (ESM). Spatial distribution was analyzed through GIS-based isobath mapping to visualize aquifer behavior across diverse zones. Observations from over 40 wells, including confined and unconfined aquifers, revealed significant trends in 23 wells during the pre-monsoon and 14 wells post-monsoon periods. Piezometric level trends showed monotonic changes ranging from -0.541 to 0.395 m/year (pre-monsoon) and -0.385 to 0.239 m/year (post-monsoon). In confined aquifers, the decline was more pronounced, ranging from -0.341 to 0.870 m/year (pre-monsoon) and -0.401 to 1.148 m/year (post-monsoon). Forecasts for 2030 project severe groundwater depletion, with pre-monsoon declines of up to 11 m in Mahoba and 8.2 m in Banda, and post-monsoon drops of 7.9 m in Mahoba and 8.7 m in Chhatarpur. Confined aquifers may experience a critical piezometric fall of 22.15 m in Jhansi. These alarming trends highlight the urgent need for region-specific groundwater management and adaptive strategies to enhance water use efficiency and sustain agricultural productivity under a changing climate.

Keywords: Mann-Kendall's Test, Sen's slope estimator, Climate change and Groundwater level.

Seeds of Change: The Digital Ecosystem Driving Quality Assurance in Indian Agriculture

Shahil Kumar[1] Sumeet Kumar Singh[2] and Satish Kumar Singh[3]

[1]Department of Seed Science and Technology, PGCA, RPCAU-Pusa, Samastipur, India

[2]Department of Genetics and Plant Breeding, PGCA, RPCAU-Pusa, Samastipur, India

Corresponding author's mail: shahilkumar400@rpcau.ac.in-+

ABSTRACT

Seed certification is a quality assurance system where by seed intended for marketing is subject to quality control and inspection. The Government of India is embarking on a transformative endeavor, the Seed Traceability Project, to build a Digital Ecosystem, to effectively monitor the seed production and distribution chain and to provide complete traceability of the seeds from point of origin till sale. A Centralized Online System for Seed Traceability by the Department of Agriculture & Farmers Welfare (DA&FW). This system encompasses a comprehensive array of features designed to ensure the utmost efficiency, transparency, and quality assurance throughout the seed production chain. Key components of the Seed Traceability Portal include the implementation of QR codes printed on seed packets, facilitating quality assurance and tracking of spurious seeds. The system integrates seven verticals of the seed chain, spanning research organizations, seed certification, licensing, inventory management, sales, and subsidy disbursement. Through this framework, only seeds with valid certification can be sold by licensed dealers to registered farmers, who receive subsidies directly in their pre-validated bank accounts via Direct Benefit Transfer (DBT). Moreover, the system enables real-time monitoring and automation of various processes, from seed certification to inventory management, dealer registration, and license issuance. Each seed packet is tagged with a QR code/barcode containing essential information such as source details, grower information, production details, and relevant regulatory compliance data. Crucially, the Seed Traceability system harnesses blockchain technology to ensure tamper-proof records and uniformity across the nation. State-specific server nodes communicate with a central blockchain server, enabling secure and immutable data storage. By enhancing traceability and accountability, this initiative promises to revolutionize the seed industry in India, fostering a paradigm shift towards greater transparency and efficiency. To monitor these events an online portal has been already developed and in use with a name SATHI. Purpose of the SATHI Portal is development and hosting of a national portal for Automation of the entire life cycle of seeds which includes Seed Certification, seed traceability and seed supply chain for all the states of India.

Keyword- Seed Certification, Traceability, SATHI, Quality Seed

Enhancing Terrestrial Carbon Sequestration through Soil and Water Conservation: A Climate Change Mitigation Strategy for Semi-Arid Watershed

Dnyaneshwar. D. More[1], Dr. Sachin. B. Nandgude[2] and Dr. Sangita. S. Shinde[3]

[1]Deptt. of Soil and Water Conservation Engineering,

[2]Dr. A. S. College of Agricultural Engineering & Technology,

MPKV, Rahuri, Dist.: Ahilyanagar (M.S), India

Corresponding author's mail: dnyamneshwarmore000@gmail.co

ABSTRACT

Climate change is a critical issue, and immediate action is required to avoid costly future adaptations. As an essential mitigation component, carbon sequestration refers to capturing CO_2 from the atmosphere and securely storing it in terrestrial or geological sinks over extended periods. While methods like afforestation, soil carbon sequestration, and carbon capture are well-known, the role of soil and water conservation (SWC) in carbon sequestration is often underestimated despite its significant potential. The paper aims to monitor and assess the carbon sequestration potential of terrestrial soils within small watersheds in rainfed areas. The research was conducted at Hiwarebazar Watershed, which was developed over three decades ago in the Ahilyanagar district, Maharashtra, India. The study found that SWC measures substantially impacted soil carbon sequestration (SCS) rates, which varied significantly across land cover types and conservation treatments. For instance, compartment bunding in agricultural lands increased the SCS rate to 343 kg C/ha/yr, compared to 190 kg C/ha/yr in untreated lands. For instance, forestry with Deep Continuous Contour Trenches (DCCT) exhibited the highest sequestration rate (1370 kg C/ha/yr), followed by forestry with Continuous Contour Trenches (CCT) at 1152 kg C/ha/yr. Agricultural lands under riparian habitat treatment and bunding demonstrated moderate sequestration rates of 856 and 820 kg C/ha/yr, respectively. Horticultural systems also showed considerable potential (1029 kg C/ha/yr). In contrast, untreated barren lands exhibited a net carbon loss (- 18.5 kg C/ha/yr), underscoring the critical role of land use management and conservation interventions in enhancing soil organic carbon stocks and mitigating climate change impacts. Notably, untreated barren lands were a net source of carbon emissions, but with SWC interventions, they transformed into carbon sinks. The findings suggest that implementing appropriate SWC measures, along with plantation and agroforestry practices, is crucial in untreated watershed areas to reduce soil carbon loss and enhance SCS rates.

Keywords: Climate Change, Carbon Sequestration, DCCT, Riparian habitat, Barren lands

Effect of nitrogen and cutting management on performance of forage pearl millet varieties

A.K. Jha and Pushpendra Yadav

Department of Agronomy, JNKVV, Jabalpur, 482004

Corresponding author's mail: amitagcrewa@rediffmail.com

ABSTRACT

An experiment was started during *Kharif 2020* at Jabalpur for study the effect of nitrogen and cutting management on yield and economics of new pearl millet varieties for prolonged quality fodder availability period. All possible combinations of four pearl millet varieties (TSFB 15-4, TSFB 15-8, Moti Bajra and BAIF Bajra-1) with two nitrogen levels (80 and 120 kg/ ha) and two cutting management two cuts and three cuts at different intervals to harvest maximum quality fodder yield was conducted in split plot design with three replication. For two cutting system, first cut was taken at 60 days after sowing and second cut at 50% flowering. In three cutting management system, first cut was done at 50 days after sowing, second at 35 after first cut and third cut was taken at 50% flowering. Experiment was conducted to evaluate two cut and three cut for maximizing green fodder yield and prolonging green fodder availability. Moti Bajra produced maximum green and dry fodder yield (636.9 and 158.1 q/ ha). Application of 120 kg/ha nitrogen produced maximum green and dry fodder yield. Three cut at different interval produced maximum green fodder and dry fodder yield (612.4 and 139.6 q/ ha) on locational mean basis. Results of economics shows that maximum gross return, net return and B:C ratio was achieved with variety Moti Bajra with application of 120 kg/ha nitrogen and three cuts at different intervals *i.e.* first at 50 days after sowing, second at 35 after first cut and last cut at 50% flowering.

Genome-editing technologies application in horticultural crop breeding

Vikash Tyagi[1], Bijendra Singh[1], Sudhanshu Singh[1], Yashraj

Department of Vegetable Science, Collage of Horticulture

Sardar Vallabhbhai Patel University of Agriculture and Technology Meerut, U.P.

Email of corresponding author: vikashtyagi889@gmail.com

Abstract

Plant breeding, one of the oldest agricultural activities, parallels human civilization. Many crops have been domesticated to satisfy human's food and aesthetical needs, including numerous specialty horticultural crops such as fruits, vegetables, ornamental flowers, shrubs, and trees. Crop varieties originated through selection during early human civilization. Other technologies, such as various forms of hybridization, mutation, and transgenics, have also been invented and applied to crop breeding over the past centuries. The progress made in these breeding technologies, especially the modern biotechnology-based breeding technologies, has had a great impact on crop breeding as well as on our lives. Here, we first review the developmental process and applications of these technologies in horticultural crop breeding. Then, we mainly describe the principles of the latest genome-editing technologies and discuss their potential applications in the genetic improvement of horticultural crops. The advantages and challenges of genome-editing technologies in horticultural crop breeding are also discussed. particular genome editing using CRISPR/Cas9 nucleases. In this review, we have analyzed modern advances in genome editing of horticultural plants. To date, it has become possible to improve many plant characteristics using this technology, e.g., making plants resistant to biotic and abiotic stress factors, changing the time of flowering and fruit ripening, changing the growth characteristics of plants, as well as the taste properties of their fruits. CRISPR/Cas9 genome editing has been successfully carried out for many horticultural plants.

Keywords: genome editing; CRISPR/Cas9; horticultural crops; plant disease resistance; herbicide resistance; flowers longevity; flowers colour changes; fruits and berries improvement

Characterization of Traditional Maize Landraces from NEHR for Agro-Morphological and Pigmentation Traits

Neelesh Vimal[1], Vishwanath Vishwambhar Walawalkar[1], Pramod Kumar Pandey[2]*, Amarjeet Kumar[3] and Narendra Kumar[3]

[1]M.Sc. Scholar, School of Crop Improvement, CPGS-AS, CAU-Imphal, Umiam, Meghalaya

[2*]Assistant Maize Breeder, AICRP on Maize, COA, CAU-Imphal, Kyrdemkulai, Meghalaya

[3]Assistant Professor, COA, CAU-Imphal, Kyrdemkulai, Meghalaya

Corresponding author’s email: pramod.pandey84@gmail.com

ABSTRACT

Maize landraces are traditional, locally adapted genotypes of maize that have been cultivated by farmers for generations, often possessing unique traits and genetic diversity. These landraces play a vital role in maintaining agro biodiversity, food security, and cultural heritage in many regions. This study explores the phenotypic diversity of maize landraces in the North East Hill Region (NEHR) , focusing on various agro-morphological traits such as plant height, ear diameter, days to silking, and days to tasseling. We collected 50 distinct landraces from different northeastern states. Notably, some landraces exhibited protogyny, where the female parts mature before the male parts. Significant variations were observed in traits like plant height (averaging 253.5 cm) and ear height (averaging 151.7 cm), as well as tassel length (averaging 27.81 cm) and ear height (averaging 118.39 cm, potentially referring to a different aspect of ear height). Pigmentation was commonly observed in the brace roots of most maize landraces, whereas their leaf sheaths generally lacked any visible coloration. In a few landraces, silk pigmentation was noticeable at the time of cob emergence. Our qualitative evaluation revealed that approximately 39% of the landraces exhibited pigmentation at the base of the glume, while 16% showed pigmentation in the anthers during flowering. Additionally, around 34% had pigmentation on the glumes excluding the base. Regarding cob characteristics, most landraces were found to have conico-cylindrical cobs with straight kernel row arrangements and a sparse distribution of spikelets. The study highlighted considerable diversity among the landraces, with certain genotypes demonstrating superior agronomic traits that are well-suited to the local cultivation conditions. This variation highlighted the significance of conserving these traditional landraces, as they possess valuable genetic attributes that can support future maize improvement efforts and strengthen food security in the region.

Weaving the Future: Reviving Heritage through Youth Entrepreneurship in Sericulture

Mebanlamshwa Jyrwa[1], Nafisa Chirimbit[2] and M.Sangma[3] Smita Kumari''

COA, CAU (Imphal), Kyrdemkulai, Meghalaya

Corresponding author's email: mjyrwa2002@gmail.com

ABSTRACT

Sericulture, the art and science of rearing silkworms, is far more than just silk production. It is a dynamic, eco-friendly agro-based industry that connects agriculture, culture, and rural enterprise. Offering low-investment yet high-employment potential, it opens doors for agripreneurship, particularly among youth, women, and marginalized communities. From mulberry cultivation to silk weaving and marketing, sericulture fosters inclusive growth and micro-entrepreneurship in remote and tribal areas.Aligned with the Sustainable Development Goals (SDGs), sericulture promotes poverty reduction (SDG 1), zero hunger (SDG 2), gender equality (SDG 5), reduced inequalities (SDG 10), decent work and economic growth (SDG 8), and responsible consumption and production (SDG 12). Its eco-conscious, land-based practices support biodiversity and contribute to climate action (SDG 13) through carbon sequestration by mulberry trees.

In Meghalaya, iculture transcends economics. It's a living cultural legacy. Known for its indigenous Eri silk (Ryndia), the region's sericulture traditions empower rural households with sustainable livelihoods while preserving ancestral knowledge. Recognizing its multifaceted value, both the Meghalaya and Central Governments have launched schemes offering subsidies, skill training, and infrastructure support to bolster the sector. Ryndia was recently granted the Geographical Indication (GI) tag, affirming its uniqueness and quality. This recognition not only protects indigenous knowledge but also boosts the market value and global visibility of Meghalaya's silk heritage.What makes sericulture even more promising is its ability to generate a diverse range of valuable by-products, reinforcing its status as a zero-waste and circular industry. These add-ons not only enhance income streams but also contribute to environmental sustainability. In essence, sericulture is a powerful tool for weaving together tradition, innovation, and opportunity. With its blend of cultural richness and economic promise, it stands as a vibrant path toward youth-led rural transformation.

Factors influencing farmers decision to participate in e-auction: A case of Electronic National Agriculture Market (e-NAM) in Karnataka, India

Nithish Reddy[1] GB, Harsha Ramalad[2] and Sharanbasav

[1]University of Agricultural Sciences, Dharwad- 580005

Corresponding author's e-mail: nreddygb@gmail.com

ABSTRACT

This study aimed to analyze farmers' perceptions and the factors influencing their decision to participate in e- auctions in Karnataka. Primary data were collected through interviews with 250 farmers and analyzed using logistic regression and SMOTE Tomek techniques. The study revealed that the average age of the farmers was 46 years, and the average annual income was Rs 5.2 lakh. Only 12.40 percent of farmers were aware of e-NAM. While 68.80 percent of farmers knew about the electronic quality assaying process, only 36.00 percent could interpret the assaying report, and just 20.40 percent considered the assaying report for price determination. Majority of farmers (90%) reported selling Basmati rice through e- NAM, followed by cotton (84.80%), potato (76.40%), kinnow (28.80%), and green peas (16.80%). All farmers checked commodity prices before bringing their produce to the market, primarily relying on commission agents (100%) for price information, followed by fellow farmers (98.40%) and media/social media (18%). Most farmers (94.40%) owned a smartphone, while 5.60% had a simple phone. All farmers indicated that the open auction method was used at APMC, with the price determination process taking 3 to 5 minutes (60%) or more than 5 minutes (39.2%). After being informed about the e- auction process of e-NAM, 89.6% of farmers preferred e-auction over open auction. Payment settlements were mainly handled by commission agents, with cash being the preferred method, and payments were typically received within 3 to 5 days after the sale. Major constraints faced by farmers in using e-NAM included lack of guidance, fear of losing commission agents' assistance, absence of grading facilities, and complexities in the selling process. Key parameters predicting farmers' preference for open auction over e-auction were their loan sources, family background, education, family size, annual income, and age.

Key words: Commission Agent, E-auction, E-NAM, Market, Price

Promoting Agripreneurship Among Rural Youth for Viksit Bharat

Shreya Choughule[1], Akshay Jangam[2]

[1]College of Agriculture, Dapoli, Dr.BSKKV, Dapoli, Ratnagiri, Maharashtra
[2]General Management Area, K J Somaiya Institute of Management, Mumbai, Maharashtra

Corresponding author - shreyachougule6350@gmail.com

ABSTRACT

India stands at a critical juncture in its development trajectory, aiming to become a Viksit Bharat (Developed India) by 2047. The transformation of agriculture—still is a primary source of livelihood for the majority of rural households—into a vibrant, technology-driven, and youth-led sector is imperative. Agripreneurship, which integrates agriculture with innovation and entrepreneurship, is emerging as a powerful tool to uplift rural communities, empower youth, and foster economic inclusion. This research paper investigates how agripreneurship can be promoted among rural youth to support India's development vision.

Youth in rural India face high levels of unemployment and are often disinterested in traditional farming due to its limited profitability. However, when paired with startup models, digital tools, and market linkages, agriculture offers untapped potential. The paper reviews existing literature on agripreneurial trends, government schemes like Start-Up India and RKVY-RAFTAAR, and highlights successful innovations in the field. Through secondary research and case study analysis, the study identifies barriers such as lack of entrepreneurial training, credit access, and inadequate rural infrastructure. It recommends targeted interventions including incubators in Agri-universities, customized training programs, and digital literacy drives.

This research contributes to the policy discourse by proposing sustainable models of agripreneurship that align with the goals of Atmanirbhar Bharat and Viksit Bharat. By harnessing the entrepreneurial potential of rural youth, India can transform its agricultural sector into a hub of innovation, job creation, and inclusive growth.

Keywords: Agripreneurship, Start-up & Innovation, Viksit Bharat

Studies on management of Anthracnose of mung bean caused by *Colletotrichum lindemuthianum*

Ashish Kumar [1*], Prabhakar Patel[1], Stuti Sharma[2], R. Shivrama Krishnan[3], Radheshyam Sharma[4], Anurag Chouhan[1] and Akshay Kumar Khare[1]

[1]Department of Plant Pathology, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh 482004

[2]Department of Plant Breeding and Genetics, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh 482004

[3] Department of Plant Physiology, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh 482004

[4]Department of Biotechnology, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh 482004

Corresponding author's email: ashishashish2612@gmail.com

ABSTRACT

Mung bean (*Vigna radiata* L.), a key short-duration pulse crop cultivated extensively in India, is often vulnerable to seed-borne fungal pathogens, which severely compromise seed quality, germination, and ultimately yield. Among these, *Colletotrichum lindemuthianum*, the incitant of anthracnose, is of major concern due to its widespread occurrence, rapid spread, and ability to survive in and transmit through seed. This study was undertaken to evaluate the efficacy of various natural farming formulations, botanicals, fungicides, and biocontrol agents for disease suppression and seed quality enhancement. Among the different natural farming formulation including Beejamrit (5%), Jeevamrit (10%), Kunapajal (10%), and cow urine (10%), Beejamrit (5%) significantly enhanced seed germination (93.33%), seedling vigour, and root-shoot length, resulting in the highest seed vigour index (2434.67). The application of *Trichoderma asperellum* (1×10^8 cfu/ml) and *Pseudomonas fluorescens* also contributed to disease suppression and seedling health, demonstrating their biocontrol potential. Fungicidal treatments showed marked efficacy, with Difenoconazole (0.1%) and Carbendazim (0.5%) showing maximum improvement in germination percentage, root length, and vigour index, while simultaneously reducing seed infection by *C. lindemuthianum* and *F. oxysporum*. *In vitro* screening of botanical extracts further revealed that 15% aqueous extracts of *Ocimum tenuiflorum* (tulsi) and *Azadirachta indica* (neem) were highly effective in inhibiting the mycelial growth of *C. lindemuthianum*. Among systemic and combination fungicides tested in dual culture assays, Propiconazole 25% EC and Azoxystrobin + Difenoconazole 200 SE at 1000 ppm exhibited complete inhibition of fungal growth. This study clearly demonstrated promising role of natural farming inputs, biocontrol agents, and eco-friendly botanicals in improving seed health. Furthermore, the efficacy of targeted chemical fungicides, particularly in integrated disease management (IDM) strategies, highlights the need for tailored and sustainable approaches for managing anthracnose and associated seed-borne fungi.

Youth-Led Agripreneurship: A Catalyst for Rural Employment and Inclusive Growth

Dr Tejinder Singh Riar[1], Dr Poonam Sachdev[2] And Karanvir Singh

Punjab Agribusiness Incubator

Punjab Agricultural University, Ludhiana

Corresponding author's email:

ABSTRACT

Youth engagement in agriculture through entrepreneurship is reshaping the landscape of rural employment in India. This study explores how young agripreneurs, supported by incubation ecosystems, are generating sustainable livelihoods while addressing core challenges in agriculture. Drawing on field experience from the Punjab Agri Business Incubator (PABI) at Punjab Agricultural University, Ludhiana, the paper highlights youth-led startups engaged in black soldier fly-based animal feed, fortified snack production, and bio-waste recycling as key examples of scalable rural enterprise models. The study analyses the multidimensional impact of such ventures—including job creation, local sourcing, women's employment, and climate resilience. It also reflects on the crucial role of institutional support in capacity building, prototype validation, funding access, and market linkages. The success of these startups demonstrates that with appropriate handholding and policy support, youth can be positioned not just as beneficiaries, but as drivers of agrarian transformation. The paper concludes with recommendations for building a supportive agri-entrepreneurial ecosystem at the grassroots level, emphasizing the need for integration of incubation support with rural skilling programs and FPO networks. These insights are intended to inform both academic discourse and policy frameworks focused on inclusive, youth-centric agricultural development.

Mushroom cultivation as an enterprise in Karnataka

Sanath Totiger[1], Mallikarjun Havinal[2] and Manjunath Hiremath[3]

University of Agricultural Sciences Dharwad- 580005

Corresponding author's email: sanathtotiger47@gmail.com

ABSTRACT

Mushroom cultivation has emerged as a promising agribusiness in Karnataka, offering significant opportunities for income generation, nutritional security, and rural employment. The state's diverse agro-climatic zones, particularly in regions like Malnad and the Western Ghats, provide a conducive environment for growing various mushroom species, including oyster (Pleurotus spp.), button (Agaricus bisporus), and milky mushrooms (Calocybe indica). Technically, mushroom cultivation involves key stages such as substrate preparation, pasteurization or sterilization, spawning (inoculation of mushroom seed/spawn), incubation, and controlled environmental management for fruiting. Substrates like paddy straw, sugarcane bagasse, and sawdust are commonly used, and maintaining ideal conditions of temperature (20–30°C), humidity (80–90%), and ventilation is crucial for optimal yield.

This low-investment, high-return enterprise is increasingly attracting small and marginal farmers, women self-help groups (SHGs), and urban entrepreneurs. With support from institutions such as the University of Agricultural Sciences, Dharwad, and various Krishi Vigyan Kendras (KVKs), technical training, spawn production facilities, and market linkages are becoming more accessible. Despite the potential, challenges such as inadequate cold storage, perishability, pest and disease management, and limited consumer awareness persist. Nevertheless, with proper capacity building, infrastructure development, and value addition (e.g., mushroom pickles, powders, and fortified products), mushroom cultivation in Karnataka can evolve into a sustainable rural enterprise and contribute significantly to the state's agrarian economy.

Agri-Voltaic: A Win-Win-Technology for Sustainable Future

Ramkishor Kurmi[1], Shivam Chaubey[1], Gaurav Kumar[1], Shubham Chaudhary[1]

[1]PhD Scholar, Division of Agricultural Engineering ICAR-Indian Agricultural Research Institute, New Delhi-110012

[Corresponding Author Email ID: ramkishorkurmi5103@gmail.com]

ABSTRACT

Agri-voltaic technology, which integrates photovoltaic (PV) systems with agricultural practices, presents a promising dual-use approach to land management, offering a sustainable solution to the growing demand for clean energy and food production. This innovative system enables simultaneous harvesting of solar energy and cultivation of crops on the same land, thereby maximizing land use efficiency and reducing land-use conflicts. The deployment of elevated or spatially optimized PV arrays above croplands allows sufficient solar radiation to reach plants while simultaneously capturing energy. The partial shading created by the PV modules contributes to a moderated microclimatic environment by reducing surface temperatures and evapotranspiration rates, which can enhance plant physiological responses, particularly in water-stressed and arid agroecological zones. The yield improvements in shade-tolerant crops and significant reductions in irrigation water requirements are reported outcomes under Agri-voltaic technology. The synergy between solar panels and crops promotes environmental sustainability, boosts farm income, and supports climate resilience in rural economies. This win-win technology aligns with the goals of sustainable development by addressing food-energy-water nexus challenges. As global concerns about climate change, food security, and energy scarcity intensify, agri-voltaic systems emerge as a viable and scalable solution for a more sustainable and self-reliant future.

Keywords: Agri-voltaic, Sustainable crop production, food and energy security

Integration of Renewable Energy Systems for Small-Scale Farm Mechanization

Gaurav Kumar[1*], Abhishek Kumar Ansh[1], Shubham Chaudhary[1], Abhishek Pandey[1] and Nidhi Rani[2]

[1]Research Scholar, Division of Agricultural Engineering, ICAR-Indian Agricultural Research Institute, New Delhi 110012

[2]Research Scholar, Indian Institute of Technology, Kharagpur

*Corresponding author's email: gaurav28998@gmail.com

ABSTRACT

The integration of renewable energy in farm mechanization provides a sustainable solution to rising energy costs and environmental challenges. Smallholder farmers face difficulties due to the high cost and limited availability of fuel-based machinery. Renewable energy-powered solutions like solar pumps, solar threshers and mini-tractors offer clean, reliable, and cost-effective alternatives. Bioenergy systems such as biogas plants and crop residue-based power reduce fossil fuel dependency. Hybrid systems using solar, wind, and battery storage ensure continuous operation of farm equipment. Energy-efficient designs improve the performance of small implements and optimize energy use. Economic studies show significant savings and better profitability for small farms using these technologies. Custom hiring centres powered by renewable energy can create entrepreneurship opportunities for rural youth. These centres make advanced machinery affordable and also generate rural employment. Renewable-powered mechanization reduces greenhouse gas emissions and supports carbon neutrality goals. Skill development in renewable energy technology including installation and maintenance is essential for youth empowerment. Government schemes, subsidies, and financial support can accelerate the adoption of these solutions. Startups focusing on renewable-powered agricultural equipment have great potential to transform rural economies. Renewable energy-based mechanization, supported by policies and youth-led entrepreneurship, can enhance farm productivity and profitability. This approach promotes energy security, resource conservation, and environmental sustainability while building a resilient and prosperous agricultural sector.

Keywords: Renewable energy, Mechanization, Energy security, Environment

A Comprehensive Analysis of GPS Applications Across Agricultural Disciplines

Abhishek Kumar Ansh1*, Gaurav Kumar1, Sambhu Singh2

1 Research Scholar, Division of Agricultural Engineering, ICAR-IARI, New Delhi

2 Senior Research Fellow, Division of Agricultural Engineering, ICAR-IARI, New Delhi

Corresponding author: anshabhishekiitkgp@gmail.com

ABSTRACT

The Global Positioning System (GPS) has a lot of applications in agriculture and allied sectors. A comprehensive literature search was conducted across multiple scientific databases, yielding 342 articles from peer-reviewed sources. Following quality assessment based on relevance, methodological rigor, and publication recency, 203 studies were selected for analysis. The selected literature was categorized into six agricultural disciplines: farm machinery and power systems, soil and water conservation, animal and livestock management, alternative energy sources, food transportation and packaging, and horticulture. Analysis revealed that machinery monitoring, navigation, and control applications dominated the literature, representing the most extensively researched GPS applications in agriculture. Additional significant applications included animal tracking systems, weather forecasting integration, and agricultural land surveying for precision farming implementation. The review demonstrates that GPS technology offers substantial potential for enhancing agricultural productivity through location-based services and site-specific management practices. Findings indicate widespread applicability of GPS systems across diverse agricultural operations, supporting precision agriculture adoption at commercial scales. The synthesized knowledge provides agricultural researchers and practitioners with a comprehensive understanding of current GPS applications and identifies opportunities for future technological integration in sustainable farming systems.

Keywords: Precision agriculture, site specific, monitoring, sensors, GPS

Farmer’s perception and determinant of horticultural crops in nagaland and manipur states

Prof. Amod Sharma and Th Motilal Singh*

Senior Professor & Ex. Head, Department of Agricultural Economics

School of Agricultural Sciences, Nagaland University

Medziphema Campus, District: Chumoukedima-797106 (Nagaland)

* In charge, PC & SMS (Extension), ICAR for NEH Region, KVK, Imphal (Manipur)

Corresponding author’s e-mail:

ABSTRACT

The present research work was undertaken to known about the farmer perception and determinant for adoption the horticultural crops and major production constraints faced by them, by selecting 50 respondents each from Dimapur and Kohima districts of Nagaland and 50 respondents each from Senapati and Thubal districts of Manipur by using purposive stratified simple random sampling technique with the help of data collected through personnel interview methods during the Agricultural calendar year 2019 to 2022 (contain 3 years survey field data). About the farmer’s perceptions for the horticultural crops in the study area viz; pineapple and chilli both were selected due to the prominent crops; based on benefit-cost ratio pineapple crops of Nagaland was recorded as highest (3.31: 1) returns, followed by pineapple crop of Manipur (3.01: 1) state; also based on benefit: cost ratio, chilli crop of Manipur was recorded highest (2.70: 1) returns, followed by chilli crop of Nagaland (2.76: 1) state, respectively. About the perception level it increases by maximum 17 per cent for Dimapur Pineapple, followed by Thoubal Chilli was 16 per cent, Kohima Chilli was 12 per cent and minimum Senapati Pineapple was 10 per cent, respectively. About the major constraints faced by the respondents during the production the foremost was due to need of high investment on inputs, followed by size of land holding and lack of technical knowledge, respectively.

Keywords: Nagaland, Manipur, Perception, Determinant, Horticultural crops.

Climate-resilient farming a youth-centric pathway to India's prosperity

Dr. Sanjay K. Dwivedi
Principal Scientist/Professor, Department of Agronomy, College of Agriculture
Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, 492012,
Corresponding author's e-mail: skd@igkv.ac.in, sanjayigau@gmail.com

ABSTRACT

Climate change poses a serious threat to global food security and India's agrarian economy, necessitating a transition to more resilient farming practices. This abstract proposes youth entrepreneurship in climate-resilient agriculture (CRA) as a pathway to sustainable prosperity, with a focus on rice-based cropping systems. Implementing robust Climate-Resilient Agriculture (CRA) interventions is vital for India's agricultural sector, especially for rice, a global staple. Key interventions include adopting Direct Seeded Rice (DSR) over Puddled Transplanted Rice (PTR) a low-cost, water-efficient, and machine-based method particularly suitable for youth to establish custom hiring centers at the local level. DSR significantly enhances water and environmental sustainability by reducing water consumption and methane emissions, while maintaining productivity. Complementary practices such as conservation agriculture, optimized crop establishment, weed management and precise nutrient management are also crucial for improving productivity and profitability in systems like rice–linseed.

Linseed, cultivated on 1.75 lakh hectares, with a production of 1.13 lakh tons & average productivity of 644 kg ha^{-1} in India during 2023-24. It offers diverse economic potential. Its seeds, rich in protein, can fortify foods. Crucially, linseed fiber presents a robust opportunity for high-value products like textiles and handicrafts. Projects like ICAR, NAHEP-W2W have demonstrated success, increasing yields by up to 50% and empowering rural youth through linseed yarn product development. This creates youth income streams, aligns with sustainability goals and fosters rural economic growth, self-reliance and innovation.

Hence, research on various aspects such as suitable crop establishment methods (including mechanization), balanced nutrient management practices, weed management interventions for Direct Seeded Rice (DSR) and linseed production technologies (including fiber extraction and value addition) has been conducted and field-validated over the past five years.

In conclusion, integrating scientific CRA advancements with strategic youth engagement is critical for India's sustainable development. By promoting DSR, optimizing rice-linseed systems, and fostering entrepreneurship in linseed fiber, India can simultaneously enhance food security, environmental sustainability and create economic opportunities for its youth, paving the way for a prosperous future.

Keywords: Climate-Resilient Agriculture, Youth, Direct Seeded Rice (DSR), Linseed

Socio-economic Impacts of Climate Change on Indian Agriculture

Palak, Vikash Tyagi[1], Bijendra Singh[1], Sudhanshu Singh

College of Agriculture

Department of Vegetable Science, Collage of Horticulture

Sardar Vallabhbhai Patel University of Agriculture and Technology Meerut, U.P.

Corresponding author's email: palakbaliyan4545@gmail.com

ABSTRACT

The ultimate impact of climate change on human systems will depend on the natural resilience of ecosystems on which societies rely as well as adaptation measures taken by agents, individually and collectively. The analysis of impact of climate change on agriculture in India is an important exercise as it deals with food security of more than a billion people. This study uses an integrated modeling framework to assess the socio-economic impacts of climate change on Indian agriculture. Crop simulation model is used to estimate the yield changes under various climate change scenarios for two main cereal crops, rice and wheat. Aggregated crop yield changes are then introduced as gradually occurring supply shocks to the economy in an applied general equilibrium model and the socioeconomic impacts of climate change are assessed. The results indicate that the projected large changes in the climate would lead to significant reductions in the crop yields, which in turn adversely affect the agricultural production. The economic and welfare impacts, captured through change in indicators such as value added and calorie intake, show that climate change would place significant burden on the economy. The results also show that people in the poorer sections of the population are likely to bear a greater share of the burden imposed by the climate change. Consideration of carbon fertilization effects resulted in reducing the adverse impacts to some extent. The study also discusses the role of various policies in ameliorating the negative impacts of climate change.

Key words: Climate Change, Indian Agriculture, Economic Impacts

Promoting Agripreneurship Among Rural Youth for Viksit Bharat: A Case Study from Naxal-Affected Tribal Jharkhand

Navneet Prabhakar Sukla

Ph.D. Scholar, Department of Economics, PGCA, RPCAU, Pusa, Bihar, India

Corresponding author's email: navneetprabhakarsukla@gamil.com

ABSTRACT

Agripreneurship is defined as the integration of agricultural activities with entrepreneurial strategies that represents a powerful mechanism for transforming India's rural youth from job seekers into job creators. Aligned with the national vision of *Viksit Bharat@2047*, which aspires to build a self-reliant, inclusive, and developed India, agripreneurship has the potential to revitalize rural economies, address unemployment, and deter illicit practices. This study examines agripreneurial interventions in the Naxal-affected tribal region of Arki block, Khunti district, Jharkhand, where agriculture is often constrained by poverty, marginalization, and historical dependence on illegal opium cultivation. The research was conducted through action-based fieldwork under the author's leadership as CEO of a Farmer Producer Organization (FPO), focusing on two sustainable agribusiness models: mushroom cultivation and marigold flower farming. Farmers were particularly former opium growers and landless laborers were mobilized and trained in scientific cultivation, value addition, and market linkage strategies. In the mushroom model, participants adopted button mushroom production using low-cost kits (₹190) with assured buyback and linkages with CRPF camps, supported by doorstep delivery and FSSAI certification. In the marigold model, saplings sourced from West Bengal enabled farmers to enter underserved markets in Tamar block, particularly during festive seasons, despite initial weather-related setbacks. Both models demonstrated significant success: mushroom growers reported a tenfold rise in demand for subsequent cycles, while flower farmers accessed previously untapped market opportunities, building economic confidence and managerial capacity. The findings suggest that targeted agripreneurship interventions, when supported by institutional frameworks, training, and assured marketing, can serve as effective tools for rural transformation. These localized, scalable models not only offer viable alternatives to illicit economies but also present replicable pathways to achieving inclusive development in remote tribal and conflict-affected areas of India.

Natural Farming: A Way Forward for Sustainable Crop Protection

Suman Samui

Dept. of Agriculture, Central University of Odisha, Koraput-763004

Corresponding author's email: sumansamui369@gmail.com

ABSTRACT

Natural farming, which has its roots in ancient Indian agricultural science, incorporates ideas from the *Vedic Agricultural System* and *Vrikshayurveda*. Over 6.5 lakh hectares of agricultural land in 11 states in India already use this technique, and its sustainability and effectiveness are becoming more widely acknowledged. With an emphasis on ecological balance and the eliminating of synthetic chemicals, natural farming is becoming a viable substitute for conventional agriculture. It uses traditional methods and natural inputs to support food safety, biodiversity, and soil health. With the help of programs like the Bharatiya Prakritik Krishi Paddhati Programme (BPKP) and the Paramparagat Krishi Vikas Yojana (PKVY), natural farming seeks to improve rural development, lessen the reliance on purchased inputs, and ease the financial burden on smallholder farmers. States like Andhra Pradesh, Madhya Pradesh, Chhattisgarh, Kerala, Odisha and Himachal Pradesh have adopted it at scale, recognizing its potential to reduce input costs and environmental damage. The approach focuses on four key components: *Jeevamrut* (a microbial culture), *Beejamrut* (seed treatment), *Achhadana* (mulching), and *Waaphasa* (soil aeration). These practices enhance plant immunity and reduce pest incidence naturally. For crop protection specifically, natural farming employs techniques such as the use of botanical extracts (e.g., neem, garlic-ginger sprays), cow-based formulations like *Agniastra* and *Brahmastra*, biological control agents, trap cropping, and intercropping. These methods not only deter pests but also preserve beneficial organisms and enhance biodiversity on farms. Its low-cost approach is especially beneficial for small and marginal farmers. However, wider adoption requires awareness, scientific validation, and policy support. Natural farming not only reduces chemical dependency but also builds resilience against climate variability. Under the conditions of climate change, achieving food security would necessitate a holistic system approach that incorporates natural agricultural principles for a sustainable agriculture. By blending traditional knowledge with ecological principles, it offers an effective, low-input solution to modern agricultural challenges.

Keywords: Climate change, Crop protection, Natural farming, Sustainability.

Nanopesticides in Crop Protection: A Sustainable Strategy to Reduce Chemical Residues and Resistance

Souvik_Mohanty[1], Th. Robindro Singh[2], and Nilima Karam[1]

[1]Department of Entomology, College of Agriculture, Central Agricultural University, Imphal, 795004, Manipur, India

[2] Deputy Director Extension Education, DEE, Central Agricultural University, Imphal, 795004, Manipur, India

Corresponding author's e-mail: souvikmohanty@outlook.com

ABSTRACT

The intensive use of conventional pesticides in agriculture has enabled effective crop protection but has also resulted in increased chemical residues in food and the environment, as well as growing pest resistance. These trends highlight the urgent need for more sustainable approaches to pest management. Nanopesticides offer a transformative approach, lowering chemical use, reducing contamination and curbing pest resistance through utilization of advancements in nanotechnology to deliver active ingredients with greater precision. Recent field studies have demonstrated that these formulations can achieve equal or even superior pest control using significantly reduced doses, resulting in fewer chemical residues in crops, soil and water while also lowering agriculture's environmental footprint**.** The shift toward nano-pesticides is gaining momentum, with significant progress being made in the agricultural sector, reflecting a strong focus on innovative and eco-friendly crop protection solutions. Recent developments in nano-pesticide research, such as nanoemulsions, suspensions, encapsulation plant-based nanomaterials and bio-inspired formulations marks a significant step towards sustainable crop prrotection, controlled release of nanoformulation of imidacloprid and controlled release formulation of ethofenprox have used extensively for pest control also rotenone have demonstrated strong efficacy against major crop pests, while innovations like "smart" nanocarriers designed for sustained release and improved plant surface adhesion are further enhancing the efficiency, safety and performance of these products.. Their mainstream adoption could enable safer food production and healthier ecosystems, advancing sustainable agriculture.

Keywords: Nanopesticides, nanoemulsions, nanocarriers

An economic analysis of pearl millet (pennisetum glaucum l.) In alwar and jaipur districts of rajasthan

Amit Kumar[1], Amod Sharma[2], Sanjoy Das[3], Nikhil Nikas[4]

[1]Research scholar, Department of Agricultural Economics, School of Agricultural Sciences, Medziphema, Nagaland University-797106

[2]Sr. Professor, Department of Agricultural Economics, School of Agricultural Sciences, Medziphema, Nagaland University-797106

[3]Prof, Department of Agricultural Economics, School of Agricultural Sciences, Medziphema, Nagaland University-797106

[4]Research scholars, Department of Agricultural Economics, School of Agricultural Sciences, Medziphema, Nagaland University-797106

Corresponding author's e-mail: amitchoudhary9950345694

ABSTRACT

The research entitled "**An Economic Analysis of Pearl Millet (*Pennisetum glaucum* L.) in Alwar and Jaipur Districts of Rajasthan**" was carried out for the agricultural year 2023–24. It involved primary data collection from a total of 112 pearl millet cultivators, categorized by landholding size into marginal, small, semi-medium, medium, and large farmers, along with 12 market participants including traders and retailers. The study examined long-term trends in pearl millet cultivation using Compound Growth Rate (CGR) analysis for the period 2006 to 2023. At the state level, the area under cultivation recorded a statistically significant decline of 1.14%, while productivity increased significantly by 3.02%; however, the growth in production (1.84%) was statistically insignificant. In Alwar district, cultivated area expanded significantly by 1.58%, with positive but non-significant changes in production (3.88%) and significant improvements in productivity (2.26%). Jaipur district exhibited a marginal and insignificant growth in area (0.29%), whereas production and productivity rose significantly by 3.19% and 2.89%, respectively. Cost analysis revealed that large-scale farmers incurred the lowest per hectare cultivation cost (Rs. 31,542.49), with the total cost increasing as farm size decreased. Similarly, gross and net farm incomes were highest among large farmers. Variable costs accounted for over 75% of total cultivation expenses, with machinery and manures being the largest contributors. The Benefit-Cost (B:C) ratio was also most favorable for large farmers, standing at 2.31. Regarding market structure, the majority of pearl millet (61.48%) was marketed through Channel-3 (Producer → Trader (Agent) → Wholesaler → Retailer → Consumer), though it involved the highest marketing cost (Rs. 156.67 per quintal). Conversely, Channel-1 (Producer → Consumer) accounted for only 15.38% of sales but demonstrated the highest marketing efficiency (33.28). The study identified several production constraints including inadequate irrigation, pest and disease prevalence, and heavy weed infestations. In marketing, the lack of a minimum support price was found to be a critical issue. Based on these findings, the study recommends the development of irrigation infrastructure, promotion of integrated pest management (IPM) practices, introduction of pest-resistant cultivars, implementation of price support mechanisms, and improvements in storage and transportation facilities.

Keywords: pearl millet, trends, economic, marketing, constraints

Assessments of the genetic divergence among the tomato germplasms

Sudhanshu Singh[1]*, Bijendra Singh[1], Vikash Tyagi[1], Raj Kumar[2], Vivek Kumar[2], Satya Prakash[1], and Vipin Kumar[1]

[1]Department of Vegetable Science, College of Horticulture, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, U.P. India.

[2]Department of Genetics and Plant Breeding, College of Agriculture, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, U.P. India

Corresponding author's e-mail: singhsudhanshu.16896@gmail.com

ABSTRACT

The presence of diverse genotypes and their identification is a major requirement for any crop improvement program. Current study aims to estimate the genetic diversity present in 48 tomato genotypes using D2 analysis. Experiment was conducted during Rabi 2022-2023 and Rabi 2023-2024 using 48 diverse genotypes at the Horticulture Research Centre, located at Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, following Randomized Complete Block Design within three replications. Genetic diversity analysis revealed that in both seasons of 2022-2023 and 2023-2024, including pooled analysis of 48 genotypes, was categorized into six clusters. The distribution of genotypes of pooled data indicated that clusters V and VI (10 each) comprise the highest number of genotypes. The mean of clusters revealed that the fruit yield per plant was highest in cluster I in pooled analysis. The maximum inter-cluster distance in the 2022-2023 season was observed between clusters I and III, while in 2023-2024, it was between clusters III and IV and, in pooled data, between clusters I and III. Pooled analysis revealed that selection of genotypes from clusters having the highest inter-cluster distance, like cluster I (Kashi Amul, Kashi Shardul, Punjab Chhuhara, Naveen, EC-620441, EC-617055, EC-620482 and EC-631404) and III (Pusa Ruby, Pusa Gavaru, Pusa Upakr, Pusa Sheetal, KashiAmrit, Moany Makar and EC-620440), can be further selected for generation of genetic variation to exploit heterosis in other breeding programs.

Key words: Tomato, Genetic diversity, D2 analysis, Germplasm.

Studies on genetic diversity and management of Macrophomina phaseolina (Tassi) Goid causing charcoal rot of soybean

Anurag Chouhan [1*], Ashish Kumar[1], Stuti Sharma[2], Radheshyam Sharma[3], R. Shivrama Krishnan[4], Nishi Mishra[5] and Akshay Kumar Khare[1]

[1]Department of Plant Pathology, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh 482004

[2]Department of Plant Breeding and Genetics, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh 482004

[3]Department of Biotechnology, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh 482004

[4]Department of Plant Physiology, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh 482004

[5]Seed Technology Research Centre, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh 482004

Corresponding author's email: anuragchouhan2712@gmail.com

ABSTRACT

Soybean (*Glycine max* L.) is a vital oilseed crop significantly affected by charcoal rot, a destructive disease caused by the soil-borne necrotrophic fungus *Macrophomina phaseolina* (Tassi) Goid. The present study was conducted to assess the cultural and genetic variability among ten different isolates of *M. phaseolina* representing five agro-climatic zones of Madhya Pradesh. Cultural characterization revealed that Potato Dextrose Agar (PDA) and Oat Meal Agar (OMA) were most effective for promoting radial growth of the pathogen, whereas Richards Agar (RA) supported maximum microsclerotia production. Genetic diversity was estimated using six RAPD and seven ISSR markers. RAPD analysis generated 41 amplicons, of which 36 (86.50%) were polymorphic, with an average PIC value of 0.333. The primer OPA-09 exhibited the highest PIC value (0.426). In ISSR analysis, 34 out of 45 amplicons (73%) were polymorphic, with an average PIC value of 0.253, and the primer LMB-C showed the highest PIC value (0.407). All the isolates could be grouped into two major clusters which were corelated with each other based on virulence of the isolates as well as location of diseased samples. Further, fungicidal evaluation revealed that among 12 fungicides, Carbendazim 25% + Mancozeb 50% WS, Tebuconazole 25.9% w/w EC and Carbendazim 50% WP exhibited 100% inhibition of *M. phaseolina* at all tested concentrations (100, 250, and 500 ppm). These findings provide crucial insights into the variability and management of *M. phaseolina*, contributing to effective disease control strategies in soybean cultivation.

Keywords: *Macrophomina phaseolina,* soybean, charcoal rot, genetic diversity

Conservation Agriculture as an option to revitalize rural income and environmental stewardships

Tarun Sharma[1*], Nishant[2], Lalit Kumar Mainway[1] and Yash Rahangdale[1]

[1]Division of Agronomy, ICAR-Indian Agricultural Research Institute, New Delhi 110012

[2]Division of Vegetable science, ICAR-Indian Agricultural Research Institute, New Delhi 110012

*Corresponding author's email: tarun.sharma06620@gmail.com

ABSTRACT

Conservation agriculture (CA) significantly contributes to improving rural incomes by promoting sustainable and cost-effective farming practices that enhance soil health and agricultural productivity. The core principles of CA: minimal soil disturbance (no-till), permanent soil cover (residue retention), and crop diversification (rotations/intercropping) help restore and maintain soil organic matter, improve soil structure, and increase microbial activity. These biological and physical improvements enhance the soil's ability to retain moisture and nutrients, reducing the need for expensive external inputs such as chemical fertilizers, irrigation, and pesticides. As a result, farmers experience lower production costs and higher input-use efficiency, which directly improves their profit margins. Moreover, improved soil health under CA leads to more stable and resilient crop yields, even in the face of climatic variability such as droughts or irregular rainfall. This resilience provides greater income security for small and marginal farmers who are often the most vulnerable to weather-related shocks. Crop diversification further allows for risk reduction and income enhancement by enabling farmers to grow high-value crops, pulses, or fodder in rotation, thereby meeting both market and household needs. In the long term, CA prevents land degradation and conserves the natural resource base, ensuring sustained agricultural productivity. This is particularly crucial in rural areas where farming is the primary livelihood. Additionally, the potential for carbon credit incentives and ecosystem service payments under CA opens up new income avenues for rural communities. By integrating ecological sustainability with economic viability, conservation agriculture not only supports better soil health but also fosters inclusive rural development, increased food security, and improved livelihoods for farming households. Thus, CA serves as a practical and scalable approach to revitalizing rural economies while ensuring environmental stewardship.

Keywords: Soil health, carbon credit, no-tillage

Promoting Agripreneurship Among Rural Youth for Vikasit Bharat

Nitin Mehetre [1*], Ashwini Jadhav [2], Arun Shelke [3]

[1&2]Department of Agricultural Botany

[3]Department of Agronomy

Samarth Agriculture College Deulgaon Raja, Dist. Buldhana 443204 Maharashtra

Corresponding author’s email: nitinmehetre29@gmail.com

ABSTRACT

The Indian government has created the "Viksit Bharat 2047" agenda which aims to transform India into a developed nation by 2047. One important aspect of this plan is the role of agriculture in India's development strategy. This paper focuses on promoting an Agripreneurship Revolution and Exploring the impact of Agripreneurship on rural livelihood to address several challenges faced by Indian agriculture, such as low productivity, limited financial resources, small landholdings, outdated techniques and environmental damage. The plan outlines various government interventions in infrastructure, human potential, culture, economics, society and ecology to achieve the goal. Strategies like promoting agripreneurship in dairy, goatry, poultry, seed production, sericulture, floriculture, mushroom production, fish farming, agriclinic center, biopesticides & chemical pesticide unit, food processing unit, modernizing agricultural markets, supporting agri-startups, encouraging organic farming and empowering smallholders through cooperative projects are essential. There is a need for robust legislative frameworks to tackle structural challenges such as farmer debt, timely crop insurance schemes and regional disparities in rural credit accessibility. Emphasis is given to increasing the interest of educated young people in farming and establishing a trend to boost rural economies, along with the challenges and benefits that come with it. The paper also stresses the importance of ecological sustainability and supports organic farming methods to enhance climate change resistance and support biodiversity conservation. It underscores the urgency to move towards agroecological principles to ensure food security, environmental sustainability and inclusive rural development. By adhering to this roadmap & promoting agripreneurship among rural youth, India can achieve its vision of a prosperous, equitable, and sustainable agricultural sector and contribute significantly to the overall goal of Viksit Bharat.

Keywords: Viksit Bharat, Agri-startups, Agripreneurship, Organic Farming, Seed Production Food Security, Rural Development.

Green insecticides: Use of Botanicals and Biopesticides for Pest Management In Sustainable Agriculture

Nikita Talukdar[1], Jeti Konsam[2] and Nilima Karam[3]

Department of Entomology, College of Agriculture, Central Agricultural University, Imphal, 795004, Manipur, India

Corresponding author's e-mail: nikitatalukdar16@gmail.com

ABSTRACT

The rising emphasis on sustainable agriculture has spurred greater interest in eco-friendly crop protection, particularly through the use of botanicals and biopesticides for pest resistance management. Botanical pesticides and biopesticides, derived from plant extracts and microorganisms, are valued for their low toxicity, rapid biodegradation, and minimal impact on beneficial organisms. Recent research highlights the effectiveness of plant-based compounds like azadirachtin, pyrethrin, limonene, etc against major crop pests, while field trials conducted across different regions in Asia and Africa demonstrate significant reductions in pest damage and post-harvest losses when botanicals are incorporated into crop management systems. For instance, neem-based formulations exhibit insecticidal, repellent, and antifeedant properties against aphids and whiteflies while microbial biopesticides like *Bacillus thuringiensis*, *Beauveria bassiana*, etc. specifically infect and suppress insect pests. Innovations such as nano-formulations and nano-emulsified botanical oils such as neem oil nanoformulations have improved the stability and delivery of these natural agents, boosting their efficacy in the field, with some studies reporting higher pest mortality compared to conventional treatments. Botanicals are increasingly recognized for their ability to disrupt pest biology, deter oviposition, and suppress feeding mechanisms that contribute to sustainable pest control without promoting resistance. In India, large-scale adoption of crop-specific botanicals and biopesticides has been supported by farmer training and field demonstrations, leading to improved yields and lower pesticide residues. The integration of green insecticides into pest management not only helps manage resistance but also promotes biodiversity and supports beneficial insect populations including natural enemies, establishing these natural solutions as a cornerstone of future sustainable agriculture.

Keywords: Botanicals, Bio-pesticides, Crop Protection

A Review of Indian Agriculture's Journey from Food Scarcity to Food Surplus

Shripati Dwivedi[1]*and D.K. Sinha[2]

[1]Assistant Professor, Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar, India-848125

[2]Rted. Professor, Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar, India - 848125

Corresponding author's e-mail: shripati3165@gmail.com

ABSTRACT

Agriculture is the backbone of Indian economy and about 49.6% of the workforce is employed in this sector, and contributes about 17% of the country's gross domestic product (GDP). India has undergone significant economic transformations, especially agriculture since independence. It is a great achievement for India that was severely food scarce in the mid-1960s to become food surplus in 2020-21 by exporting rice, wheat and different agricultural commodities. Similarly, breakthroughs in poultry, fisheries, fruits and vegetables, cotton, and cotton crops. It was possible to make all this happen through modern technology, institutional innovations, and government policies that allowed farmers to participate in this change and enabled cultivators to receive the right kind of incentives. This has the potential to benefit many developing nations in South Asia, South East Asia, and Africa. However, India still faces many food security challenges during present era when global warming is the major issue in front of whole world. As water tables are decreasing rapidly throughout the country, agricultural production begs the question of sustainability, and malnutrition rates are high among children. Agri-households earn little money largely due to small holdings, so the food system must change from 'tonnage centric' to farmer and market centric. By introducing digital technologies in agriculture and building efficient supply chains with Farmer Producer Organizations, India is focusing the next technological revolution to promote efficiency, inclusion, and sustainability. This paper discuses the journey of Indian agriculture from food scarce to food surplus.

Keywords: GDP, Economic transformations, Food surplus, Food scarce and Sustainability.

Blockchain Technology In Agricultural Marketing: Enhancing Transparency And Efficiency In India

Nikhil Nikas [1], Amod Sharma[2], Amit Kumar[3], Sonu Kumar[4], Vipul Kumar Mishra[5]

[1]Research scholar, Department of Agricultural Economics, School of Agricultural Sciences, Medziphema, Nagaland University-797106

[2]Sr. Professor, Department of Agricultural Economics, School of Agricultural Sciences, Medziphema, Nagaland University-797106

[3]Research scholars, Department of Agricultural Economics, School of Agricultural Sciences, Medziphema, Nagaland University-797106

[4]Research scholars, Department of Agricultural Economics, School of Agricultural Sciences, Medziphema, Nagaland University-797106

[5]Research scholars, Department of Agricultural Economics, School of Agricultural Sciences, Medziphema, Nagaland University-797106

Corresponding author's e-mail: nikhilnikas15@gmail.com

ABSTRACT

The agricultural marketing system in India is often hindered by inefficiencies such as non-transparent pricing, delayed payments, product adulteration, and a lack of trust among stakeholders. This study explores the transformative potential of blockchain technology in streamlining the marketing of agricultural commodities, with a focus on enhancing traceability, transparency, and efficiency across the supply chain. Blockchain's decentralized and tamper-proof ledger enables real-time tracking of commodities, secure peer-to-peer transactions, and the use of smart contracts for automated payment settlements. Through case studies of emerging platforms such as Agri10x, Ninjacart, and DeHaat, this research examines the practical implementation of blockchain solutions in connecting farmers directly to markets, reducing intermediaries, and ensuring quality compliance. The findings suggest that blockchain enhances farmers' income through better price discovery, increases buyer trust through transparent logistics, and facilitates faster transaction cycles. However, challenges such as digital illiteracy, infrastructure limitations, and regulatory uncertainty persist. The study concludes with policy recommendations to foster inclusive blockchain adoption through public-private partnerships, digital capacity-building, and supportive legal frameworks.

Economics of Maize (Zea mays L.) Cultivation in Purnia and Buxar Districts of Bihar

Sonu Kumar[1], Amod Sharma[2], Sanjoy Das[3], Nikhil Nikas[4], Vipul Kumar Mishra[5]

[1]Research scholar, Department of Agricultural Economics, School of Agricultural Sciences, Medziphema, Nagaland University-797106

[2]Sr. Professor, Department of Agricultural Economics, School of Agricultural Sciences, Medziphema, Nagaland University-797106

[3]Prof, Department of Agricultural Economics, School of Agricultural Sciences, Medziphema, Nagaland University-797106

[4]Research scholars, Department of Agricultural Economics, School of Agricultural Sciences, Medziphema, Nagaland University-797106

[5]Research scholars, Department of Agricultural Economics, School of Agricultural Sciences, Medziphema, Nagaland University-797106

Corresponding author's e-mail: sonubao0102@gmail.com

ABSTRACT

The current study entitled "*Economics of Maize (Zea mays L.) Cultivation in Purnia and Buxar Districts of Bihar"* was carried out in four blocks—Srinagar and Jalalgarh in Purnia district, and Kesath and Dumraon in Buxar district—covering a sample of 128 Maize farmers in the year 2024-25. At the same time 12 Maize wholesalers/retailers were also selected in order to study the issues relating to the marketing patterns of Maize from the different markets in the study area.Both primary and secondary sources of data were utilized. The key objectives were to study the trends in area, production and productivity of Maize, estimate the cost and returns of Maize cultivation, study the marketing pattern of Maize, and identify the constraints faced in production and marketing. Findings showed that the majority of the respondents (88.28 per cent) were male. The maximum (47.65 per cent) belonged to the middle-aged group (33–54 years), followed by the older age group (34.37 per cent), with young farmers (below 33 years) accounting for (17.96 per cent). Regarding marital status, (93.75 per cent) of the farmers were married. Most families were medium-sized (4–7 members), representing (43.75 per cent), and the average family size was 5.43 members. In terms of education, (57.04 per cent) of the farmers were literate. Landholding status revealed that (79.68 per cent) were marginal farmers. The primary occupation of most respondents was Business plus Agriculture (70.31 per cent), followed by Agriculture alone (22.65 per cent). Purnia accounted for (19.52 per cent) of Bihar's Maize production in 2023–24, with 11.44 lakh qtll produced, whereas Buxar contributed only (0.03 per cent) with 1,682 MT. The overall average cost of cultivation per ha was ₹32,863.11, with marginal farmers incurring ₹32,905.74/ha, small farmers ₹33,880.42/ha, and semi-medium farmers ₹31,803.20/ha. The average gross income was ₹62,153.70 per ha, and the overall benefit-cost ratio was 1.89, highest among semi-medium farmers (1.96). Two marketing channels were identified: Channel-I (Producer → Consumer), adopted by (23.43per cent) of farmers, and Channel-II (Producer → Village Trader → Wholesaler → Retailer → Consumer), adopted by (76.56per cent). The marketing cost was ₹58.38 per qtll in Channel-I and ₹208.47 per qtll in Channel-II. The marketing margin in Channel-II was ₹235.85, with a price spread of ₹444.32, compared to ₹58.38 in Channel-I. The producer's share in the consumer rupee was 96.22 per cent in Channel-I and lower in Channel-II. Major production constraints included damage by wild animals (rank I), pest and disease incidence (rank II), and high weed infestation (rank III). Marketing constraints were led by the absence of a support price (rank I), lack of

market sheds (rank II), and lack of timely market news (rank III). The study suggests that, improving market infrastructure, ensuring support price mechanisms, promoting hybrid varieties, and strengthening extension services will enhance Maize profitability in the region.

Keywords: Maize, Cost and Return, Marketing Pattern, Constraints, B:C Ratio, Purnia, Buxar, Bihar.

Beyond Aesthetics: Post-Harvest Innovations in Ornamental Crops for Functional and Commercial Products

[1]Hiran Raajan P, [2]Kishore G, [3]Danaganapathy R

[123] UG scholar, Department of Horticulture, Faculty of Agriculture, Annamalai Nagar, Annamalai University, Chidambaram, Cuddalore, Tamil Nadu, India-608 002

Corresponding author's e-mail: hiranraajan7@gmail.com

ABSTRACT

Ornamental crops have long been valued for their aesthetic appeal and landscape utility. However, recent research has expanded their relevance into the domains of health, wellness, and sustainable commercial product development. This paradigm shift is driven by post-harvest innovations that enable the transformation of floral biomass into high-value functional and marketable products. The present study explores novel post-harvest strategies that unlock the hidden potential of ornamental flowers beyond their traditional decorative roles. Many ornamental species, including *Rosa spp., Tagetes erecta, Chrysanthemum indicum, Jasminum sambac,* and *Hibiscus rosa-sinensis,* are rich in bioactive compounds such as anthocyanins, flavonoids, carotenoids, and essential oils. These phytochemicals have proven benefits in pharmaceutical, nutraceutical, cosmeceutical, and food industries. Post-harvest interventions like dehydration, fermentation, solvent extraction, cold pressing, and encapsulation have enabled the development of value-added products such as flower-based teas, herbal infusions, essential oil blends, skincare formulations, natural dyes, bio-pesticides, and edible garnishes. This abstract highlights case studies where simple and cost-effective post-harvest techniques have been adopted to develop commercially viable floral products. For instance, marigold petals processed for lutein extraction, rose petals converted into gulkand, jasmine used for perfumery, and chrysanthemum in floral teas all showcase the transformation of perishable blooms into shelf-stable, functional commodities. Additionally, innovative packaging, quality enhancement through cold chain management, and standardization of active constituents have contributed to product competitiveness in domestic and export markets. The integration of post-harvest technology with entrepreneurship, especially at the grassroots level, has created new income streams for floriculturists, women led SHGs, and startups. These innovations also address environmental concerns by minimizing floral waste and promoting circular utilization of floral resources. In conclusion, ornamental crops hold tremendous untapped potential as sources of functional products through thoughtful post-harvest innovation. Leveraging this approach not only enhances the commercial value of floriculture but also contributes to sustainable agriculture, livelihood security, and bio-based economic development.

Keywords: Ornamental crops, post-harvest technology, value addition, functional products, floral utilization, bioeconomy.

Empowering Tribal Youth through Climate-Smart Agroforestry: Innovations for Sustainable Livelihoods in Koraput, Odisha

Dr. Aman Kumar, Assistant Professor,

Department of Forestry, Central University of Odisha, Koraput, India

Corresponding author's e-mail: amn.wildlife@gmail.com

ABSTRACT

Koraput district of Odisha, recognized as a Globally Important Agricultural Heritage System (GIAHS) by the FAO, represents a biodiverse tribal landscape where traditional agroforestry practices sustain local ecology and culture. Despite this, youth migration and livelihood insecurity remain pressing challenges. Leveraging agroforestry for youth empowerment offers a pathway to integrate ecological sustainability with skill, innovation, and entrepreneurship.

This study explores a scalable agroforestry model focused on:
1. Enhancing livelihood opportunities through skill-based interventions,
2. Promoting youth entrepreneurship in agroforestry,
3. Strengthening ecological resilience through integrated land-use systems.

The approach integrates secondary data analysis from NABARD- and GiZ-supported agroforestry interventions (spanning 380 ha, 496 farmers) with field-based observations from youth-led cooperatives managing shade-grown crops like coffee. Participatory rural appraisal (PRA), interviews with tribal youth, and case reviews of ongoing agroforestry enterprises were used to validate feasibility and replicability. The agroforestry-based livelihoods in Koraput have demonstrated tangible outcomes. Over 4,300 tribal farmers have engaged in coffee cultivation across 3,500 ha under producer cooperatives. Institutional training (by KVK-Koraput and NGOs) has built youth capacity in nursery raising, intercropping, and MPT-based models. Entrepreneurial activities such as bamboo, millets, medicinal tree value chains are emerging, supported by green livelihood schemes and carbon financing (IDRECCO project). GI-tagged crops like Kalajeera rice and Koraput coffee provide branding potential, aligning with 'Vocal for Local' and FPO strategies. This model of climate-smart agroforestry in Koraput provides a replicable blueprint for rural development rooted in ecological and economic sustainability. The integrated strategy linking skill development, innovation, and enterprise creation positions tribal youth not merely as beneficiaries, but as leaders of agroforestry-based transformation. Such initiatives can significantly contribute to India's green economy and biodiversity goals while addressing rural distress through sustainable entrepreneurship.

Keywords

Agroforestry, Tribal Youth, Koraput, Climate-Smart Agriculture, Entrepreneurship, Skill Development

Blending Traditional Indian Knowledge System with Innovative Sustainable Pest Management Practices

S. Ojha[1] , S. Sarkar[2] and R. D. Mukherjee[2]

[1] Department of Agricultural Statistics, Uttar Banga Krishi Viswavidyalaya, Pundibari

[2]Cooch Behar Krishi Vigyan Kendra, Uttar Banga Krishi Viswavidyalaya, Pundibari

Corresponding author's e-mail: sankalpa@ubkv.ac.in

ABSTRACT

The Indian knowledge system (IKS) also known as Bharatiya Gyan Parampara is made up of a vast and varied body of knowledge that has developed over many centuries. Traditional IKS including Ayurveda documented methods for managing pests using natural substances such as plant extracts, ashes and animal products. Sustainable farming methods have long been used in Indian agriculture and they naturally manage pest population. Techniques such as mixed cropping, crop rotation, and intercropping are used to naturally control pest populations by disrupting their habitats and food sources. Biological control methods were in practice long before modern science recognized their effectiveness. For example, predatory insects and birds are encouraged in agricultural landscapes to control pest populations naturally. Indigenous communities in India possessed rich ethnobotanical knowledge about plants that repel or deter pests. This knowledge has been passed down through generations and is often integrated into local farming practices. This grassroots knowledge exchange contributed to adaptive pest management strategies tailored to local conditions. In recent decades, there has been increasing recognition of the value of integrating traditional knowledge with modern scientific approaches in pest management. Agricultural entomologists are studying traditional practices to identify effective, sustainable pest management techniques. Overall, the Indian knowledge system has provided a foundation of sustainable and ecologically friendly pest management practices that continue to inform modern agricultural strategies. A holistic strategy to pest control that is successful, environmentally sustainable and culturally acceptable may be developed by fusing traditional knowledge with modern scientific study.

keywords: Knowledge Management, Pest Management, Sustainable Farming

Digital Agribusiness: Transforming Rural Markets through E-commerce

Dr. Viralkumar P. Chaudhari[1], Yuvraj Vinodbhai Rajput[2], Amit Vijay Bhagat[3], Udaykumar birari[4]

[1]Assistant Professor, P. G. Institute of Agribusiness Management, JAU, Junagadh

[2,3,4] Research Scholar, Department of Agribusiness Management, PG institute of Agribusiness management, JAU, Junagadh

Corresponding author's e-mail: viral6929@gmail.com

ABSTRACT

The traditional agricultural marketing system in India has long been plagued by inefficiencies such as limited market access, dependence on intermediaries, price manipulation and poor logistics. However, the increasing penetration of digital technologies and internet connectivity in rural areas has led to a significant transformation in the agribusiness sector. Digital agribusiness, driven by e-commerce platforms, is reshaping how agricultural inputs, produce and services are marketed and delivered. It enables farmers to connect directly with consumers, retailers and exporters, ensuring fair price realization, transparency and broader market participation. This outlines the evolution of digital agribusiness, tracing its growth from SMS-based advisory systems to integrated platforms utilizing AI, blockchain and mobile payments. It highlights how platforms like AgriBazaar, DeHaat, Ninjacart and KrishiHub are improving the efficiency of supply chains, offering real-time market intelligence, cold-chain logistics and digital input services. The adoption of these platforms is not only improving farmer incomes but also fostering entrepreneurship among rural youth and women. Despite its vast potential, several barriers such as digital illiteracy, weak infrastructure, limited trust in online systems and regulatory gaps hinder its widespread adoption. Government initiatives like e-NAM, AgriStack and DBT schemes have provided a policy framework to support this transformation. However, further efforts are needed in digital literacy training, inclusive financing, rural infrastructure development and clear policy guidelines. With strategic investments and collaborative efforts between public and private sectors, digital agribusiness can become a scalable and sustainable model for inclusive rural development. It offers a powerful solution to age-old agricultural challenges and promises a resilient future for farming communities.

Keywords: Digital agribusiness, E-commerce, Rural markets, Agricultural value chain, Farmer Producer Organizations (FPOs), Digital literacy, Agri-tech startups, Supply chain, Government initiatives, Fintech in agriculture

Sustainable Use of Banana Waste for Soil Nutrient

Prerna[1*], Malom Hankar[1], Pradeepto Pal[1], B. Vanlalneihi[1]

[*1]College of Horticulture, Central Agricultural University (Imphal) Thenzawl, Mizoram, India

Corresponding author's e-mail: prernasha95@gmail.com

ABSTRACT

Banana cultivation generates significant volume of organic waste, including peels, pseudostems, leaves, and rejected fruits, which are often discarded without proper management. This study examines the sustainable use of banana waste to improve soil fertility and promote eco-friendly agricultural practices. Banana waste is rich in potassium, phosphorus, calcium, and organic matter which offers a natural and renewable source of nutrients for improvement of soil fertility, structure, and microbial activity. Through methods such as composting, vermicomposting, and biochar production, banana waste can be transformed into effective soil amendments. These processes not only reduce environmental pollution and waste accumulation but also provide a low-cost alternative to chemical fertilizers. The integration of banana waste into soil management systems supports a circular economy approach in agriculture, promoting sustainability and long-term productivity. The paper reviews recent research and case studies that demonstrate the effectiveness of banana waste in improving crop yields, restoring degraded soils, and enhancing soil biodiversity. The findings underscore the potential of banana waste as a valuable resource in sustainable farming, particularly in banana-producing regions where waste availability is high. This approach aligns with This approach aligns with global efforts to reduce agricultural waste, enhance soil health, and support environmentally responsible farming practices and United Nations Sustainable Development Goals *viz*., SDG 2: Zero Hunger, SDG 9: Industry, Innovation, and Infrastructure, SDG 12: Responsible Consumption and Production, SDG 13: Climate Action and SDG 15: Life on Land.

Keywords: Banana waste, soil fertility, circular economy, SDG's

Sustainable Use of Banana Waste for Soil Nutrient

Prerna[1*], Malom Hankar[1], Pradeepto Pal[1], B. Vanlalneihi[1]

[*1]College of Horticulture, Central Agricultural University (Imphal) Thenzawl, Mizoram, India

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Keywords: Banana waste, soil fertility, circular economy, SDG's

From Genes to Greens: Metabolomic Insights Driving Next-Gen Vegetable Breeding

Nishant[1], Ramesh Kumar Yadav[1], Reshav Naik[1] and Tarun Sharma[2]

[1]Division of Vegetable Science, ICAR-Indian Agricultural Research Institute, New Delhi - 110012

[2]Division of Agronomy, ICAR-Indian Agricultural Research Institute, New Delhi – 110012

Corresponding author e-mail ID: nishant1998katoch@gmail.com

ABSTRACT

Global agriculture is threatened due to climate change and the vegetable crops are continuously suffering from several types of abiotic stresses. To speculate the crop mechanism towards stress and developing appropriate stress mitigating strategies, the assessment of biological system through metabolite is a requisite. Metabolomics is referred to as the study of an entire set of metabolites which are small organic molecules involved in varied enzymatic reactions. The technique of metabolomics aims at characterizing a metabolome biochemically and changes related to genes and environment. This seems to be an appealing tool for defining metabolic phenotypes known as metabotypes used for individual stratification. The plant genes encompass the information about metabolite synthesis, its production which gets triggered by varied growth and environmental stages. Phyto-nutraceuticals involve compounds that are essential in disease prevention possessing antioxidative properties such as lycopene in tomato, carotenoids in carrots etc, which could be identified and improved varieties can be developed using molecular breeding approaches by identifying putative genes and their associated proteins. Nutritional genomics is an integration of metabolomics and genomics, which comprehends a high-throughput genomic technique of a nutritional approach by providing markers of quality traits by monitoring hundreds of biosynthetically related metabolites to develop stable genotypes for a nutritional cultivar having immense potential and wider adaptability in market. Novel approaches for reducing catabolic enzymes and various anti-nutritional compounds and required in nutritional breeding. RNAi techniques exhibit a greater potential by shutting down specific pathways linked to production of toxins and other undesirable substrates. Future insight of metabolomics is aligned towards the construction of mega-libraries of metabolites to regulate and interpret the configuration of compounds, by establishing and adjusting the spectral singularities of the metabolites.

Keywords*:* Metabolomics, Nutraceutical properties, Genomics, metabolites and Vegetables.

AI-powered Real-time Disease Diagnosis in Tomato Crop for Sustainable Crop Protection

Abhishek Upadhyay

CAET, Dr Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar – 848125

Corresponding author's e-mail: abhiupadhyay7798@gmail.com

ABSTRACT

The increasing prevalence of plant diseases in tomato crops poses a significant threat to global food security and agricultural sustainability. Conventional methods of disease detection are often labor-intensive, subjective, and reactive, leading to delayed interventions and reduced crop yields. This research proposes the development of an AI-powered real-time disease diagnosis system tailored for tomato cultivation. Leveraging advancements in computer vision and deep learning, the system employs high-resolution imaging and trained neural network models to detect and classify common tomato diseases such as early blight, late blight, and leaf curl in real time. The solution integrates edge computing and mobile deployment for on-field operation, ensuring fast and accurate feedback to farmers. By enabling early and precise diagnosis, the system supports timely disease management and reduces dependency on broad-spectrum chemical applications, promoting a more sustainable and resource-efficient approach to crop protection. This AI-driven solution holds potential to transform disease surveillance in horticulture and aligns with the goals of precision agriculture and climate-smart farming practices.

Keywords: Real-time diagnosis, Computer vision, Deep learning, Precision agriculture, Smart farming, Sustainable crop protection.

Youth Driven Agripreneurship: A Pathway to Self-Reliance and Rural Prosperity

[1*]Hem Prakash Verma, [2]Eshant Kumar Sukdeve, [3]Rahul Kumar Kaushik and [4]Sanket Kaushik

[1*]Young Professional, ICAR-National Institute of Biotic Stress Management, Baronda, Raipur (C.G.)

[2]Guest Teacher, Agricultural Extension, CARS, Pakhanjore, IGKV, Raipur (C.G.)

[3]PhD Research Scholar, Department of Agricultural Economics, IGKV, Raipur (C.G.)

[4]MSc, Department of Agronomy, IGKV, Raipur (C.G.)

Corresponding author's email: hemverma1996@gmail.com

ABSTRACT

India's agrarian economy and growing youth population have the potential to transform its rural landscape through agripreneurship. This approach not only addresses rural unemployment and migration but also promotes self-reliance and inclusive development. Agripreneurship integrates entrepreneurship with agriculture, including input supply, value addition, agro-processing, marketing, and agri-tech innovations. Rural youth, with their enthusiasm, adaptability, and digital literacy, are well-positioned to lead this transformation. Agricultural extension programs like Agri-Clinics and Agri-Business Centres (ACABC), Skill India, and the RKVY-RAFTAAR scheme support youth-led agri-startups. Digital agriculture, precision farming, protected cultivation, and value chain development are also promoting youth participation. Success stories of young agripreneurs show that agriculture can generate sustainable livelihoods and stimulate rural economies. However, challenges like a lack of capital, limited market access, and inadequate mentorship need to be addressed through policy convergence, credit support, and incubation services. Empowering rural youth as agripreneurs can significantly enhance agricultural productivity, ensure value addition, and drive socio-economic progress. Strategic support through extension education, institutional backing and a favourable ecosystem is essential to unleash the entrepreneurial spirit of rural youth and transform Indian agriculture into a vibrant, youth-led enterprise sector.

Keywords: Agripreneurship, Rural Youth, Agricultural Extension, Self-Reliance, Rural Development

Genotypic Evaluation of Amaranth (*Amaranthus* spp.) for Yield and Yield-Attributing Traits Under Prayagraj Agro-Climatic Conditions

Manisha Meena[A], Nitesh Meena[B] and Bineeta M. Bara[A+]

[A]Department of Genetics and Plant Breeding, Sam Higginbottom University of Agriculture technology and sciences, Prayagraj – 211007

[B]Department of Mycology and Plant Pathology, Banaras Hindu University, Varanasi, U.P., 225001

ABSTRACT

The present study, titled "Genotypic Evaluation of Amaranth (*Amaranthus* spp.) for Yield and Yield-Attributing Traits Under Prayagraj Agro-Climatic Conditions," was conducted during the Rabi season of 2022–2023 at the central research field of the Department of Genetics and Plant Breeding, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj. The experiment aimed to assess the performance of twelve *Amaranthus* genotypes, including two check varieties, laid out in a Randomized Block Design (RBD) with three replications. Five plants were randomly selected and tagged from each plot to record growth and yield-related parameters. Among the tested genotypes, EC-198136 recorded the highest seed yield per plant (22.42 g) and showed significantly superior performance in plant height (166.07 cm), leaf length (29.93 cm), days to 50% flowering (48.33), days to maturity (86.33), inflorescence length (66.47 cm), leaf area (49.89 cm²), stem diameter (2.68 cm), biological yield per plant (80.15 g), 1000-seed weight (1.05 g), fiber content (8.08%), and oil content (9.01%). On the other hand, EC-198132 exhibited the highest number of leaves per plant (68.27), number of branches per plant (29.69), and harvest index (34.61%), indicating notable genotypic variability for agronomic and seed-related traits among the evaluated genotypes.

Keywords: *Amaranthus* spp., genotypic evaluation, seed yield, yield-attributing traits, randomized block design

Phytotherapeutic Approaches for Replacing Antibiotics in Aquaculture

Shivam Pandey[1*], RK Gupta[2] Gajender Singh[2],

[1]Department of Aquatic Animal Health Management, College of Fisheries Science, CCS Haryana Agricultural University, Hisar, 125004

[2]Department of Zoology, College of Basic Sciences & Humanities, CCS Haryana Agricultural University, Hisar, 125004

Corresponding author's email: karateshivam97@gmail.com

ABSTRACT

The aquaculture industry, despite its significant economic contributions, faces considerable challenges from infectious diseases and the growing threat of antimicrobial resistance (AMR). Phytotherapy, the use of plant-derived bioactive compounds, presents a promising alternative to conventional pharmaceuticals for disease management. Medicinal plants have demonstrated antiparasitic, antibacterial, and antifungal properties, enhancing fish immunity and overall health. The incorporation of herbal supplements in aquafeeds can reduce dependence on synthetic chemotherapeutics, lowering environmental risks and supporting sustainable aquaculture practices. Additionally, phytotherapy has been shown to improve growth performance, bolster disease resistance, and enhance fish welfare, ultimately leading to increased production efficiency. As consumer demand for sustainably farmed seafood rises, the integration of phytotherapy into aquaculture can strengthen the industry's sustainability profile and market competitiveness. This review explores the potential of phytotherapy in revolutionizing disease management strategies and promoting environmentally responsible aquaculture.

Keywords:- Phytotherapy, Aquaculture, Antimicrobial Resistance, Fish Immunity

Temporal Analysis of Water Chemistry in Mahseer (*Tor* spp.) Breeding Habitats of the Narmada River, Jabalpur

Prateek Kumar Tiwari[1]*, Shriparna Saxena[1], Sona Dubey[2]

[1]Department of Aquaculture, School of Agriculture, Sanjeev Agrawal Global Educational (SAGE) University Bhopal, Madhya Pradesh, India

[2]Department of Aquaculture, College of Fishery Science, Nanaji Deshmukh Veterinary Science University, Jabalpur, Madhya Pradesh, India

Corresponding author's email: prateekkumartiwari26@gmail.com

ABSTRACT

The present study assessed the physico-chemical characteristics of the Narmada River across four selected sites (T1–T4) within Jabalpur district over a 12-month period from April 2023 to March 2024. Monthly water samples were analyzed to evaluate seasonal variations and ecological stability using standard methodologies. The parameters examined included water temperature, pH, dissolved oxygen (DO), free carbon dioxide (CO_2), alkalinity, and ammonia (NH_3). Results indicated thermally stable conditions throughout the year, with temperature fluctuations remaining within a narrow range (27.48 °C to 29.39 °C). pH levels were consistently within a neutral to slightly alkaline range (7.58–7.94), favoring biological productivity and nutrient availability. DO levels remained above the critical threshold of 6.5 mg/l, supporting a healthy aquatic ecosystem conducive to the survival of sensitive species like Mahseer. Low CO_2 concentrations and stable alkalinity values reflected a well-buffered system, while ammonia levels were minimal (0.03–0.04 mg/l), indicating negligible anthropogenic pollution. The overall findings suggest that the studied stretch of the Narmada River maintains good water quality and ecological balance, although localized human activities may still pose risks. Continued monitoring is essential for the sustainable conservation of this important riverine habitat.

Keywords:- Physico-chemical parameters, Narmada River, Mahseer habitat, Water quality assessment

Promoting Agripreneurship among Rural Youth for Vikshit Bharat

Aman Singh[1] and Nitin Barker[2]

Research Scholar and Associate Professor

Department of Agricultural Economics

Sam Higginbottom University of Agriculture Technology and Science, Prayagraj

Corresponding author: amansingh.agro@gmail.com

ABSTRACT

Promoting agripreneurship among rural youth is vital for building a Vikshit Bharat (Developed India), as agriculture remains the backbone of the Indian economy. With rising unemployment and migration from rural areas, empowering youth through agripreneurship offers a sustainable solution to revitalize the agricultural sector while generating employment and enhancing rural livelihoods. Agripreneurship integrates innovation, technology, and entrepreneurship into farming practices, transforming traditional agriculture into a profitable and attractive enterprise. Initiatives such as skill development programs, access to institutional credit, market linkages, and incubation support are essential to encourage youth to view agriculture as a viable career option. Leveraging digital tools, agri-tech startups, and value chain development can further enhance productivity, reduce post-harvest losses, and create rural-based agro-industries. Special focus on promoting women agripreneurs can also ensure inclusive development. Government schemes like Agri-Clinics and Agri-Business Centres (ACABC), PMFME, and RKVY-RAFTAAR play a pivotal role in nurturing rural agripreneurs. By fostering an enabling ecosystem, rural youth can become change agents for sustainable agriculture and rural transformation. Thus, promoting agripreneurship is not just an economic strategy but a national mission to empower youth, boost rural economies, and pave the way for a self-reliant and developed India.

Keywords: Agripreneurship, Economy, transformation, Ecosystem

Nano-enabled Biocatalysis for Circular Bioeconomy: A Waste-To-Wealth Approach for Biofuel Production

Shreshtha Saxena[1], Avinash. P. Ingle[1], Mangesh. P. Moharil[1], Pravin.V. Jadhav[1], Surendra. R. Kalbande[2], Aniket. K. Gade[3], Shyam S. Munje[4]

[1]Biotechnology Centre, Post Graduate Institute, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, INDIA

[2]Department of Unconventional Energy Sources & Electrical Engineering, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, INDIA

[3]Department of Biological Science and Biotechnology, Institute of Chemical Technology (ICT), Mumbai, Maharashtra, INDIA

[4]Regional Research Centre (RRC), Amravati, Maharashtra, INDIA

Corresponding author's e-mail: ingle.avinash14@gmail.com

ABSTRACT

The unchecked burning of agro-residues after harvest remains a critical environmental issue in India, with over 23 million metric tonnes (MMT) of stubble burned annually during September and October. This practice not only degrades air quality but also represents a massive underutilization of biomass. As crude oil reserves diminish and the need for renewable energy intensifies, repurposing agricultural waste through circular bioeconomy models becomes both an ecological and economic imperative. Sugarcane bagasse (SB), a lignocellulosic byproduct of sugar processing, holds significant potential for conversion into bioethanol. However, conventional biorefining methods face persistent challenges, including high enzyme costs and poor catalytic efficiency. To address these limitations, this study explores a nanotechnological approach to biomass valorization. By immobilizing cellulase enzymes onto magnetic nanoparticles, a nanobiocatalyst system was developed to enhance enzymatic hydrolysis of SB. When using free enzymes, hydrolysis of 1 gram of SB yielded 21.37 g/L of fermentable sugars. In comparison, nanobiocatalysts achieved a sugar yield of 71.25 g/L i.e. over a threefold increase, enabled by enzyme reusability across four cycles. This not only improves the process efficiency but also significantly reduces operational costs. The resulting sugar-rich hydrolysate can be directly fermented to produce bioethanol, aligning with waste-to-wealth strategies for green energy production. This approach demonstrates how nanobiocatalysis can advance circular bioeconomy frameworks by transforming low-value agricultural waste into high-value biofuels driving innovation and entrepreneurship in the green energy sector.

Keywords: Agricultural waste; Lignocellulose hydrolysis; Nanobiocatalysts; Circular bioeconomy; Bioethanol; Green entrepreneurship

Dual role of indigenous *Bacillus thuringiensis* Strains: Plant growth promotion and biocontrol potential

Utkarsh G. Ingle[1], M. P. Moharil[1], Shreshtha Saxena[1], A. P. Ingle[1], Shyam S. Munje[2], Nitin Gupta[3]

[1]Biotechnology Centre, Post Graduate Institute, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, INDIA

[2]Regional Research Centre (RRC), Amravati, Maharashtra, INDIA

Corresponding author's e-mail: mpmoharil@gmail.com

ABSTRACT

Bacillus thuringiensis (Bt), widely recognized for its insecticidal Cry and VIP proteins, is a foundation of biological pest control. However, recent investigations into indigenous Bt isolates have open a second, equally impactful trait: their ability to promote plant growth. In this study, local Bt strains were screened for both entomopathogenic potential and plant growth-promoting characteristics. Three local Bt isolates PDKV-Bt-SAk-12, SBn-2, and SDa-1 were identified as potent PGPR candidates based on their biochemical traits and seedling bioassays. SAk-12 exhibited the highest indole-3-acetic acid (IAA) production (63.5 µg/mL), SBn-2 exhibited the highest ammonium production (40.59 µg/mL) and SDa-1 exhibited the highest phosphate solubilization ability, resulting in a vigor index of 2420. All three strains significantly enhanced germination, root and shoot growth, with vigor indices well above 2300.

In addition to their growth-promoting effects, the Bt strain SBn-2 showed the entomopathogenic properties against *Helicoverpa armigera* (76.67 % mortality) and *spodoptera litura* (63.33 % mortality) and SAk-12 against *Spodoptera frugiperda* (70.00 % mortality). These dual combined traits make Bt strong candidates for use as multifunctional bio inputs in sustainable agriculture, offering both plant growth benefits and biocontrol potential.

Keywords: *Bacillus thuringiensis*, Plant growth-promoting rhizobacteria, Insecticidal activity

Integrative MAS Approach for Dual Trait Soybean: Enhanced Nutrition and Disease Resistance

Umesh Shinde[1], Pravin Jadhav[1], Mangesh Moharil[1], Satish Nichal[1], Shyam Munje[1], Aditya Rathod[1], Balwant Munde[1], Vineet Kumar[2], Anita Rani[2], Shyamsundar Mane[1]

[1]Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola 444104, MS

[2]ICAR-National Soybean Research Institute, Indore, MP

Corresponding author's e-mail: mpmoharil@gmail.com

ABSTRACT

Soybean (*Glycine max* L. Merr.) is a vital crop known for its high seed nutritional value and wide-ranging industrial and food applications. Despite genetic improvements enhancing its adaptability and economic potential, productivity in Vidarbha and Central India remains constrained by the presence of the Kunitz trypsin inhibitor (KTI) and susceptibility to charcoal rot disease. This study, funded by the Department of Biotechnology (DBT), Government of India, aimed to develop soybean lines combining the null KTI allele with resistance to charcoal rot through marker-assisted backcross breeding. The null KTI allele from NRC-101 and NRC-127 (ICAR-NSRI, Indore) was introgressed into the resistant soybean genotypes Suvarna Soy (AMS-MB-5-18) and AMS-MB-5-19 (Dr. PDKV, Akola). Charcoal rot resistance was evaluated using sick plot assays and calcium silicate treatment. Transcriptome profiling in infected tissues identified 48 significantly upregulated differentially expressed genes (DEGs), and RNA-Seq analysis facilitated the establishment of the first transcriptomic database related to charcoal rot resistance under silicon treatment. Allele-specific markers enabled accurate selection of progenies carrying the null KTI allele, with absence of the KTI peptide validated via native PAGE. The F_1 generation showed a 12% success rate, and recurrent parent genome recovery (RPGR) exceeded 90% in BC_1F_2 and BC_2F_2 generations. By Kharif 2023, RPGR reached 83.97% in BC_1F_4 and 93.15% in BC_2F_3, with 24 advanced lines successfully pyramiding the null KTI allele and charcoal rot resistance. QTL mapping identified key loci on chromosomes 1, 5, 12, 14, and two regions on chromosome-2. Expression analysis revealed higher KTI3 gene expression at R5 stage (1.39–267.64 fold) compared to R6 (8.19–130.77 fold), with line C42-101 mimicking the donor's null expression pattern. The developed KTI-free soybean lines were further utilized to produce nutritious soy-based food products. Standard operating procedures (SOPs) for these innovations have been submitted for patent protection (Application No. 202321015534; The Patent Office Journal No. 12/2023). These novel lines represent a significant advancement in food-grade soybean improvement, offering reduced anti-nutritional factors, enhanced disease resistance, and economic benefits to farmers through direct market access facilitated by Farmer Producer Organizations (FPOs).

Millets 2.0: Transforming Climate-Resilient Crops into a Global Business Opportunity

Manoranjan Biswal[1*], Stuti Sharma[2], Dr. H. Nanita Devi[1], Jeti Konsam[3] and Thoithoi Huidrom[1]

[1] Department of Genetics and Plant Breeding, College of Agriculture, Iroisemba, Central Agricultural University, Imphal, Manipur-795004, India.

[2]Department of Genetics and Plant Breeding, College of Agriculture, Jawaharlal Nehru Krishi Vishwavidyalaya, Jabalpur, M.P.- 482004, India.

[3]Department of Entomology, College of Agriculture, Iroisemba, Central Agricultural University, Imphal, Manipur-795004, India.

[*]Corresponding author: manoranjanbiswal096@gmail.com

ABSTRACT

Millets, formerly a conventional staple crop, are now becoming an essential element of sustainable agriculture and a profitable commercial prospect. Millets, as climate-resilient and nutrient-dense crops, correspond with global food security objectives, especially in light of escalating food prices, diet-related health issues, and environmental challenges. The International Year of Millets (IYM 2023) has emphasised their significance in mitigating food insecurity, enhancing biodiversity and aiding smallholder farmers. India, the foremost producer of millet, has had a 27% growth in output in recent years; nonetheless, millet-based firms continue to be an underutilised economic sector. This concept paper analyses the entrepreneurial prospects of millets, emphasising value enhancement, digital branding, and international market growth. India's millet exports totalled $64.28 million in 2022, while the global market is valued at $4.4 billion. Consequently, innovative millet-based enterprises, including alternative dairy products, cloud kitchens, eco-friendly cutlery, baby food, and health-oriented bakery items, are experiencing significant growth. Notwithstanding these prospects, obstacles endure, encompassing low productivity, processing inefficiencies, and restricted consumer knowledge. Institutional support, encompassing NutriHub incubation programs, governmental incentives such as the Production Linked Incentive Scheme for Food Processing Industry (PLISFPI) and the Pradhan Mantri Formalisation of Micro Food Processing Enterprises (PMFME), along with the incorporation of millets into the One District One Product (ODOP) initiative, is essential for fostering growth. Digital marketing, social media interaction, and SEO-focused branding are becoming essential for millet entrepreneurs. Furthermore, the minimal water and energy demands of millets, along with their resilience to severe climatic circumstances, render them a viable substitute for resource-intensive crops. Integrating legislative assistance, technical innovation, and market-driven strategies can transform millet-based entrepreneurship, yielding advantages for farmers, consumers, and the environment. This concept paper emphasises the necessity for a deliberate transition towards millet commercialisation, framing these "small seeds" as a significant business potential for a healthier and more sustainable future.

Keywords: Millet entrepreneurship, sustainable agribusiness, food security & nutrition, value-added millet products, global millet market, climate-resilient crops.

Carbon-Smart Village Hubs: A Sustainable Agricultural Model for Climate Resilience and Rural Empowerment

Gokul. S[1], CS. Gowtham[1], T. Deepak[1*]

Department of Agriculture, Faculty of Agriculture, Annamalai University, Annamalai Nagar,

Chidambaram, Cuddalore, Tamil Nadu, India – 608002

*Corresponding author: deepakmaba@gmail.com

ABSTRACT

Agriculture is a vital sector for food security and livelihoods, but it is also a significant contributor to greenhouse gas emissions. The Carbon-Smart Village Hub (CSVH) is a forward-thinking, integrated model that aims to transform rural agriculture into a climate-friendly and economically resilient system. CSVHs combine practices like agroforestry, organic farming, precision agriculture, and renewable energy to create sustainable, low-carbon farming communities. Key features include decentralized biogas units for energy production from organic waste, solar-powered cold storage and irrigation systems, and crop diversification to improve soil health and reduce input dependency. Additionally, the model encourages the use of IoT-based moisture sensors to enable water-efficient irrigation techniques such as Alternate Wetting and Drying (AWD), particularly in paddy cultivation. A core innovation of this idea is the establishment of a local carbon credit cooperative, enabling farmers to monetize their sustainable practices through verified carbon markets. By connecting ecological responsibility with economic opportunity, CSVHs empower rural communities to combat climate change while enhancing food security and income. This approach is scalable, adaptable, and aligns with both national climate goals and the broader agenda of sustainable development.

Keywords: Carbon-smart village hubs, sustainable agriculture, agroforestry, biogas, precision farming, carbon credit, rural empowerment, climate-smart agriculture.

Aromatic Agroforestry: Empowering Rural Youth through Sustainable Fragrance Products

Krisha Patel[1]*,Dr. Bimal Desai[1],
Department of Botany, College of Forestry,
Navsari Agricultural University, Navsari 396450, Gujarat

Corresponding author's email: kp8584265@gmail.com

ABSTRACT

India's rural communities hold significant potential for green entrepreneurship and sustainable livelihoods. Aromatic and medicinal plants offer a unique opportunity to transform the rural economy by tapping into the growing domestic and international market for natural fragrance products such as essential oils, incense sticks, and herbal perfumes. This poster highlights how cultivating and processing aromatic crops can empower rural youth by providing skill-based training, local employment, and income generation through sustainable, low-cost methods. By encouraging decentralized processing and community-based cooperatives, fair income distribution and collective growth can be ensured. Integrating fragrance crop production with circular bio economy principles supports waste-to-wealth models, organic farming, and soil regeneration, enhancing environmental sustainability. This approach directly contributes to the vision of 'Viksit Bharat' and aligns with national goals such as doubling farmers' incomes, climate-smart agriculture, youth empowerment, and carbon neutrality. Capacity building, market linkages, branding, and policy support will help rural youth become successful fragrance entrepreneurs, turning villages into hubs for natural product industries. Moreover, involving rural women through self-help groups and micro-enterprises enhances inclusivity and strengthens local economies. Partnerships with research institutions and industry stakeholders can promote high-value aromatic crops and new product development that meets quality standards. Empowering youth to view agriculture as an innovative, dignified profession ensures resilient rural communities and sustainable development. By fostering entrepreneurship, technology adoption, and community participation, this model can create green jobs, boost rural incomes, and secure a cleaner, more prosperous future.

Keywords: Rural Youth Empowerment, Aromatic Plants, Sustainable Livelihood, Green Entrepreneurship.

Innovative Approache for Climate Smart and Resource Efficient Vegetable Farming

[1]Bhavesh Verma and and [2]Hem Prakash Verma

[1*]PhD Research Scholar, Department of Vegetable Science, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.)

[2]Young Professional, ICAR-National Institute of Biotic Stress Management, Baronda, Raipur (C.G.)

Corresponding author's email: bhaveshverma7@gmail.com

ABSTRACT

Climate change is posing significant challenges to vegetable production, impacting crop yields, resource availability and farm sustainability. Climate-smart agriculture (CSA) is a sustainable approach to vegetable production that focuses on optimizing water, nutrients, land, and labour while ensuring economic viability and environmental sustainability. Key innovative approaches include precision farming technologies like sensor-based irrigation, fertigation systems, and drone-assisted nutrient management, which reduce wastage and improve crop productivity. Protected cultivation techniques like low-cost polyhouses, shade nets, and hydroponics provide controlled microclimates, mitigating weather extremes and pest pressure. Vertical farming and hydroponics are gaining traction for efficient land and input use, particularly in peri-urban areas. The use of drought-tolerant, early-maturing, and heat-resistant vegetable varieties through biotechnological and conventional breeding enhances adaptability to climate stress. Integrating organic amendments, biofertilizers, and mulching improves soil health and conserves moisture, contributing to long-term sustainability. Decision support tools and ICT-based advisory services empower farmers with real-time data for informed decision-making. These innovations significantly increase water and nutrient use efficiency, improve yield stability under variable climates, and reduce the carbon and ecological footprint of vegetable production systems. However, widespread adoption requires policy support, capacity building, and access to credit and infrastructure. In conclusion, integrating climate-smart and innovative resource-efficient approaches in vegetable farming is crucial for ensuring food and nutritional security under changing climatic scenarios.

Keywords: Climate-Smart Agriculture, Vegetable Farming, Protected Cultivation, Resource Use Efficiency, Climate-Resilient Varieties

Development of Tomato Ketchup Slices Using Hydrocolloid Gelation

Prashant Patoliya[1], Jaymin Desai [2] and Monark Tanna

College of Food Processing Technology & Bio-energy

Anand Agricultural University, Anand

Corresponding author's email: patoliyaprashant31@gmail.com

ABSTRACT

The present study explores a novel method for formulating *tomato ketchup slices* using hydrocolloid-based gelation techniques, eliminating the need for conventional drying processes. Ketchup, a popular condiment known for its viscous consistency, is typically not portable or mess-free in its traditional form. To address this, we developed a sliceable ketchup formulation by incorporating food-grade hydrocolloids such as Agar, pectin, and carrageenan, which enable gel formation at ambient conditions. The process involved standardizing the optimal concentration of hydrocolloids to achieve desirable textural and organoleptic properties while preserving the characteristic flavor and color of ketchup. Calcium ion-mediated gelation was used to form thermo-irreversible gels that retained their structure at room temperature. The physicochemical properties, including moisture content, firmness, color stability, and shelf-life, were analyzed. Sensory evaluation was conducted to assess consumer acceptability. Results indicated that a Agar (0.9 %) produced the most stable and acceptable slice, with high sensory scores and minimal syneresis. This innovative ketchup slice presents a convenient, clean-label alternative suitable for use in burgers, sandwiches, and ready-to-eat meals, potentially reducing food waste and enhancing product portability. This study demonstrates the feasibility of using hydrocolloid gelation as a drying-free technique to transform semi-liquid condiments into solid, user-friendly formats, opening avenues for further applications in food structure innovation.

Keyword's : Tomato ketchup slice**,** Hydrocolloids**,** Gelation**,** Drying-free preservation

Odisha’s take on “Vocal for Local” Crops

Kumud Pawar

Jawaharlal Nehru krishi Vishwavidyalaya, College of Agriculture, Jabalpur

Corresponding author's email - kumudpawar958@gmail.com

ABSTRACT

Odisha is a state of rich agro biodiversity, also being among the leading conservators of rice germplasm in India. Thanks to the flood resistance 13A gene from *indica* rice from coastal Odisha which led to the development of several submergence - tolerant rice varieties. The state has registered over 900 farmer's varieties with the **Protection of plant varieties and farmer's varieties authority.**Department of agriculture and farmer's empowerment, government of Odisha launched “Revival and sustainable intensification of forgotten food and neglected crops in Odisha”. The crops which nurtured generations and kept them alive through difficult times and coastal challenges are now being forgotten and pushed to extinction due to commercialization of farming and focusing on making profit through high demand crops.Continuous ignorance over decades has led to traditional crops and practices being forgotten. Local food has shaped the community over centuries, sudden changes due to modern practices leads to the roots being forgotten and without roots shall we reap no good. Thus, to change the fate of these local crops and heritage, a 5 years scheme (budget - ₹247.0245 Cr) will be implemented from 2025-26 to 2029-30 across 25 blocks in 15 districts. It will focus on communities near key diversity hotspots - Bhitarkanika and Chilika, ansula wetlands etc. This scheme adopts a multi-stakeholder engagement model involving farmers, local communities, organisations, academia, and government departments. “We aim to position Odisha as a global model for revalorising forgotten foods and neglected crops” - Arabinda Kumar Padhee, Principal secretary, DA&FE, Odisha.Through this vision and combined efforts, the initiative is expected to yield rich documentation of nature, landraces and traditional food practices, enhance the supply and visibility of these crops, generate nutritional data, and contribute to an open digital knowledge platform.

Keywords - local crops, traditional farming practices, nutrition

Startup Innovation in Natural Farming: A Business Model Approach

Vikas Kumawat

B.Sc. Ag. (Hons.) Natural Farming, School of Natural Farming, PGCA, RPCAU, Pusa, Bihar, India

Corresponding author's email: kumawatvikas203@gmail.com

ABSTRACT

The shift toward sustainable agricultural practices has accelerated the growth of startups focusing on organic and eco-friendly solutions. This study presents an innovative business model a startup aimed at promoting natural farming through the production and commercialization of three traditional products: Neem Oil (Neemastra), Dashparni Ark, and Ghanjeevamrit. These bio-inputs are rooted in indigenous knowledge and cater to the rising demand for chemical-free agriculture. The methodology involved extensive market research, traditional product formulation, cost analysis, business model development, and financial feasibility assessment. Inputs were sourced using sustainable methods and processed using cold-pressing, fermentation, and eco-friendly techniques. Sales strategies combined digital marketing with direct farmer engagement and B2B models. Results showed significant market viability, with a projected first-year revenue of ₹25.8 lakhs against an investment of ₹17.9 lakhs. The startup achieved an impressive Internal Rate of Return (IRR) of 94.15% and a payback period of just nine months. Strategic location planning and product pricing enhanced accessibility and affordability. The findings underscore the potential of integrating traditional agricultural knowledge with modern entrepreneurial models. The business not only addresses environmental sustainability but also supports rural livelihoods and promotes self-reliant farming practices. Lastly study exemplifies how grassroots innovations in natural farming can evolve into scalable, financially viable startups. It contributes meaningfully to India's vision of sustainable agriculture while fostering farmer prosperity, making it a replicable model for agri-entrepreneurship across developing regions.

Harnessing Gene Editing to Improve Salt Tolerance in Wheat

Hetvi Butani[1*], Harvi Vora[1] and Ruchi Chhodvadiya[2]

[1] M.Sc. (Agri.), Department of Genetics and Plant Breeding, College of Agriculture, Junagadh Agricultural University, Junagadh-362 001(Gujarat), India

[2.] Ph.D., Department of Genetics and Plant Breeding, College of Agriculture,

Junagadh Agricultural University, Junagadh-362 001(Gujarat), India

Corresponding author's email: hetvibutani111@gmail.com

ABSTRACT

Global wheat production is being threatened by soil salinization, which drastically decreases yields and put food security in areas affected by salt at risk. Due of the complex polyploid genome of wheat and the multigenic nature of salt stress responses, traditional breeding for salt tolerance has not been very successful. Plant breeders now have the unique ability to directly modify important genetic determinants of salt tolerance thanks to the latest developments in precise gene editing techniques, especially the CRISPR/Cas systems. In addition to critically analyzing how gene editing is being used to get around these obstacles, this review summarizes the state of knowledge about the physiological and molecular causes of salt stress in wheat. Researchers discovered key mechanisms of salt tolerance including osmotic adjustment, ion

transport control and stress-responsive gene networks, and they specify particular potential genes and regulatory elements that had been or may be targeted by cutting-edge gene editing techniques. Researchers also found noteworthy achievements, enduring problems including polyploidy issues and off-target consequences, and new approaches to address them. Last but not least, Researchers also described how combining gene editing with complementing techniques such as high-throughput phenotyping and speed breeding might hasten the creation of resilient, salt-resistant wheat cultivars appropriate for a range of agro-ecological settings. Innovative gene editing applications have the potential to revolutionize wheat development pipelines toward climate-smart, resilient production systems as the world's agricultural landscape faces growing salt issues.

Keywords: Salt tolerance, CRISPR/Cas, Stress, Gene editing

Harnessing Potential of Wastewater in Crop Production

Rameshwar Dhakad
Division of Water Science and Technology, ICAR-IARI, New Delhi 110012
*Corresponding author's mail: - dhakadram123@gmail.com

ABSTRACT

The reuse of treated wastewater for irrigation has emerged as a viable strategy for enhancing agricultural productivity while mitigating freshwater scarcity. A series of field experiments were conducted to evaluate the impact of wastewater irrigation on different crops, including tuberose (*Polianthes tuberosa L.*), Indian mustard (*Brassica juncea*), lemongrass (*Cymbopogon flexuosus*), cauliflower (*Brassica oleracea*), and maize (*Zea mays*). In tuberose cultivation, wastewater irrigation at 1.2 ID/CPE significantly improved flowering characteristics such as spike length and floret count without affecting keeping quality (Gurjar et al., 2018). For Indian mustard, sole wastewater irrigation enhanced soil fertility, increasing available NPK and microbial biomass carbon, leading to higher crop productivity (Gurjar et al., 2016). Lemongrass exhibited improved herbage yield and essential oil production under wastewater irrigation at 1.0–1.2 ID/CPE, with heavy metal concentrations in the oil remaining below permissible limits (Lal et al., 2013). Cauliflower irrigated with municipal wastewater through subsurface drip laterals showed increased curd yield and reduced inorganic fertilizer dependency, though some heavy metal accumulation in the crop was noted (Tripathi et al., 2016). Maize irrigated with treated wastewater using hybrid multi-soil-layering technology demonstrated enhanced biomass, protein, and sugar content, highlighting its potential as an alternative nutrient source (Zidan et al., 2024). Overall, these studies confirm that wastewater irrigation can sustain agricultural productivity while conserving freshwater, though careful monitoring of soil and crop quality is necessary to mitigate potential environmental risks.

Keywords:- Sustainable agriculture, Treated wastewater, Irrigation, Agricultural productivity, Freshwater conservation, Crop yield, Soil fertility, Heavy metal accumulation

Genome editing tools for crop improvement: A Revolutionary approach to enhance Biotic and Abiotic stress tolerance

Sneha Kurchaniya B.Sc.(hons) Agriculture, Jawaharlal Nehru Krishi Vishwavidyalaya Jabalpur; College of agriculture Jabalpur, krishinagar Adhartaal Jabalpur (MP) 482004

Corresponding author – Sneha Kurchaniya UG Scholar at JNKVV Jabalpur

Corresponding author's email: snehakurchaniya@gmail.com

ABSTRACT

Agriculture faces numerous challenges due to Biotic and Abiotic stresses, impacting crop yield, quality and food security and hence Crop improvement is crucial for ensuring food security particularly in the face of Biotic and Abiotic stresses. Genome editing tools have revolutionised crop improvement, enabling Plant breeders to develop the crop varieties with Resilient mechanism to Biotic and abiotic stress. The CRISPR or CAS system is a popular genome editing tool that has shown great potential in Crop improvement ; it works by making targeted changes to the Crop's genome allowing a breeder to introduce desirable traits. There are several variants of CRISPR/CAS that has been developed including CRISPR/CAS9 known for its accuracy and efficiency. CRISPR/CAS 12 and CRISPR/CAS13 targets RNA rather than DNA offering new possibilities. Beside CRISPR there are newer editing tools offering more precision and flexibility. BASE EDITING: Allows to make targeted change in base pairs in genome. PRIME EDITING: A more advanced tool that combines the precision of base editing with the efficiency of CRISPR/CAS9. Overall genome editing tools have the potential to revolutionise crop improvement by enabling a Plant breeder to develop crops that are Resilient, sustainable and productive.

Keywords: CRISPR/CAS9; CRISPR/CAS12; CRISPR/CAS13; Prime editing, Base editing; Biotic and Abiotic stresses.

Development of Milk Tablets with Nutritional Benefits

Jaymin Desai[1*], Monark Tanna[2] and Prashant Patoliya

College of Food Processing Technology & Bio Energy, Anand Agricultural University, Anand, Gujarat

*Corresponding author's email: desaijaymin40@gmail.com, M.no:9825919669

ABSTRACT

Innovations in dairy processing have led to solid milk tablets that package milk's nutrition into portable, shelf-stable units. These tablets aim to deliver milk's key nutrients (high-quality protein, essential amino acids, calcium and vitamins) to groups such as children or nutritionally at-risk populations who may lack regular access to fresh milk. For instance, a Thai school-feeding project formulated protein-rich milk tablets for rural children, noting benefits like a "long shelf-life, convenience, and [suitability] for distribution to remote areas". Milk powders are naturally rich in nutrients (e.g. 100 g skim milk powder contains ~1300 mg calcium), and such components can be preserved in tablet form. An early patent even describes tablets containing ~20% butterfat, 10% protein and 60% carbohydrate (plus milk minerals) so they dissolve into a normal beverage, demonstrating the feasibility of mimicking milk's full nutritional profile. Modern formulations may further include added vitamins or probiotics – one example is a "probiotic milk tablet" claimed to be nutrient-rich, with a high viable probiotic count and many added vitamins. In terms of processing, the milk is first dried (e.g. spray-dried) and then compressed. Patent descriptions note spray-drying skim milk powder (often with a carbohydrate binder like maltose) and compressing it with coagulants into solid tablets. Alternatively, freeze-drying (lyophilization) has been used to produce fast-dissolving Oro dispersible milk tablets for pediatric use. These solid forms retain milk's key nutrients while offering clear advantages: they are lightweight, non-perishable, and require no refrigeration. Researchers emphasize the "ease of consumption, transportation, and storage" of milk tablets compared to liquid milk. In one example, a compressed infant-formula tablet was reported to provide the same nutrition as a standard scoop of powder. By combining milk's inherent nutrients (calcium, protein, vitamins) with modern processing, nutrient-fortified milk tablets offer an innovative and practical means of improving nutrition through a convenient, shelf-stable format.

Keywords: Milk tablet, calcium, protein, vitamins, spray drying, lyophilization, compressed milk, shelf-stable.

Acai Sorbet: Development of a Healthy Antioxidant-Rich Frozen Dessert as an Alternative to Traditional Ice Creams

Monark Tanna, Jaymin Desai, Prashant Patoliya}*[1], Khawaish*[2]

College of Food Processing Technology & Bio-energy Anand Agricultural University, Anand

College of Agricultural Engineering Godhra, Anand Agricultural University, Anand

*Corresponding author's email: tannamonark@gmail.com

ABSTRACT

This research explores the formulation of a vegan acai sorbet designed as a nutritious, antioxidant-rich alternative to traditional dairy ice creams. Acai (Euterpe oleracea) berries are known for their exceptional polyphenol content, comprising approximately 25.5% of the dry pulp weight. The dominant antioxidants cyanidin-3-glucoside and cyanidin-3-rutinoside impart deep purple coloration and high oxidative scavenging potential. The frozen dessert was crafted using pure acai pulp, water, sugar, and natural plant-based thickeners to ensure clean-label appeal and functional integrity. The nutritional profile of the formulated sorbet aligns with health-conscious consumer trends. Per 100 g serving, it offers about 70 kcal, 5 g of healthy unsaturated fats, 4 g carbohydrates (with only 2 g from natural sugars), and 2 g of dietary fiber. Antioxidant metrics demonstrated high bioactivity, including DPPH activity of approximately 16.6 µmol Trolox/g and total phenolics close to 14 mg GAE/g, exceeding those of comparable berry sorbets and significantly surpassing conventional ice cream in nutritional value. Storage studies confirmed that the sorbet maintained high levels of anthocyanins and polyphenols over long periods, with minimal degradation during frozen storage at –18 °C for up to 120 days. Its colour, texture, and functional properties remained stable, validating the sorbet matrix as an effective carrier for heat-sensitive bioactives. Consumer sensory evaluations revealed high acceptability, primarily driven by the distinctive berry flavour and smooth, scoopable texture achieved using plant-based gums that mimic the creaminess of dairy. Over 70% of variance in acceptance scores was attributed to flavour satisfaction. Furthermore, the acai sorbet shows promise as a functional dessert platform, capable of supporting probiotic viability and additional enrichment with gut-health–promoting fibers and fruit flours. In conclusion, the developed açaí sorbet delivers a palatable, low-fat, antioxidant-dense frozen treat, offering both nutritional and functional advantages over conventional ice cream.

Keyword's: Acai Sorbet, Antioxidants, Functional Foods, Polyphenols, Vegan Dessert, Cyanidin compounds, Gut-health

Youth involvement and innovation in agriculture

Elampoorni R.G[1*] and Elanthendral Manivanan[1]

[1]Faculty of Agriculture, Department of Agriculture, Annamalai Universty Chidambaram, Cuddlore , Tamil Nadu, India – 608002

*Corresponding author's email: elampoorani2004@gmail.com

ABSTRACT

India is considered one of the most diverse country and also has the largest youth population in the world. Approximately 65% India's population is under the age of 35 though, Only 23-25% of youth population has been involved directly in agriculture. Youth involvement and innovation in agriculture are critical drivers for sustainable development and food security in the 21st century. As the India's population grows the agricultural sector must adopt modern technologies and create solutions to improve the efficiency also enhance productivity with no or less environmental impact. Young farmers and agripreneurs bring fresh perspectives, digital literacy and a willingness to embrace advancements such as precision farming, agri-tech startups sustainable practices. However challenges such as limited access to land, financing. skill and training gaps, the thought of low prestige and low income often hinder their full participation. Therefore ,this could be overcome by creating interest, leveraging technologies and innovations, ,promoting agriculture as a viable career, providing education and training, facilitating access to resources , government policies and initiative, digital marketing, promote entrepreneurship, success stories, highlight ICTs and other development. The agricultural sector can harness the potential of youth to ensure a resilient and future-ready food system. Thus, collaboration between the government, industry and educational institutions is important in these efforts and together we can secure a bright for agriculture and the nation.

Keywords: Youth in agriculture, agripreneurship, training, digital marketing, leveraging technologies, sustainable farming.

Affordable Motorized Crop Transplanter

Khawaish[1], Monark Tanna[2]

Department of farm machinery, College of Agricultural engineering Godhra, Anand Agricultural University, Anand, Gujarat

College of Food Processing Technology & Bio- energy Anand Agricultural University, Anand, Gujarat

Corresponding author's email: khwaish20xxx@gmail.com , khawaishbhangalia@gmail.com

ABSTRACT

Rice cultivation is critical for food security in Asian countries, necessitating efficient and sustainable farming practices. Although India achieved a rice production of 135.4 million metric Tonnes in 2023–24, over 70% of paddy is still transplanted manually primarily by marginal and smallholder farmers cultivating less than 2 hectares of land. This significant gap in mechanization underscores the urgent need for affordable, adaptable, and labor-saving transplanting solutions.The proposed transplanter addresses this need through a lightweight, foldable frame integrated with an adjustable depth control mechanism and replaceable pickup arms, enabling its use for multiple crops such as onion, sugarcane, and tomato. A depth sensor ensures uniform seedling placement, promoting better crop establishment and higher yield potential. To minimize manual labor, the machine incorporates a motorized drive unit powered by a solar panel and battery system, offering sustainable and uninterrupted operation even in remote rural areas.

Looking forward, this innovation has the potential to reduce manual labor by 60–70% and enhance transplanting efficiency by 30–40%, depending on field conditions and its real-world application.

Keywords:
Rice transplanter, agricultural mechanization, seedling spacing, solar-powered machine, smallholder farmers

Circular Bioeconomy and waste to wealth models for green entrepreneurship

Akanksha Dhuper[1]
[1]B.Sc.(Hons.)Agriculture(4th year), College of Agriculture, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishwavidyalaya, Palampur, Himachal Pradesh,176061
Corresponding author's email: adhuper2100@gmail.com

ABSTRACT

While studying agriculture at CSKHPKV, Palampur, I often noticed how crop residues and even cow dung were treated as waste. But over time, I came to understand that these by-products have a lot of value and that's where the concept of circular bioeconomy comes into focus. This abstract is about how rural waste, when used properly, can become the foundation for green entrepreneurship in rural areas. Through self-study and field exposure, I have come across examples where farmers are converting agricultural waste into income-generating products like vermicompost, substrate for mushroom cultivation, and even bio-bricks made from cow dung. These activities not only support household income but also reduce stubble burning and improve village sanitation. One of the most practical experiences for me was during my final-year ELP (Experiential Learning Programme), where we practiced organic farming and cultivated *Dhingri* mushrooms on substrate from waste agriculture straw, which is otherwise burnt. We even prepared our own vermicompost using biodegradable crop residues. This practical exposure showed me how simple innovations can lead to meaningful outcomes. The most interesting thing is how little capital is needed to get started, especially with support from initiatives like the Waste to Wealth Mission and Krishi Vigyan Kendras. Yet, despite these, many rural youth hesitate to step into green entrepreneurship often due to limited awareness or fear of failure. To me, these practices are not just environmentally friendly but can also help in mitigating climate change. With the right knowledge and encouragement, such local and low-cost green entrepreneurship activities can lead to an independent and greener India.

Keywords: Circular bioeconomy, green entrepreneurship, Agricultural waste utilization

Relevance Of Indigenous Technical Knowledge Of North East India In Sustainable Agriculture

Ayushman Baruah[1] and Himangshu Parasar[2]

[1]College of Agriculture, Assam Agricultural University, Jorhat, Assam

[2]College of Community Science, Assam Agricultural University, Jorhat, Assam

Corresponding author's email: ayushman.baruah.aj23@aau.ac.in

ABSTRACT

The ecological diversity and traditional heritage of Northeast India have brought up a wealth of Indigenous Technical Knowledge (ITK) systems, many of which have significant potential to contribute to sustainable agriculture in the modern era. However, such practices are increasingly marginalised in policy and practice due to rapid commercialisation, technological shifts, and lack of documentation. This research revolves around the relevance and applicability of indigenous agricultural knowledge prevalent among tribal and rural farming communities in the region. The study adopts a qualitative & quantitative mixed method approach involving focused group discussions and field-level observations across selected districts of Assam and Arunachal Pradesh. Emphasis is placed on traditional cropping patterns, soil conservation techniques, pest management and seed preservation practices. Preliminary findings reveal that many ITKs promote ecological balance, resilience to climate variability, and low-cost farming, aligning closely with modern principles of sustainability. However, challenges such as generational knowledge gaps, lack of scientific validation, and limited institutional support creates gap in their wider adoption. The study shows for an integrative approach where ITK is scientifically validated, documented, and blended with contemporary practices.

KEYWORDS*:* Indigenous Knowledge, Northeast India, Sustainable Agriculture, Traditional Practices, Agroecology, Rural Innovation

Role of Remote Sensing and GIS in Climate-Smart Agriculture

Rima Das[1*], Shivam Chaubey[1] and Prashant Shukla[1]

[1]Division of Agricultural Engineering

ICAR-Indian Agricultural Research Institute, Pusa, New Delhi-110012

*Corresponding Email: rimadas1512@gmail.com

ABSTRACT

The goals of climate-smart agriculture (CSA) are to lower greenhouse gas emissions, improve climate change resilience, and raise agricultural productivity in a sustainable manner. By facilitating accurate monitoring, spatial analysis, and data-driven decision-making, remote sensing (RS) and geographic information systems (GIS) are essential to accomplishing these objectives. This study examines practical uses of RS and GIS technologies in climate-smart farming methods. Crop health monitoring, drought and flood risk prediction, land use/cover change assessment, and fertilizer and irrigation optimization have all benefited from the use of satellite imagery, UAVs (drones), and geospatial data. For example, crop growth patterns under

different climatic conditions have been tracked with the aid of NDVI and other vegetation indices obtained from multispectral sensors. Zoning and vulnerability assessments for climate-resilient crop planning have been made easier by GIS-based spatial modeling. Case studies from Sub-Saharan Africa and India show how integrated RS-GIS approaches help with sustainable land management and climate adaptation plans. The integration of RS and GIS in CSA not only improves agricultural productivity but also fosters resource conservation and climate resilience in vulnerable farming systems.

Keywords: Drought prediction, land use mapping, climate-smart agriculture, NDVI, climate resilience, remote sensing, GIS, crop monitoring, and spatial analysis

Predatory Insects for Sustainable Agriculture

Puyam Nikesh Singh and P. Bhumita

Department of Entomology, College of Agriculture, Iroishemba, Central Agricultural University, Imphal, Manipur 795004

Corresponding author's email: pnikesh76@gmail.com

ABSTRACT

Sustainable pest management is crucial for modern agriculture, necessitating eco-friendly solutions that enhance both productivity and sustainable agriculture. Predatory insects, such as Coccinellidae (lady beetles), Chrysopidae (green lacewings), and Reduviidae (assassin bugs), play a pivotal role in regulating pest populations, reducing reliance on chemical pesticides, and maintaining ecological balance in agroecosystems. Their integration into pest management programs promotes biodiversity, increases crop yields, and supports economic stability for farmers, contributing to long-term food security. The abstract highlights the significance of these natural predators in biological control strategies and also discusses their socio-economic impact, particularly in rural farming communities. Key challenges, including habitat loss, pesticide exposure, and climate change affecting predator efficiency, are addressed. Recent advancements in conservation biological control, habitat manipulation, and integrated pest management (IPM) approaches, such as the use of banker plants and floral resources to enhance predator survival, offer promising solutions for optimizing predatory insect efficiency in sustainable agriculture. By fostering the adoption of natural farming-based pest control measures, predatory insects can significantly contribute to rural prosperity while ensuring a resilient and sustainable agriculture. To fully harness the potential of predatory insects, future research should focus on enhancing mass-rearing techniques, improving farmer education, and strengthening policy frameworks that support nature-based pest control solutions in modern agriculture.

Keywords: Predatory insects, biological control, sustainable agriculture

Genome Editing Tools for Crop Improvement for Biotic and Abiotic Stress Tolerance

Swati chourasia

Jawaharlal Nehru krishi Vishwa vidyalaya

College of agriculture jabalpur 482004

Corresponding author's Email - chourasiyaswati63@gmail.com

ABSTRACT

Agriculture in the 21st century faces complex and multifaceted challenges ranging from climate variability, declining soil fertility, and water scarcity to rising incidences of pests and diseases. These biotic and abiotic stresses pose significant threats to crop productivity, food security, and farmer livelihoods. In this context, genome editing has emerged as a revolutionary technology that holds immense promise for accelerating crop improvement with unprecedented precision and efficiency.

This thematic area focuses on the development and application of genome editing tools, particularly CRISPR-Cas systems, to enhance the resilience of crops against environmental stresses. Traditional breeding techniques, though effective, are often time-consuming and limited in scope. In contrast, genome editing allows for targeted modifications of specific genes associated with desirable traits—such as drought tolerance, heat resistance, disease resistance, and salinity adaptation—without introducing foreign DNA. This ensures that the improved varieties are both safe and publicly acceptable.

Biotic stress tolerance, especially resistance to pathogens and pests, can be significantly improved by editing resistance (R) genes or altering plant immune responses. For example, editing susceptibility genes in rice and wheat has already shown great success in combating fungal diseases like blast and rust. On the other hand, abiotic stress resilience—such as tolerance to drought, extreme temperatures, or nutrient deficiencies—can be achieved by modifying regulatory genes involved in stress signaling pathways, water-use efficiency, or root architecture.

Furthermore, genome editing can contribute to nutritional security by improving the nutritional profile of staple crops, reducing anti-nutritional factors, and enhancing post-harvest qualities. The technology also offers immense potential in accelerating breeding programs through the rapid development of elite cultivars suited to local agro-climatic conditions.

From a policy and ethical standpoint, it is crucial to build public trust and awareness about the safety and benefits of genome-edited crops. Streamlining regulatory frameworks, encouraging public-private partnerships, and investing in research and capacity building are vital to maximizing the impact of these tools in Indian agriculture.

In conclusion, genome editing represents a paradigm shift in modern agriculture, enabling precise, rapid, and sustainable crop improvement. By harnessing this technology, India can not only mitigate the risks posed by biotic and abiotic stresses but also move closer to achieving food and nutritional security in a climate-resilient and economically viable manner.

Promoting Agripreneurship Among Rural Youth for Vikasit Bharat

Kartike Sharma

Dr. Y.S. Parmar University of Horticulture and Forestry, Solan, Himachal Pradesh – 173230

Corresponding author's email: sharmakartike50@gmail.com

ABSTRACT

Promoting agripreneurship among rural youth is crucial for achieving Viksit Bharat 2047, which aims to transform India into a developed, self-reliant economy by integrating agriculture with entrepreneurship. Agripreneurship empowers rural youth to innovate beyond traditional farming by adopting modern technologies such as precision farming, IoT-based monitoring, and digital marketplaces, thereby increasing productivity and profitability. Skill development and capacity building through training programs in agribusiness management, financial literacy, and digital skills equip youth to manage and scale their enterprises effectively. Access to affordable finance, subsidies, and market linkages via government schemes like e-NAM and rural startup funds reduces entry barriers and enhances income opportunities. The integration of AgriTech innovations, including mobile apps for weather forecasting, supply chain management, and blockchain for traceability, fosters transparency and efficiency. Emphasizing sustainability through organic farming, renewable energy use, and water conservation aligns agripreneurship with environmental goals, ensuring long-term rural resilience. Coordinated policy support involving government, educational institutions, and the private sector creates an enabling ecosystem with mentorship, incubation centers, and infrastructure development. Agripreneurship generates employment by creating self-employment and wage opportunities, reducing rural unemployment and underemployment among youth. It also diversifies income by integrating allied sectors like food processing, dairy, and fisheries, reducing vulnerability to agricultural risks. Enhanced rural opportunities curb distress migration to urban areas, promoting balanced regional development. Furthermore, empowering marginalized groups, including women and smallholder farmers, fosters inclusive growth and social upliftment. Strategic recommendations include establishing dedicated agripreneurship hubs for training and market access, strengthening digital infrastructure, promoting public-private partnerships, integrating agripreneurship into formal education, and continuously monitoring programs to adapt strategies based on impact assessments. Holistically addressing these dimensions can catalyze sustainable rural development, drive innovation-led growth, and significantly contribute to the vision of Viksit Bharat 2047.

Keywords: E-National Agriculture Markets (e-NAM) and Economic milestones (GDP growth, per capita income)

Use of AI, Drones, and Mobile Applications in Horticulture

Brijesh Kumar[1], Amod Sharma[2]

Dr. Brijesh Kumar, Associate Professor, Department of Horticulture, R.B.S. College, Agra

Prof. Amod Sharma, Senior Professor, Nagaland Central University, Medziphema Campus, Nagaland

Corresponding author's email: sharmakartike50@gmail.com

ABSTRACT

The integration of Artificial Intelligence (AI), drones, and mobile applications is revolutionizing horticulture by enhancing precision, productivity, and sustainability. This technological convergence has enabled a paradigm shift from traditional practices to data-driven decision-making processes in crop planning, disease management, irrigation, and post-harvest handling. AI-based models help in predicting pest outbreaks, optimizing resource use, and providing real-time recommendations to farmers. These intelligent systems analyze vast datasets including weather patterns, soil health, and crop imagery to guide timely interventions. Drones play a vital role in horticulture by enabling aerial monitoring of large farm areas, facilitating high-resolution imaging for early detection of stress, nutrient deficiencies, and disease symptoms. They also assist in targeted spraying, reducing chemical usage and environmental impact. This contributes significantly to labor efficiency and cost-effectiveness, especially in high-value crops such as fruits, vegetables, and ornamentals. Mobile applications bridge the gap between advanced technology and grassroots farmers by delivering user-friendly tools that offer crop advisory, market information, weather alerts, and AI-based diagnostics. These apps are increasingly becoming lifelines for small and marginal farmers who lack access to expert consultation. In India, where horticulture is a major contributor to agricultural GDP, the adoption of these technologies is critical for sustainable intensification and climate resilience. The combined use of AI, drones, and mobile apps supports informed decision-making, improves crop quality, and reduces post-harvest losses, thereby increasing farmers' income and livelihood security.This paper explores the practical applications, benefits, and challenges of implementing AI, drones, and apps in the horticultural sector, with case studies and field data from Uttar Pradesh and Nagaland. The authors advocate for policy support, digital literacy, and infrastructure development to promote widespread adoption of smart horticulture technologies.

Keywords: Artificial Intelligence, Drones, Mobile Apps, Precision Horticulture, Smart Farming, Sustainability, India.

Rice Spiders: Natural Allies in Sustainable Pest Management of Rice Ecosystem

Maibam Stephen Singh and Prof. K. Mamocha Singh

Department of Entomology, College of Agriculture, Central Agricultural University, Imphal, 795004, Manipur, India

Corresponding author's e-mail: maibamstephen5@gmail.com

ABSTRACT

Rice spiders are increasingly recognized as vital natural allies in sustainable pest management for rice ecosystems worldwide. Diverse spider communities in rice fields play a critical role in suppressing key insect pests such as planthoppers, leafhoppers, and stem borers, leading to notable reductions in crop damage and less reliance on chemical pesticides. Evidence from India demonstrates that rice fields with abundant spider populations often experience fewer pest outbreaks and maintain stable yields even without heavy chemical inputs. Notable recent Indian studies have documented over 30 spider species from paddy fields in Dakshina Kannada, Karnataka, with families like Tetragnathidae and Oxyopidae proving especially effective in pest control. Research in Kerala's Kuttanad region found representatives from 16 spider families, with Salticidae, Araneidae, and Tetragnathidae as the most prevalent, highlighting high local biodiversity and its contribution to pest regulation. Eco-engineering approaches such as planting flowering plants on field margins or bunds are enhancing spider populations and natural pest suppression in several Indian regions. Additionally, habitat management trials in places like Haryana have shown that techniques such as using straw bundles or border cropping help boost spider numbers and provide refuges, which in turn strengthen their biological control of pests. Integrated pest management programs in India are increasingly combining these biological strategies with resistant rice varieties and minimal, targeted pesticide applications. With emerging tools like digital monitoring platforms and participatory tracking of pest and predator dynamics, farmers are empowered to make informed, environmentally sound decisions. These advances and discoveries from India underscore the critical role of rice spiders as frontline agents in sustainable agriculture, offering practical pathways for reducing chemical use, safeguarding biodiversity, and ensuring the long-term productivity and resilience of rice ecosystems.

Keywords: rice spiders, sustainable pest management, biodiversity conservation

CRISPR Tools for Crop Improvement for Biotic and Abiotic Stress Tolerance

Anand Kirar[1]*, Shashank Vishvakarma[2], Akansha Sen[2], Pankaj Kumar Umar[3] and Jyoti[3]

[1]Department of Animal Nutrition, College of Veterinary Science & Animal Husbandry (NDVSU), Jabalpur, M.P. 482001

[2]Department of Veterinary Gynaecology & Obstetrics, College of Veterinary Science & Animal Husbandry (NDVSU), Jabalpur, M.P. 482001

[3]Department of Veterinary Pharmacology & Toxicology, College of Veterinary Science & Animal Husbandry (NDVSU), Jabalpur M.P. 482001

Corresponding Author's- Email id- kiraranand98@gmail.com

ABSTRACT

Modern agriculture faces mounting challenges due to climate variability, emerging pathogens and increasing global food demand. The advent of CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) genome-editing technology has provided a revolutionary tool for precise and efficient genetic modification in crops. CRISPR/Cas systems, particularly CRISPR/Cas9 and CRISPR/Cas12a, enable targeted editing of genes associated with both biotic stress resistance (against diseases and pests) and abiotic stress tolerance (such as drought, salinity, heat and cold). In biotic stress management, disruption of susceptibility genes (e.g., *MLO*, *eIF4E*) and enhancement of disease resistance genes (*R* genes) have conferred improved resistance to fungal, viral and bacterial pathogens. In parallel, genes regulating abiotic stress responses—such as *DREB*, *NHX1* and *OsPYL*—have been modified to enhance tolerance to salinity, dehydration and oxidative stress. The ability of CRISPR tools to create DNA-free, non-transgenic mutations increases their acceptability under regulatory frameworks in many countries. Moreover, multiplex genome editing allows for simultaneous targeting of multiple traits, expediting the breeding of stress-resilient crops. This technology holds transformative potential to develop climate-smart, high-yielding varieties that can thrive under adverse environmental conditions, thereby supporting sustainable agriculture and global food security.

Keywords: Genome Editing, Stress Tolerance in Crops

Entomopathogen-Based Biopesticides: A Sustainable Frontier in Insect Pest Management for Crop Protection

Bhritishma Kalita[1], K.I. Singh[1], Nilima Karam[1] and Karishma Kalita[2]

[1]Department of Entomology, College of Agriculture, Iroishemba, Central Agricultural University, Imphal, Manipur, India 795004

[2] Department of Entomology, Assam Agricultural University, Jorhat, Assam, 785013

Corresponding author's email: bhritishmakalita1@gmail.com

ABSTRACT

Although synthetic chemicals are extensively used, they exhibit several notable disadvantages that constrain their long term sustainability and safety. While entomopathogen based biopesticides made from natural insect killing organisms like fungi, bacteria, viruses and nematodes are becoming safe and eco-friendly alternatives to chemical pesticides. Globally, the use of biopesticides is on a strong upward trajectory especially in under developed countries. In India, the biopesticide sector is experiencing steady annual growth and is expected to double by 2030. Bt, a well-known bacterial biopesticide, used in many bio-formulations, can lower armyworm damage in maize by almost three-quarters. In Indian agricultural systems, entomopathogenic nematodes have proven capable of controlling caterpillar infestations with over 90% mortality in less than 10 days. Native farmers while using *Metarhizium* saw a big drop in harmful insect numbers by more than half. Researchers are now combining various entomopathogenic organisms to broaden the spectrum of pest control and enhance overall efficacy. In soybean farming using a consortia of entomophagous fungi has shown better efficacy against insect-pests than using only one type, giving stronger and long-lasting control. Scientists are now creating special versions by using silver from fungi to make sprays that last long and work better under sunlight. By offering effective crop protection, reducing dependency on synthetic chemicals, and supporting safer food systems, entomopathogen based biopesticides are poised to become a cornerstone of future pest management strategies. With continued investment in research, innovation, and policy support, these biologically based solutions can play a vital role in advancing global crop protection.

Keywords: Entomopathogen, biopesticide, sustainable agriculture

Increasing the Self Stability of Yogurt

Pankaj Khichar

College of Dairy Science Amreli

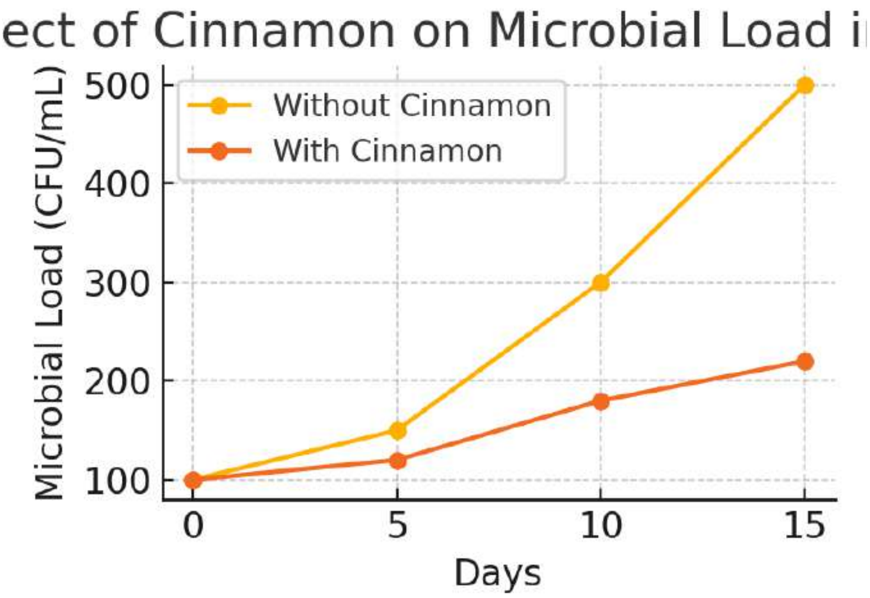
Corresponding author's email: 0pankajkhichar@gmail.com

ABSTRACT

Yogurt is a widely consumed fermented dairy product known for its probiotic benefits; however, its shelf life is limited due to microbial spoilage. This study investigates the use of cinnamon (Cinnamomum verum) as a natural antimicrobial agent to reduce microbial load and extend the shelf life of yogurt. Cinnamon contains bioactive compounds, primarily cinnamaldehyde and eugenol, which exhibit strong antibacterial and antifungal properties. When added in controlled concentrations, cinnamon can inhibit the growth of spoilage organisms without significantly affecting the viability of beneficial lactic acid bacteria. The incorporation of cinnamon also enhances the sensory profile of yogurt, offering a warm, aromatic flavor favored by many consumers. Results demonstrate that cinnamon-enriched yogurt shows delayed microbial growth during storage, reduced risk of contamination, and an extended shelf life compared to control samples. These findings support the potential of cinnamon as a natural, clean-label preservative in functional dairy products.

Keywords : Yogurt, Cinnamon, Shelf life, Antimicrobial, Probiotics

Figure: Effect of Cinnamon on Microbial Load in Yogurt



Exploring Digital Agriculture: A Step Towards Sustainable and Efficient Farming

Digvijay Singh[1*], Ratnesh Kumar Jha[1], Harshita Singh[2]

[1]Department of Agronomy, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India- 848125

[2]Department of Agronomy, Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj, Uttar Pradesh, India – 211007

Corresponding author's e-mail: dvrs0411@gmail.com

ABSTRACT

Agriculture is one of the foremost contributors to the Indian economy currently valued at USD 370 billion. The GDP contribution of the agricultural sector has increased a bit from 17.8% in 2019–20 to 19.9% in 2020–21 as per the economic survey 2020–21. Feeding an estimated population of 9.2 billion in the world by 2050 is a big challenge for agricultural policymakers in light of maintaining food security and securing long-term sustainable development that may further require a colossal transformation of Indian agriculture towards a technological revolution. Labour scarcity, several environmental stresses, the economic burden on the agrarian sector, and the issues related to climate change are increasing day by day. As a result, the efficiency of the agricultural system has been decreasing making agriculture less profitable and reducing the sustainability of the system. Therefore, augmentation of the efficiency of agricultural systems by using modern integrated smart technologies are need of the hour. In this context, digital agriculture tools can support a deeper understanding of interrelations within the agricultural production system and the resultant effects on the performance of farm production while balancing human health and well-being, social and environmental aspects, and sustainability associated with the agricultural system. The Ministry of Agriculture and Farmers Welfare declared the commencement of the Digital Agriculture Mission 2021–25 promoting to advancements in the data ecosystem, processing, and human-computer interactions. One of the prime aspects of digitalization in agriculture is the introduction of innovative Information and Communication Technology (ICT), Internet of Things (IoT), big data analytics, and interpretation techniques, blockchain technology, machine learning (ML), and Artificial Intelligence (AI). The government has signed five memorandums of understandings (MoUs) with CISCO, Ninjacart, Jio Platforms Limited, ITC Limited and NCDEX e-Markets Limited (NeML), for advancing the digital agriculture through some pilot projects.

Keywords: Digital Agriculture, Environment, Food Security, Human Health, Sustainability, Transformation

Functional Group Analysis and Spectroscopic Characterization of Humic Substances: A Comprehensive Review

Govind Vishwakarma[1]* and Digvijay Singh[2]

[1]Department of Soil Science, Dr. Rajendra Prasad Central Agricultural University, Pusa Samastipur, Bihar, India- 848125

[2]Department of Agronomy, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India- 848125

Corresponding author's e-mail: govind49.bhu@gmail.com

ABSTRACT

Humus is the stable, dark colored organic material that forms in soil from the decomposition of plant and animal residues. It represents the final stage of the microbial breakdown of organic matter and is a key component of soil organic matter (SOM). Unlike fresh residues, humus is highly resistant to further decomposition and can persist in soil for decades or even centuries. Humus plays a vital role in maintaining soil fertility and ecosystem health. Chemically, humus is made up of complex, high molecular weight compounds collectively known as humic substances, which include fulvic acid (FA), humic acid (HA), and humin. Among these humic fractions, fulvic acid is soluble in both acidic and alkaline conditions. HA represents the fraction that is soluble exclusively in alkaline conditions. The most insoluble component of humus is humin, which remains insoluble in both acidic and alkaline conditions. In this study, humic and fulvic acids were extracted, isolated, and purified from manures and then examined for their functional groups and through various spectroscopic methods. It was observed that fulvic acid contained higher amounts of total acidity (9.4 me g^{-1}), carboxyl groups (6.2 me g^{-1}), and phenolic OH groups (3.2 me g^{-1}) compared to humic acid, which showed 7.2, 4.2, and 3.0 me g^{-1}, respectively. Among these functional groups, carboxyl groups contributed a greater share to the total acidity than phenolic OH groups in both humic substances. When examining their light absorption properties, the E4/E6 ratio (which compares the light density at 465 nm to 665 nm) was higher for fulvic acid (6.17) than for humic acid (4.34). Although the composition of the two acids was different, their UV spectra showed a similar pattern, with optical density gradually decreasing as the wavelength increased.

Key words: Ecosystem, Humus, Soil Fertility, Soil Organic Matter

Startups and Innovations in Agriculture – Harnessing Parabiotic and Postbiotics for Sustainable Food Solutions

Deepak Singh Patel

Ph.D. Scholar, Division of Biochemistry, ICAR-IARI, New Delhi 110012, India

Corresponding author's email: deepak201patel@gmail.com

ABSTRACT

The agricultural sector is witnessing a paradigm shift driven by startups and technological innovations aimed at enhancing sustainability, food security, and health benefits. One such groundbreaking innovation is the development of parabiotic and postbiotics derived from probiotic *Lactobacilli*, which present a transformative alternative to conventional probiotics. Unlike live probiotics, these non-viable microbial components (probiotics) and their metabolic byproducts (postbiotics) overcome challenges related to viability, storage, and safety, while retaining significant health-promoting properties such as antibacterial, antifungal, and antioxidant activities. This research aligns with the growing Agri-startups ecosystem by focusing on the isolation, characterization, and functional validation of parabiotic and postbiotic compounds for their biotherapeutic potential. The study aims to optimize production methodologies and validate their efficacy in food matrices, particularly soymilk, to address gaps in commercialization and scalability. The outcomes hold immense potential for startups to innovate in the nutraceutical and functional food sectors, offering sustainable, health-centric products tailored for an aging population and health-conscious consumers. By integrating cutting-edge biotechnology with entrepreneurial opportunities, this work exemplifies how agricultural innovations can bridge science and industry. It underscores the role of startups in driving the adoption of novel solutions, such as postbiotic-fortified foods, to meet global demands for safe, sustainable, and functional nutrition. The research not only contributes to scientific advancement but also provides a roadmap for agri-entrepreneurs to leverage microbial technologies, fostering economic growth and food system resilience.

Keywords: Agri-startups, Innovation, Parabiotic, Postbiotics, Functional Foods, *Lactobacilli*, Sustainability, Nutraceuticals, Biotechnology.

Soil carbon sequestration enhancement through agricultural practices

Deepak Kumar Dwivedi[1], N. Janaki Singh[1]*, Gayatri Pralhad Turkar[2], Amit Mishra[1], Sanjay Swami[3] and Pramod Kumar Pandey[4]

[1]SNRM, CPGS-AS, (Central Agricultural University-Imphal), Umiam, Meghalaya, India

[2]Department of Soil Science & Agricultural Chemistry, JNKVV, Jabalpur, Madhya Pradesh

[3]Dean, CoA, (Central Agricultural University-Imphal), Pasighat, Arunachal Pradesh

[4]CoA, (Central Agricultural University-Imphal), Kyrdemkulai, Ri-Bhoi District, Meghalaya

Corresponding author's email: - naorem2005@gmail.com

ABSTRACT

Soil organic carbon plays an important role in the stability and fertility of soil and is influenced by different management practice. Human efforts to produce more food for increasing populations leave marks on the environment. The use of conventional agricultural practices, including intensive tillage based on the removal of crop residue, has magnified soil erosion and soil degradation. In recent years, the progressive increase in the concentration of greenhouse gases (GHGs) has created global interest in identifying different sustainable strategies in order to reduce their concentration in the atmosphere. Carbon stored in soil is 2–4 times higher than that stored in the atmosphere and four times more when compared to carbon stored in the vegetation. The process of carbon sequestration (CS) involves transferring CO_2 from the atmosphere into the soil or storage of other forms of carbon to either defer or mitigate global warming and avoid dangerous climate change. Climate change mitigation is possible through a reduction in net GHG emission by the process of carbon sequestration. Storage of carbon in a stable solid form through direct and indirect fixation in soil leading to carbon sequestration can result in an annual growth rate of 0.4% in the soil carbon stock and significantly reduce CO_2 concentration in the atmosphere. The long term sequestration of carbon, viz, carbon stabilization is possible through both abiotic and biotic factors. Soil organic C stocks are altered by biotic activities of plants (the main source of C through litter and root systems), microorganisms (fungi and bacteria) and 'ecosystem engineers' (earthworms, termites, ants). In the meantime, abiotic processes related to the soil-physical structure, porosity and mineral fraction also modify these stocks. Agricultural practices such as tillage, fallow elimination and erosion control and methane mitigation reduce carbon loss while crop management, nutrient management, land use systems, agro forestry and Nano-technology enhance carbon inputs. These agricultural management practices can facilitate carbon stabilisation by acting through both biotic and abiotic mechanisms.

Keywords: Carbon sequestration, climate change, global warming, soil conservation, zero tillage

Recent Advances in Precision Horticulture

Rathod Nirav Kamleshbhai

Dr. Parag Pandit, Asst. Prof. Post harvest department,

Aspee College of Horticulture, NAU Navsari

Corresponding author's email: nkrathod2141@gmail.com

ABSTRACT

Precision horticulture is an emerging field that integrates advanced technologies and data-driven approaches to optimize crop production, resource utilization, and environmental sustainability. Recent advancements in this domain have revolutionized traditional horticultural practices by enhancing efficiency and productivity. Key developments include the use of remote sensing technologies, such as drones and satellite imagery, which provide real-time data on crop health, nutrient status, and pest or disease outbreaks. Geographic Information Systems (GIS) and Global Positioning Systems (GPS) facilitate site-specific management practices, enabling precise application of water, fertilizers, and pesticides.

Artificial Intelligence (AI) and Machine Learning (ML) algorithms have further enhanced decision-making by analyzing large datasets to predict crop yields, assess plant stress, and recommend timely interventions. The Internet of Things (IoT) has enabled real-time monitoring of environmental parameters through smart sensors, leading to better control of microclimatic conditions in greenhouses and open fields. Automation technologies such as robotic harvesters and autonomous vehicles are also gaining traction, reducing labor dependency and operational costs.

Additionally, variable rate technology (VRT) allows for the customized application of inputs, minimizing waste and promoting sustainability. Advances in genomics and phenotyping tools have enabled the development of precision breeding techniques for improved cultivars.

In conclusion, recent advances in precision horticulture offer transformative solutions for addressing global challenges such as food security, climate change, and resource scarcity. These innovations support more resilient, productive, and sustainable horticultural systems, marking a significant leap forward in modern agricultural practices.

Precision agriculture and smart farming

Anita Chaudhary

Department of Agriculture

Navsari Agricultural University, Navsari 396450, Gujarat

Corresponding author's email: anitachaudhary2125@gmail.com

ABSTRACT

Precision agriculture and smart farming represent a transformative shift in the agricultural industry, leveraging advanced technologies to enhance productivity, efficiency, and sustainability. These modern farming approaches integrate tools such as GPS, remote sensing, Internet of Things (IoT), big data analytics, and machine learning to enable data-driven decision-making. By precisely monitoring field variability and managing resources like water, fertilizers, and pesticides, precision agriculture minimizes waste and environmental impact while maximizing crop yield.

Smart farming extends the principles of precision agriculture by incorporating automation and real-time monitoring systems. Technologies such as drones, autonomous tractors, soil sensors, and cloud-based data platforms allow for continuous assessment of crop health, soil moisture, and weather conditions. This enables farmers to make timely interventions and optimize resource utilization at the micro-level. Additionally, predictive analytics can forecast pest outbreaks, disease risks, and market trends, further supporting proactive farm management.

The adoption of these technologies not only addresses the challenges posed by climate change, labour shortages, and rising input costs but also contributes to global food security by enhancing agricultural resilience. Moreover, smart farming practices support sustainability goals through reduced chemical usage, improved soil health, and efficient land use.

Despite the promising potential, the widespread implementation of precision agriculture faces challenges such as high initial costs, limited digital literacy among farmers, and inadequate infrastructure in rural areas. Addressing these barriers through policy support, education, and technological innovation is crucial for scaling adoption.

In conclusion, precision agriculture and smart farming are revolutionizing traditional farming practices, offering a path toward more productive, sustainable, and technologically integrated agriculture. As these technologies continue to evolve, they hold the potential to significantly reshape the future of global food systems.

Key-Words: Sensor, data analytics, Automation, sustainability, IoT (Internet of Things)

The Promotion of Natural and Organic Farming: A Path Towards Sustainable and Healthy Agriculture

Kaklotar Utsav Ghanshyambhai

College of Agriculture (NAU) Waghai, (Dangs) - 394730

Corresponding Author’s Email: utsavkaklotar60@gmail.com

ABSTRACT

Modern industrial agriculture, driven by synthetic fertilizers, pesticides, and genetically modified organisms, has significantly increased food production but at a great cost. This chemical-intensive approach has led to severe environmental and social problems, including soil degradation, water pollution, biodiversity loss, and climate change. Furthermore, it poses health risks to consumers from chemical residues and to farmers from direct exposure, often trapping small farmers in cycles of debt. There is an urgent global need to shift towards sustainable and healthy farming systems.

This paper explores natural and organic farming as a vital solution. These eco-friendly methods, which work with nature rather than against it, reject harmful chemicals and embrace practices that enhance ecological balance. Natural farming, with its "do nothing" philosophy, uses minimal external inputs and traditional wisdom. Organic farming follows a systematized approach with certified standards, relying on techniques like composting, crop rotation, and biological pest control.

The promotion of these methods offers substantial benefits. Environmentally, they improve soil health, conserve water, protect biodiversity, and mitigate climate change. Health-wise, they provide safer, more nutritious food and protect farmers from toxic chemicals. Economically, they reduce production costs and can fetch premium prices, empowering small farmers and creating rural employment. Socially, they preserve traditional knowledge and foster vibrant rural communities.

Despite challenges like a lack of awareness, costly certification, and initial yield gaps, a concerted effort is essential. This requires supportive government policies, simplified certification processes, and focused research and development. Additionally, training for farmers and consumer education are crucial to building a sustainable agricultural future. Ultimately, promoting natural and organic farming is not merely a choice—it is a necessary movement towards global health, sustainability, and harmony with the earth

Youth and Agriculture: Revitalizing Rural Economies

Viralkumar P. Chaudhari[1], Udaykumar Birari[2], Krunalbhai R. Patel[3], Yuvraj Vinodbhai Rajput[4]
[1]Assistant Professor, PGIABM, JAU, Junagadh
[2]PG Institute of Agribusiness Management, JAU, Junagadh
[3]Research Scholar, NMIMS, Mumbai
[4]Research Scholar, Department of Agribusiness Management, PGIABM, JAU, Junagadh

Corresponding Author's Email: yvrajput@jau.in

ABSTRACT

Agriculture remains a cornerstone of food security and rural livelihoods in developing countries. However, a growing generational gap threatens the sustainability of the sector, as youth increasingly disengage from agriculture due to limited access to land, capital, modern education, and viable markets. This trend has contributed to urban migration, aging farming communities, and declining agricultural productivity. This article emphasizes the importance of youth engagement in agriculture to reverse these trends and rejuvenate rural economies. Young people bring innovation, energy, and technological adaptability to agriculture. They are more inclined to adopt digital tools, precision farming, and climate-smart practices, making them pivotal for modernizing agricultural systems. Despite this potential, youth face critical challenges: lack of land ownership, limited financial support, insufficient agricultural training, and weak market access. To address these barriers, the article proposes solutions including agripreneurship promotion, digital technology adoption, vocational training, and policy support. Government schemes like ARYA, RKVY-RAFTAAR, and the Agri-Infra Fund offer institutional backing. Platforms such as Agri-business Incubation Centres and Mkulima Young in Kenya are also successful models fostering youth participation through training and market connectivity. By empowering young farmers through education, access to technology, and supportive ecosystems, rural regions can be transformed into innovation hubs. Such initiatives will not only boost food production but also create employment, reduce migration, and build resilient agricultural systems.

Keywords: Youth in agriculture, Agripreneurship, Rural economy, Agricultural innovation, Skill development, Digital agriculture, Sustainable farming

Advancements in aquaculture: sustainable practices for fish production

Rajput Y.V.[1], Zankat H.M[2], Pithiya K.G[3] and Bamaniya A.B.
PG Institute of Agribusiness Management, JAU, Junagadh – 362001, Gujarat, India
College of Fisheries Science, Kamdhenu University, Himmatnagar – 383010, Gujarat, India
Corresponding Author: yuvrajput867@gmail.com

ABSTRACT

Aquaculture is a rapidly expanding sector that plays a pivotal role in meeting the rising global demand for seafood while alleviating pressure on wild fish stocks. Sustainable aquaculture is essential for environmental conservation, economic viability, and social responsibility. Recent advancements include innovative systems such as Recirculating Aquaculture Systems (RAS), Integrated Multi-Trophic Aquaculture (IMTA), offshore farming, and bio floc technology—all designed to maximize resource efficiency and minimize ecological impact. The adoption of alternative fish feeds (e.g., plant- and insect-based proteins), artificial intelligence (AI), and automated monitoring has revolutionized precision fish farming, improved productivity and reducing costs. Additionally, sustainable water management, biosecurity measures, and regenerative practices like mangrove and oyster reef restoration further enhance aquaculture’s ecological benefits. Despite these advancements, challenges remain in climate adaptation, habitat degradation, and market access. Future directions point toward gene editing, improved carbon footprint tracking, and greater policy support. This paper highlights the critical innovations in sustainable aquaculture and emphasizes their importance in securing global food security without compromising aquatic ecosystems.

Keywords: Sustainable Aquaculture, RAS, IMTA, Bio floc Technology, Fish Feeds, AI in Aquaculture, Water Management, Regenerative Practices

Transforming Indian Agriculture through Forestry-Based Innovations: Pathways to Sustainable and Climate-Resilient Farming

Chinmaya Sahu*, Department of Forestry, Central University of Odisha, Koraput,763004

Subham Kumar, Department of Agriculture, Central University of Odisha, Koraput,763004

Barsha Kuanra, Department of Dairy Science, Central University of Odisha, Koraput, 763004

Corresponding Author: schinmaya2007@gmail.com

ABSTRACT

Agriculture in India stands at a critical crossroads, challenged by declining soil productivity, erratic climate patterns, and unsustainable land-use practices. This paper explores forestry-based innovations as a transformative solution for sustainable agricultural intensification. By integrating principles of agroforestry, silviculture, and watershed management, the study demonstrates how forestry interventions can restore degraded farmlands, enhance biodiversity, and ensure long-term food security. Agroforestry, which involves the strategic incorporation of trees and shrubs into cropping and livestock systems, offers multiple benefits—ranging from improved nutrient cycling and soil organic matter to enhanced pollination and pest control. Indigenous tree-crop models, bio-fencing techniques, and carbon-positive farming are presented as scalable strategies to augment agricultural resilience. Field insights from Odisha's tribal belts and Southern India substantiate the potential of diversified farm-forest systems in stabilizing yields and improving rural livelihoods. This submission positions forestry science as a strategic enabler of agricultural modernization, advocating for interdisciplinary collaboration, policy integration, and farmer-centric innovation. The vision presented underscores the role of forestry professionals in steering India's agriculture towards sustainability, profitability, and ecological balance by 2050.

Keywords: Sustainable Agriculture, Agroforestry, Forestry Innovations, Climate Resilience, Indigenous Models, Rural Livelihoods, Farm-Forest Systems.

Metabolomic Profiling of Plants Grown under Natural Farming: Insights into Enhanced Disease Tolerance Mechanisms

Mihir P. Pansuriya[1*], Chirag D. Makwana[1], Barath B[1] and Manthan R. Sindhav[2]

[1]Department of Plant Pathology, C.P.C.A., Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar - 385506, Gujarat, India.

[2]Department of Entomology, C.P.C.A., Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar - 385506, Gujarat, India.

Corresponding author email: mihirpansuriya18.in@gmail.com

ABSTRACT

Natural farming emphasizes ecological balance, minimal external inputs and the use of indigenous resources to enhance crop health. While its agronomic and environmental benefits are widely acknowledged, the underlying molecular mechanisms by which natural farming augments plant defense against pathogens remain underexplored. Recent advancements in metabolomics offer a powerful tool to untangle the plant's biochemical changes in response to such low-input, microbe-rich systems. This review explains how natural farming operations influence the plant metabolome to render them disease-tolerant. Through cow-derived products (e.g., *Jeevamrit*) and indigenous microbial inoculants, natural farming fosters beneficial soil microbiota, which, in turn, trigger systemic responses in plants. Untargeted metabolomic studies with LC-MS and GC-MS have shown elevated levels of phenolic compounds, alkaloids and terpenoids well documented for their antimicrobial and signaling agencies in naturally farmed crops. For instance, in tomato plants cultivated under natural farming, elevated accumulation of chlorogenic acid and rutin was found correlated with reduced incidence of *Alternaria solani*. These secondary metabolites interfere with fungal cell wall integrity and inhibit spore germination. Similarly, rice plants cultivated using Panchagavya amendments had elevated levels of phytoalexins like sakuranetin, which resisting *Magnaporthe oryzae* infection. The review also explains how metabolomics can be combined with transcriptomics to offer key pathways (e.g., phenylpropanoid, jasmonate and salicylic acid biosynthesis) induced under natural farming. Such insights not only validate traditional practices through a molecular lens but also provide new avenues for breeding disease-resilient cultivars suited for chemical-free farming. In conclusion, metabolomics is a pivotal tool to decode plant-pathogen interactions within natural farming systems, offering scientific validation and future prospects for sustainable crop protection strategies.

Keywords: Natural farming, Metabolomics, Plant-pathogen interactions, Disease resistance, Secondary metabolites

Genome Editing via CRISPR/Cas9 for Biofortification of Fruit Crops Against Hidden Hunger

Pooja Tanwar[1]*, Dr. H. N. Leua[1] and Dr. Piyush Verma[2]

[1]Department of Fruit Science, College of Horticulture, Sardarkrushinagar Dantiwada Agricultural University, Jagudan, Mehsana-384 460, Gujarat

[2]Professor, College of Horticulture, Sardarkrushinagar Dantiwada Agricultural University, Jagudan, Mehsana-384 460, Gujarat

Corresponding Author's email: tanwarpooja95115@gmail.com

ABSTRACT

Hidden hunger remains a critical global health concern, particularly in developing nations due to micronutrient deficiencies. Fruits play a vital role in combating such deficiencies due to their rich micronutrient profile. While conventional breeding methods are helpful in improving nutritional traits, they are time-consuming and inefficient. Genome editing technologies, especially CRISPR/Cas9 (Clustered Regularly Interspaced Short Palindromic Repeats) technology, has emerged as a revolutionary tool for rapid, precise and targeted crop modifications without integrating foreign DNA. This review highlights the application of CRISPR/Cas9 in fruit crops such as apple, banana, kiwi, strawberry, grape, and orange to enhance agronomic traits and nutritional quality. A notable focus of these efforts is biofortification, improving the content and bioavailability of key micronutrients such as iron, folate, and zinc. The review emphasizes the transformative potential of CRISPR/Cas9 in developing nutrient-rich fruit varieties, offering a sustainable solution to combat hidden hunger globally.

Keywords: CRISPR/Cas9, Biofortification, Genome editing.

Harnessing Rootstock Breeding for Climate Resilience in Fruit Crops

Pooja Tanwar[1]*, Dr. H. N. Leua[1], Gopi D. Rabadiya[2] and Dr. K. Manasa[3]

[1]Department of Fruit Science, College of Horticulture, Sardarkrushinagar Dantiwada Agricultural University, Jagudan, Mehsana-384 460, Gujarat

[2]Department of Food Science and Nutrition, ASPEE College of Nutrition and Community Science, SDAU, Sardarkrushinagar-385506

[3]Department of Vegetable Science, College of Horticulture, Sardarkrushinagar Dantiwada Agricultural University, Jagudan, Mehsana-384 460, Gujarat

Corresponding Author's email: tanwarpooja95115@gmail.com

ABSTRACT

India is the world's second-largest producer of fruits, yet climate change increasingly threatens the sustainability of fruit production by intensifying abiotic stresses such as drought, salinity, temperature extremes, and flooding, alongside biotic challenges. In this context, rootstocks—serving as the foundational component of grafted fruit trees—play a pivotal role in enhancing resilience, yield, and fruit quality under adverse conditions. Contemporary rootstock breeding programs prioritize traits including dwarfing, tolerance to abiotic and biotic stresses, disease resistance, and compatibility with commercial scions. Prominent examples include MM-111 in apple (aphid resistance), Dogridge and 110-R in grape (Phylloxera tolerance), and Deorakhio and Olour in mango (pest resistance and canopy management). Resilient rootstocks often exhibit deeper root systems, enhanced water and nutrient uptake, elevated levels of stress-responsive compounds such as abscisic acid (ABA) and proline, and robust antioxidant activity. For instance, drought-tolerant apple rootstocks maintain photosynthetic efficiency and yield, while tetraploid citrus rootstocks enhance drought resilience through increased ABA, osmolyte accumulation, and reactive oxygen species (ROS) scavenging. Advancements in rootstock development now incorporate genomics-assisted breeding, genome-wide association studies (GWAS), CRISPR/Cas9 genome editing, and high-throughput phenotyping tools to accelerate the identification of stress-resilient genotypes. Standardizing evaluation protocols across fruit crops is essential for consistent and effective rootstock selection. Such innovations are critical for sustaining fruit production systems under the growing pressures of climate variability

Keywords: Rootstock breeding, Climate change, Abiotic Stresses, CRISPR/Cas9.

Application of the Centrifugal Method for Sex Separation in Silkworm (Bombyx mori) Production"

R Nithesh , Maruti N ,Rahul Hatti And Rahul J

University of agricultural sciences , College of Agriculture

Dharwad 580005

Corresponding Author's email: rangammanahallinithesh@gmail.com

ABSTRACT

The centrifugal method is an advanced and efficient technique employed in the sericulture industry for the sex separation of silkworm (Bombyx mori) eggs. This method utilizes the principle of differential specific gravity between male and female eggs during early embryonic stages. When subjected to centrifugal force under controlled conditions, the eggs stratify based on weight, allowing for the physical separation of sexes before hatching. This process plays a crucial role in the commercial production of sex-limited hybrid silkworms, where only one sex (usually females) is preferred for rearing due to superior cocoon quality and uniformity in growth.

In traditional silkworm rearing, mixed-sex populations often result in inconsistent cocoon characteristics and increased management challenges. The application of the centrifugal method reduces these limitations by enabling early, large-scale, and non-invasive sex separation. This leads to improved rearing practices, better feed efficiency, and enhanced economic returns for sericulture farmers and industries.The current research aims to examine the operational parameters, precision, and reliability of the centrifugal method under varied laboratory and commercial settings. It also evaluates the advantages of this technique in comparison to other methods like morphological or genetic sexing. The findings suggest that the centrifugal method, when optimized, offers a high degree of accuracy, minimizes labor input, and aligns well with sustainable and modern sericulture practices.Overall, the centrifugal method represents a significant technological advancement in silkworm egg management and has the potential to transform hybrid silkworm production by making it more economical, scalable, and efficient.

Key Words: Centrifugal Method, specific Gravity, genetic sexing

Biosynthesis and Physicochemical Characterization of Zinc Oxide Nanoparticles Mediated by *Trichoderma harzianum* for the Biocontrol of Major Rice Pathogens

Nitesh Meena, Vedant Gautam and R. K. Singh

Department of Mycology and Plant Pathology, Banaras Hindu University

Varanasi, U.P., 225001

Corresponding Author's email: niteshmeena@bhu.ac.in

ABSTRACT

This research examines the synthesis of zinc oxide (ZnO) nanoparticles utilizing the biocontrol agent Trichoderma harzianum and assesses their effectiveness against three principal rice pathogens: Rhizoctonia solani, Magnaporthe oryzae, and Meloidogyne graminicola. The produced ZnO nanoparticles underwent comprehensive characterization through Transmission Electron Microscopy (TEM), Scanning Electron Microscopy (SEM), UV-Visible spectrophotometry, Raman spectroscopy, and Fourier Transform Infrared (FTIR) spectroscopy to validate their structural and optical characteristics. Three distinct concentrations (5 ppm, 10 ppm, and 15 ppm) of ZnO nanoparticles were evaluated to ascertain the most efficacious dosage. Among these concentrations, the 15 ppm variant exhibited the highest effectiveness in alleviating the targeted rice diseases. The findings illustrated that ZnO nanoparticles at 15 ppm significantly impeded the proliferation of R. solani and M. oryzae, while also effectively diminishing nematode infestation caused by M. graminicola. The nanoparticles disrupted the cellular membranes of both fungi and nematodes, resulting in their mortality. The superior performance of the 15 ppm concentration indicates its potential as a sustainable and environmentally friendly alternative to traditional chemical treatments for rice diseases. This investigation underscores the potential of nanotechnology in the management of agricultural pathogens, presenting an innovative strategy for enhancing crop protection and productivity within rice farming.

Keywords: Zinc oxide nanoparticles, *Trichoderma harzianum*, rice pathogens, *Magnaporthe oryzae*, *Meloidogyne graminicola*.

Genotypic Evaluation of Amaranth (*Amaranthus* spp.) for Yield and Yield-Attributing Traits Under Prayagraj Agro-Climatic Conditions

Manisha Meena[A], Nitesh Meena[B] and Bineeta M. Bara[A+]

[A]Department of Genetics and Plant Breeding, Sam Higginbottom University of Agriculture technology and sciences, Prayagraj – 211007

[B]Department of Mycology and Plant Pathology, Banaras Hindu University, Varanasi, U.P., 225001

Corresponding Author's email: manishameena0119@gmail.com

ABSTRACT

The present study, titled **"Genotypic Evaluation of Amaranth (*Amaranthus* spp.) for Yield and Yield-Attributing Traits Under Prayagraj Agro-Climatic Conditions,"** was conducted during the Rabi season of 2022–2023 at the central research field of the Department of Genetics and Plant Breeding, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj. The experiment aimed to assess the performance of twelve *Amaranthus* genotypes, including two check varieties, laid out in a Randomized Block Design (RBD) with three replications. Five plants were randomly selected and tagged from each plot to record growth and yield-related parameters. Among the tested genotypes, **EC-198136** recorded the highest seed yield per plant (22.42 g) and showed significantly superior performance in plant height (166.07 cm), leaf length (29.93 cm), days to 50% flowering (48.33), days to maturity (86.33), inflorescence length (66.47 cm), leaf area (49.89 cm^2), stem diameter (2.68 cm), biological yield per plant (80.15 g), 1000-seed weight (1.05 g), fiber content (8.08%), and oil content (9.01%). On the other hand, **EC-198132** exhibited the highest number of leaves per plant (68.27), number of branches per plant (29.69), and harvest index (34.61%), indicating notable genotypic variability for agronomic and seed-related traits among the evaluated genotypes.

Keywords: *Amaranthus* spp., genotypic evaluation, seed yield, yield-attributing traits, randomized block design

Empowering Rural Youth through Agri-Skill Development: The Strategic Role of Extension Personnel

Akshat Tamrakar[1],Seema Naberia[2]

Department of Extension Education

College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidhalaya, Jabalpur (M.P.) 482002

Corresponding author's email: tamrakarakshat2@gmai.com

ABSTRACT

The agricultural sector in India is undergoing a critical transformation, with youth engagement emerging as a central pillar for sustainable rural development. However, rural youth often face challenges such as lack of employment opportunities, outdated farming practices, and limited access to technical knowledge. In this context, extension workers play a pivotal role in bridging the gap between agricultural innovations and rural youth by facilitating skill development and capacity building. The study highlights the importance of integrating agri-skill training into extension services to empower youth in diverse domains such as organic farming, nursery management, post-harvest technology, protected cultivation, and agri-entrepreneurship. By acting as facilitators, trainers, and mentors, extension personnel can mobilize youth, provide hands-on training, and promote adoption of modern and sustainable farming techniques. The study draws upon successful models from Krishi Vigyan Kendras (KVKs), ATMA projects, and State Agricultural Universities (SAUs), showcasing how structured agri-skill programs have enhanced employability, increased rural incomes, and reduced migration. Special emphasis is given to participatory approaches, ICT-based training, and the development of Farmer Producer Organizations (FPOs) led by skilled youth. In conclusion, extension personnel are not just technology disseminators, but vital enablers of rural youth empowerment. Strengthening their capacity and aligning them with skill-based rural development programs is essential for building an enterprising, self-reliant, and vibrant rural economy.

Keywords: Extension personnels, youth empowerment, agri-skill development, rural livelihoods, KVK, participatory training, entrepreneurship.

RNA-Guided Epigenome Editing: A Novel Paradigm for Enhancing Stress Resilience and Reducing Pesticide Dependency in Crops

Chirag D. Makwana[1*], Barath B[1], Bharat D Rabari[2] and Jagmal P. Khatana[3]

[1]Department of Plant Pathology, [2]Agriculture Officer, [3] Department of Agronomy, C.P.C.A., Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar - 385506, Gujarat, India.

Corresponding author's email: chigsrayka@gmail.com

ABSTRACT

RNA-guided dCas9-fused effectors can directly alter plant defence mechanisms without modifying the DNA sequence referred as a epigenome editing. Utilising histone modifiers or DNA methylation enzymes at the promoters of immunity genes enables the targeted activation of resistance loci or the repression of susceptibility factors. Targeted epigenetic reprogramming in model trials has enhanced their capacity to manage stress and combat illness. This method serves as a long-term alternative to transgenic procedures, as it allows for the reversal of changes and does not involve the incorporation of DNA from external organisms. Since no foreign genes are introduced, crops edited through epigenome techniques may not require GMO labelling and could be subject to fewer regulations. Employing RNA-guided epigenome editing to enhance defence genes in primary crops such as rice, wheat, and maize could reduce the reliance on chemical pesticides. A dCas9–histone acetyltransferase fusion activated an ABA signalling gene associated with stress response, enhancing drought resistance in Arabidopsis. This demonstrates the potential utility of this method in various contexts. Challenges include accurately achieving the desired targeting to prevent unintended consequences elsewhere and ensuring the stability of induced epigenetic states for potential transgenerational inheritance. The interaction between chromatin markers and the environment is complex, leading to potential variability in the effectiveness of alterations made. Future research will enhance the distribution methods of epigenetic editors, such as through viral vectors or ribonucleoproteins (RNPs), while also investigating the simultaneous targeting of multiple defence gene networks.

Keywords: CRISPR/Cas9; Epigenome editing; Plant immunity; Biotic stress tolerance; Sustainable agriculture.

Startups and Innovations in Agriculture

Subham kumar[1*] Chinmaya Sahu[2] Barsha kuanra[3]

Department of Agriculture, School of Agriculture,

Department of Forestry, School of Integrated Agriculture,

Department of Dairy Science, School of Integrated Agriculture, Central University of Odisha, Koraput, Odisha, 763004

*Corresponding author's email: subhamkumarsethi121@gmail.com

ABSTRACT

Agriculture is changing faster than ever, thanks to startups and new innovations that are making farming smarter, easier, and more sustainable. Young agri-tech companies are bringing fresh ideas—like using drones to monitor crops, mobile apps to give farmers real-time advice, and sensors to manage water and fertilizer more efficiently. These technologies help farmers grow more food while using fewer resources, saving both time and money. Startups are also solving long-standing problems such as poor market access and price fluctuations. Digital platforms now connect farmers directly with buyers, ensuring fair prices and reducing middlemen. Innovations in storage, cold chains, and farm-to-table delivery are reducing food loss and improving the quality of produce that reaches consumers. Another major focus of these startups is sustainable farming. By promoting climate-friendly practices and resilient crop varieties, they are preparing farmers to face the challenges of climate change. In simple terms, startups and agri-innovations are reshaping agriculture into a modern, technology-driven sector. They are not just improving productivity but also ensuring that farming remains profitable, eco-friendly, and future-ready.

Keywords: Startups, Agri-Tech, Innovations, Sustainable Farming, Market Access

Promoting Agripreneurship Among Rural Youth for Vikasit Bharat

Barsha Kuanra[1] , Subham Kumar[2], Chinmaya Sahu[3]

Department of Dairy Science, School of integrated Agriculture,

Department of Agriculture , School of Agriculture,

Department of Forestry, School of integrated Agriculture,

CUO , Koraput, 763004

Corresponding author's email: barshakunra@gmail.com

ABSTRACT

The future of Vikasit Bharati doesn't lie in concrete skylines alone—it blooms in the green resilience of India's villages. This seminar champions agripreneurship as a powerful vehicle to reframe agriculture—not merely as survival, but as strategy. Rural youth, often sidelined in development narratives, hold the potential to become architects of grassroots innovation.By integrating modern tools with indigenous wisdom, agripreneurs are redefining agriculture: drone-assisted precision farming, climate-smart irrigation, AI-driven crop analytics, and bio-entrepreneurship mark the rise of the rural tech revolution. The soil is no longer just a site of toil—it is an ecosystem of enterprise. This session explores how experiential learning, digital access, community-driven incubators, and cross-sector mentoring can spark a shift from unemployment to self-determined livelihoods. Agripreneurship becomes the bridge—linking tradition with transformation, culture with commerce. With tailored support structures, rural youth evolve from farm workers to value-chain leaders.The narrative isn't about retaining youth in agriculture out of necessity—it's about inspiring them to lead it with purpose. When local enterprise is celebrated, migration is replaced by innovation, dependency by dignity. From millet cafés to agro-tourism collectives, the village becomes a centre of possibility.In fostering agripreneurial leadership, this initiative cultivates more than crops—it cultivates futures. Vikasit Bharat will not be built by distant dreams, but by local visionaries who sow ambition into the land they call home.

Organic Ambitions and Economic Consequences: Insights from Sikkim and Sri Lanka

Anushka Chourasia[1*] and Manish Chourasia[2]

Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.)

[2] Senior Scientist and Head, Krishi Vigyan Kendra, Gariaband, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.)

Corresponding author's email: anushkachourasia22@gmail.com

ABSTRACT

As concerns grow over declining soil health and harmful chemicals, organic agriculture acts as a sustainable solution that blends age-old traditions with innovation. More than just a trend, Organic agriculture is a global transformation practiced in 188 out of 195 recognized countries. Global organic farmland reached about 96.4 million hectares by end-2022 and nearly 99 million by end-2023 (≈2.1% of agricultural land). Leading countries include Australia (~53 M ha), followed by India (~4.5 M ha). Government sources report roughly 7.3 M ha of organic cultivation by FY2024 (4.5 M ha farmland + 2.8 M ha wild collection) and about 10.17 M ha registered under organic certification by 2023. Strong national initiatives including the National Programme for Organic Production, state PGS schemes alongside rising domestic demand have driven this growth. In this zeal for conversion, Sikkim – a small Himalayan state – became 100% certified organic through a decade-long, phased transition which includes meticulous banning of chemical inputs in stages, invested heavily in farmer training and organic inputs, integrated organic farming into school curricula, built storage/processing infrastructure and even developed a Sikkim Organic brand. This comprehensive support not only covered ~76,000 ha and 66,000 families, but boosted farm incomes and eco-tourism, a success so notable that the UN FAO lauded Sikkim as a "trailblazer for the entire world". By contrast, Sri Lanka's abrupt 2021 ban on synthetic fertilizers, with no preparatory phase, led to catastrophe. Within months rice yields plunged by roughly 30% and tea production by about 18%, forcing $450 M in emergency rice imports and causing ~$425 M in lost tea export earnings. These contrary experiences highlight a vital lesson: organic agriculture can drive sustainable food systems, but it requires long-term vision and structured implementation. Only with such careful, multi-stakeholder planning can organic farming realize its promise at scale.

Keywords: Organic Farming, Sikkim, Sri Lanka, Economy

The Wealth Beneath Waste: Green Innovation in Action

Prathama Pratikshya[1], Patel Sumit.D[1], Dr. Soumya C[2], Dr. K.P. Thakar[3]

[1]Research Scholar,[2]Assistant Professor, [3]Professor&Head

Department of Agricultural Economics

C.P. College of agriculture, Sardarkrushinagar-385506, Banaskantha, Gujarat

Corresponding author's email: chaudharysumit0453@gmail.com

ABSTRACT

The global shift toward sustainability and climate resilience has increased interest in circular bioeconomy and green entrepreneurship as effective tools for tackling environmental issues. The idea of "Waste to Wealth" supports this change. It focuses on turning agricultural, industrial, and municipal waste into valuable products through innovative business models. Circular bioeconomy principles can work with entrepreneurial ventures to close resource loops, reduce reliance on fossil-based inputs, and create sustainable jobs. Emerging business models, such as bio-refineries, decentralized composting units, bioenergy startups, and upcycling companies, use local waste streams to produce value-added items like biofertilizers, bioplastics, organic food, and clean energy. These models help reduce waste while encouraging inclusive growth, especially in rural and semi-urban areas. Green entrepreneurship, motivated by sustainability goals, helps mobilize youth, women, and marginalized communities by connecting environmental care with income opportunities. India and other developing nations are in successful partnerships of technology, policy support, and community involvement. The obstacles in expanding these models, such as regulatory challenges, limited technical knowledge, and lack of funding. Impactful policy recommendations are needed to support innovation ecosystems and promote green startups that turn waste issues into business chances, strengthening the circular economy approach.

Key words: Bioeconomy, Clean energy, Green entrepreneurships, Sustainability, Bioenergy

Transforming Indian Agriculture through Climate Smart Innovations for Sustainable Resource Management

Patel Sumit.D[1*], Prathama Pratikshya[1], Joshi Rahul K[2], Parul M Patel[3]

[1]Research Scholar, [2&3]Assistant Professor

Department of Agricultural Economics C.P. College of agriculture, Sardarkrushinagar-385506, Banaskantha, Gujarat

Corresponding author's email: chaudharysumit0453@gmail.com

ABSTRACT

Indian agriculture is becoming more and more susceptible to the effects of climate change, such as unpredictable rainfall, increasing temperatures, and land degradation, threatening food and livelihood security severely. To reduce these challenges, a shift towards Climate Smart Agriculture (CSA) is necessary. CSA aims at improving agricultural productivity, climate resilience, and mitigation of greenhouse gas emissions, ensuring sustainable resource management. New technologies like precision farming, micro-irrigation, climate-resilient crops, and ICT-based agro-advisories are increasingly being used in different parts of India. These technologies have increased the efficiency of resource use, particularly in terms of water and fertilizer management, and enhanced farmers' resilience to climate shocks. Solar irrigation, agroforestry, and regenerative agriculture are turning out to be models of sustainability that ensure productivity without harming the environment. Government initiatives, agri-tech enterprises, and online platforms are helping to scale such innovations, but challenges persist in the areas of farmer awareness, policy mainstreaming, and access to finance and infrastructure. Institutional capacity building and the promotion of multi-stakeholder partnership are essential for the adoption of CSA practices across a wide area. Adopting climate-smart innovations is not only essential for revolutionizing Indian agriculture but also for the attainment of long-term sustainability, food security, and rural resilience in the face of climate change.

Keywords: Climate Smart Agriculture, Sustainable Resource Management, Precision Farming, Climate Resilience, Food Security.

Empowering Rural Youth Through Agripreneurship for a Viksit Bharat

Cultivars

Jaimik Dave[1]

[1]College of Forestry, Navsari Agricultural University, Navsari-396450 Gujarat.

Corresponding author's email: davejaimik765@gmail.com

ABSTRACT

India's vision of *Viksit Bharat*—a developed, self-reliant nation—demands inclusive growth, especially in rural regions where a majority of the population resides. Promoting agripreneurship among rural youth emerges as a powerful strategy to address rural unemployment, modernize agriculture, and boost economic development. Agripreneurship integrates agriculture with innovation, business acumen, and technology, enabling young individuals to transform traditional farming into profitable enterprises. Rural youth, often disengaged from agriculture due to low returns and outdated practices, can be re-engaged through targeted interventions such as skill development programs, access to credit, mentorship, and digital tools. By fostering an entrepreneurial mindset and introducing modern techniques like precision farming, agritech solutions, and value-added processing, rural youth can be empowered to view agriculture not merely as subsistence, but as a sustainable and scalable business. Government schemes like Start-up India, PMFME, and Agri-Clinics & Agri-Business Centres (ACABC) must be more effectively tailored to rural contexts. Strengthening incubation centers, farmer-producer organizations (FPOs), and public-private partnerships can create an enabling ecosystem for rural innovation. Furthermore, incorporating agripreneurship into school and college curricula will build a pipeline of skilled agri-leaders from a young age. Promoting agripreneurship aligns with national goals of doubling farmer incomes, ensuring food security, and reducing rural-to-urban migration. It can unlock untapped potential in the agriculture sector and position youth as change agents in rural transformation. For a Viksit Bharat, it is imperative to shift the perception of agriculture from a livelihood of last resort to one of entrepreneurial opportunity, driven by youth-led innovation and enterprise.

Keywords: Incubation centers, Rural innovation, Entrepreneurial opportunity

Yield and Productivity of Maize (Zea mays L.) as influenced by Integrated Nutrient Management in Maize–Mustard Cropping system "

Gaurav Mahajan* and R.C. Sharma

AICRP on Maize, Zonal Agricultural Research Station, J.N.K.V.V, Chhindwara, M.P. 480001, India

Corresponding author's email: aicrpagrorewa@gmail.com

ABSTRACT

To boost crop productivity, chemical fertilizers gained prominence during the Green Revolution. However, their indiscriminate and prolonged use has degraded soil fertility and led to nutrient imbalances and contamination. While chemical fertilizers remain essential in commercial agriculture with high-yielding varieties, sustainable productivity requires integrating alternative nutrient sources. Organic manures, though low in nutrient content, are rich in growth hormones and enzymes that enhance soil health and plant growth. In nutrient-demanding crops like maize, native reserves alone are insufficient. Therefore, integrated nutrient management (INM) is crucial for maintaining soil fertility and ensuring long-term productivity in systems like maize–mustard cropping. Keeping these facts in consideration, the present investigation was carried out to find out Effect of different integrated nutrient management on productivity of maize (*Zea mays* L.) in maize-mustard cropping system. The study was conducted during *Kharif* season of 2019, 2020, 2021& 2022 consecutively at a fixed site at JNKVV, Zonal Agriculture Research Station, Chandangaon, Chhindwara, M.P. It is situated at a height of 682m above mean sea level with a latitude range of 21° 28' N and longitude range of 78° 10' E. It receives an average rainfall of 1087 mm during the crop period the rains were normal. The experiment was laid out in randomized block design keeping with eleven treatments viz: **T_1**=Unmanured; **T_2**=100% RDF; **T_3**=75% RDF; **T_4**=50% RDF; **T_5**=FYM 10 t/ha + Azatobactor; **T_6**=Maize + legume intercropping (for economic produce) with FYM 10 t/ha + *Azatobactor*; **T_7**=100% RDF + 5 t/ha FYM; **T_8**=75% RDF + 5 t/ha FYM; **T_9**=50% RDF + 5 t/ha FYM; **T_{10}**=100% RDF + 5 kg Zn/ha and **T_{11}**=FYM 5 t/ha (state practice) where the RDF was 120:60:40; $N:P_2O_5:K_2O$ kg/ha. The experiment was laid out with three replications. The results from the present experiment clearly indicate that under the climatic conditions of Chhindwara, Integrated application of the 100% RDF + 5 t/ha FYM resulted in the significantly higher maize yield. Whereas, the growing maize +legume intercropping (for economic produce) with FYM 10 t/ha + *Azatobactor* resulted in higher system productivity in terms of Higher maize equivalent yield, net return and B:C.

Precision Agriculture

Kinjal Pandya[1]

College of Agriculture, Raipur, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chattisgarh

Corresponding author's email: kinjalpandya65944@gmail.com

ABSTRACT

Precision farming, or precision agriculture, is a modern farming technique that applies digital technology to optimize agricultural practices. It uses tools like GPS (Global Positioning System), drones, sensors, and data analytics to monitor real-time information on soil health, crop growth, moisture levels, and climate conditions. The main aim is to apply inputs such as water, fertilizers, and pesticides in precise amounts, at the right time and location, rather than uniformly across a field. This approach improves crop yield, reduces input costs, and minimizes environmental damage. For example, Variable Rate Technology (VRT) enables farmers to vary the amount of fertilizer or pesticide applied depending on the specific needs of different parts of the field. Remote sensing and drone imaging help detect early signs of diseases, nutrient deficiency, or pest attacks, allowing timely corrective actions. Precision farming is also a step toward sustainable agriculture, as it helps conserve water, prevents chemical runoff, and maintains soil health. However, the adoption of precision farming faces certain challenges, especially among small-scale farmers in developing countries. High initial investment, lack of digital infrastructure, and limited access to training are common barriers. In India, initiatives by the government, support from research institutions like the Indian Council of Agricultural Research (ICAR), and innovations by agritech startups are helping to promote precision farming. As technology becomes more accessible and affordable, its adoption is likely to grow rapidly. Overall, precision farming represents the future of agriculture—efficient, eco-friendly, and capable of addressing the food needs of a rising global population.

Keywords: Precision farming, GPS, crop yield, sustainable agriculture

Source: Content adapted from Indian Council of Agricultural Research (ICAR) and agricultural academic literature for educational use.

Promoting Agripreneurship among rural youth for Viksit Bharat

Roopali Singh Thakur UG scholar jawaharlal nehru krishi Vishwavidyalaya jabalpur , college of agriculture jabalpur krishi nagar Adhartal (482004)

Corresponding author – Roopali Singh Thakur UG scholar at jnkvv jabalpur

Corresponding author email : roopalisinghthakur22@gmail.com

ABSTRACT

Agripreneurship holds the key to transforming rural India and achieving the vision of *Viksit Bharat*. By empowering rural youth with entrepreneurial skills, modern agri-technologies, and access to markets, we can convert agriculture into a profitable and attractive livelihood. This approach addresses unemployment, reduces migration, and revitalizes the rural economy. Integrating innovations such as organic farming, food processing, and agri-startups creates new income opportunities. Government schemes like ACABC and Agri-Infra Fund provide strong support for aspiring agripreneurs. With proper training, financial access, and mentorship, rural youth can lead the next wave of agricultural transformation. Promoting agripreneurship ensures inclusive growth and food security. It encourages sustainable practices and strengthens the farm-to-fork value chain. Ultimately, investing in rural youth is investing in a developed and self-reliant India.

Keywords: Agripreneurship, Rural youth, Viksit Bharat, Agri-startups,Sustainable Agriculture, Government Scheme

Agri-skills for youth empowerment viksit bharat

Satyam Choudhary[1]

Satyam Choudhary UG scholar jawaharlal nehru krishi Vishwavidyalaya jabalpur , college of agriculture jabalpur krishi nagar Adhartal (482004)

Corresponding author – Satyam Choudhary UG scholar at jnkvv Jabalpur

Corresponding author's email: satyamchoudhary410@gmail.com

ABSTRACT

Empowering youth through agri-skills is a strategic pathway to rural development and national progress. With agriculture evolving into a modern, tech-driven sector, there is immense potential to engage young minds in agribusiness, precision farming, organic cultivation, and agro-processing. Equipping youth with practical skills, entrepreneurial training, and access to technology not only creates employment but also curbs migration to cities. Skill-based initiatives like Agri-Clinics & Agri-Business Centres (ACABC), FPOs, and digital agriculture tools can unlock self-reliant livelihoods. Integrating agri-skills into education and vocational programs will foster innovation and sustainability. This approach aligns with the vision of Viksit Bharat by 2047, ensuring inclusive growth and food security. Youth-led agri-entrepreneurship is key to transforming Indian agriculture into a resilient and prosperous sector.

Keywords: Agri-skills , Youth Empowerment , Agri-entrepreneurship , Rural Development , Digital Agriculture , Viksit Bharat

Latest advancements in disease resistance through genetics

Manu Dubey[1*]

Jawaharlal Nehru Krishi Vishwavidyalaya Jabalpur

Corresponding author's email: dubeymanu001@gmail.com

ABSTRACT

Advances in genetic and genomic technologies have ushered in a new era of precision breeding for disease resistance across both agricultural and biomedical fields. In plants, high-throughput sequencing, genome-wide association studies (GWAS), and pan-genome analyses have facilitated the identification of quantitative trait loci (QTLs) and resistance (R) genes associated with broad-spectrum and durable resistance. The application of CRISPR-Cas and other site-directed nucleases has enabled targeted mutagenesis and the fine-tuning of resistance pathways, such as the modification of susceptibility (S) genes and the enhancement of innate immune signaling components. Similarly, in animal systems, marker-assisted selection (MAS), genomic selection, and gene editing are being employed to introduce or enhance resistance to bacterial, viral, and parasitic infections without compromising productivity traits.

Emerging strategies such as epigenome editing, RNA interference (RNAi), and the integration of transcriptomic, proteomic, and metabolomic data are deepening our understanding of host-pathogen interactions and resistance mechanisms. Importantly, these approaches are increasingly being combined with systems biology and machine learning to predict gene function, resistance durability, and the evolutionary dynamics of pathogen populations.

Keywords :- Mutagenesis, innate immunity

Eco Friendly Fish Waste Bio Conversation

Atul Upadhyay[1]

College of fisheries science, Veraval, Gujrat

Corresponding author email : princeupadhyay470@gmail.com

ABSTRACT

The growing global demand for seafood has led to an increase in fish processing activities, resulting in the generation of substantial amounts of fish waste. Traditionally considered as a disposal problem, fish waste is now being explored as a valuable resource through eco-friendly bioconversion techniques. This study focuses on sustainable methods for converting fish waste such as heads, bones, skins, and viscera into high-value products like fishmeal, fish oil, organic fertilizers, bioactive compounds, biogas, and biodiesel. Bioconversion approaches such as composting, anaerobic digestion, enzymatic hydrolysis, and microbial fermentation offer an environmentally friendly alternative to conventional waste disposal methods. These technologies not only reduce environmental pollution and greenhouse gas emissions but also support circular economy principles by transforming waste into wealth. The abstract discusses the potential, challenges, and future prospects of fish waste bioconversion in promoting sustainability within the fisheries and aquaculture sector.

Keywords: fish, economy, aquaculture, waste, bio conservation

Climate-Smart Strategies to Stabilize Wheat Yield under Limited Irrigation through Foliar Stress Regulators

Badal Verma* and Amit Kumar Jha

Department of Agronomy, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (MP) 482004

Corresponding author's email: badalv82282@gmail.com

ABSTRACT

The Indian agriculture sector is highly vulnerable to climate variability due to its dependency on erratic weather patterns and declining water resources. In this context, climate-smart strategies are crucial for sustaining wheat production, particularly under moisture-stressed conditions. Wheat productivity is constrained by various abiotic stresses such as drought, temperature extremes, and salinity, with moisture stress being one of the most limiting factors. To address this challenge, a field study was conducted over two *rabi* seasons (2021–22 and 2022–23) at the Research Farm, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur to evaluate innovative combinations of irrigation levels and foliar stress regulators in wheat. The experiment was laid out in split-split plot design with 30 treatment combinations comprising three irrigation levels (one irrigation at CRI, two irrigations at CRI and flowering, and three irrigations at CRI, flowering, and milking stages), two wheat varieties (JW 3288 and JW 3382), and five stress regulators (control, 1% KCl, 2% KCl, 0.1% ascorbic acid, and 0.2% ascorbic acid applied at tillering and flowering stages). Results revealed that the integration of three irrigations with foliar application of 2% KCl significantly improved grain yield, water use efficiency and economic returns, particularly in variety JW 3288. This study underscores the potential of integrating deficit irrigation and foliar interventions as a climate-smart innovation to enhance resource use efficiency and stabilize wheat production under water-limited conditions.

Keywords: Climate-smart agriculture, Moisture stress, Stress regulators

Agri-skills for youth empowerment

Priyanka Meher[1]

College of Horticulture, OUAT, Chiplima

Corresponding author's email: priyankameher787@gmail.com

ABSTRACT

The empowerment of youth through the development of agri-skills is pivotal for sustainable rural development and economic transformation. Despite agriculture serving as a main source of livelihood, due to barriers such as inadequate training, restricted access to resources, and negative perceptions about agricultural careers youth engagement in this sector remains limited. Building the capabilities of youth in key agricultural skills, like- modern farming practices, agribusiness management, and value chain development—can enhance their employability, enhances entrepreneurship quality , and improve overall production. Key components of effective agricultural skills training for youth are, Core Technical Skills, Business and Financial skills, Soft skills and mind-set, Structured and Modular Curriculum. By creating integrated support network ,blending finance, technical assistance, and market connections—partnerships address multiple barriers simultaneously, empowering youth to participate truely in rural economies and agricultural value chains.

Key Words: Sustainable rural development, Business and financial skills, Agricultural value chains, Agribusiness management, Structured and modular curriculum

Start-Ups And Innovations In Agriculture

Sambit Sourav Jena,

College of Horticulture, OUAT,Chiplima,

Corresponding author’s email: sambitjena615@gmail.com

ABSTRACT

Start-ups are driving a transformative wave of innovation in agriculture by integrating advanced features and reshaping models of agribusiness. Key trends include the rise of artificial intelligence (AI),machine learning, Internet of Things (IoT) , biotechnology, and block chain. These innovations enable precision agriculture, optimize resource usage, and address challenges related to climate variability, labour shortages, and food safety.

AgTech start-upsurge revolutionizing supply chain management with digital platforms and real-time data analytics, offering solutions such as AI-powered advisory services, automated crop monitoring, and block chain-based traceability for transparent food production. In India and globally, these empowers farmers through accessible technologies for quality assessment, sustainable farming, and financial inclusion. The provision of vertical farming, regenerative agriculture, and advanced bio fertilizers enlighten a commitment to sustainability and climate resilience. With increased investment and collaboration, start-ups are not just tackling existing inefficiencies—they are laying the foundation for a smarter, more resilient global food system, promising sustainable growth and equitable value across the agricultural value chain.

Keywords: Internet of things (IoT), Blockchain, machine learning, Supply chain management

Engineering Microbial Consortia for Enhanced Biological Control: Unravelling Microbe-Microbe and Microbe-Plant Interactions.

Kalpana Gambhir[1], Dr. C. M. Bhaliya[2], Aanchal Panwar[1*]

[1]Department of Plant Pathology, College of Agriculture, Junagadh Agricultural University, Junagadh, Gujarat, 362001

[2]ICAR- India Council of Agricultural Research, Junagadh Agricultural University, Junagadh, Gujarat, 362001

corresponding author's email: aanchalpanwar23@gmail.com

ABSTRACT

Engineering microbial consortia-carefully assembled groups of beneficial microbes-offers a promising way to improve biological control in agriculture and aliened science. Unlike traditional methods that use single microorganisms, these consortia combine various bacteria and fungi with different capabilities to suppress plant diseases. By bringing together diverse microbes, these consortia can tackle a wider range of pathogens and adapt better to provoking field conditions. The microbes work together through several mechanisms: Direct antagonism: Some microbes compete with or inhibit disease-causing organisms. Induced plant resistance: Certain members boost the plant's own defences.Improved colonization: Microbial groups better establish themselves in the plant's root zone, strengthening long-term protection. Microbe-microbe interactions inside these consortia can be synergistic, meaning their ability get enhanced as they work together comparatively of being single. At the same time, their interactions with plants-such as improving growth and nutrient uptake while support plant health beyond disease resistance. Although there are some challenges, such as ensuring ability of all members remains compatible and effective, microbial consortia represent an important step forward in sustainable crop protection. Ongoing research is focused on understanding the complex relationships within these consortia and optimizing them for practical use in different crops and environments.

Key words: Microbial consortia, Plant pathology**,** Interaction.

Understanding the temporal pattern of aphid infestation is essential for developing effective and ecologically sound pest management strategies in coriander (Coriandrum sativum L.)

R. D. Dodiya[1], P. S. Patel[2], Rajendra Yadav[1] and Manthan R. Sindhav[1]*

[1]Department of Entomology, S. D. Agricultural University, Sardarkrushinagar- 385 506

[2]Directorate of Extension Education, S. D. Agricultural University, Sardarkrushinagar- 385 506

Corresponding Author's Email ID: sindhavmanthan999@gmail.com

ABSTRACT

This study was conducted during the rabi, 2023–24 and 2024-25 cropping seasons to identify the dominant aphid species infesting coriander and to elucidate their seasonal population trends under field conditions. Aphid species were identified based on morphological characteristics and confirmed through molecular analysis. Three species, *Hyadaphis coriandri, Aphis gossypii*, and *Aphis spiraecola* were found to be major pests of coriander. Their infestation began in the 4th week after germination (3rd week of December; 51st Standard Meteorological Week), peaked during the 12th week (4th week of February; 7th SMW), and declined thereafter, coinciding with crop maturity. A highly significant positive correlation was observed between aphid population and natural enemies, particularly coccinellids and syrphid fly larvae, indicating a density-dependent predator response. The findings highlight the importance of monitoring aphid population dynamics and conserving natural enemies for timely and sustainable aphid management in coriander ecosystems.

Estimation of Anthocyanin Content in Pigmented Maize (Zea mays L.) Landraces of North-eastern Hill Region (NEHR)

Neelesh Vimal[1], Vishwanath Vishwambhar Walawalkar[1], Pramod Kumar Pandey[2*], Amarjeet Kumar[3] and Narendra Kumar[3]

[1]M.Sc. Scholar, School of Crop Improvement, CPGS-AS, CAU-Imphal, Umiam, Meghalaya

[2*]Assistant Maize Breeder, AICRP on Maize, COA, CAU-Imphal, Kyrdemkulai, Meghalaya

[3]Assistant Professor, COA, CAU-Imphal, Kyrdemkulai, Meghalaya

Corresponding author's email: pramod.pandey84@gmail.com

ABSTRACT

Pigmented maize landraces of the Northeastern Hill Region (NEHR) are rich in anthocyanins-natural flavonoid compounds known for their potent antioxidant properties and potential health benefits. In this study, selected pigmented maize landraces were evaluated for their anthocyanin content using spectrophotometric analysis. The landraces were cultivated under field conditions, and mature kernels were collected for biochemical estimation. The anthocyanin content was quantified using the cyanidin-3-glucoside equivalent method, based on absorbance at 530 nm. Considerable variation was observed in anthocyanin concentration across the landraces, indicating a broad genetic base and differential pigment expression. The genotype COAKM 183 (Ong Nagi Shoong) recorded the highest average anthocyanin content (0.8042 mg CGE /g), while genotype COAKM 187 (Tagen Rvdv) showed the lowest (0.0161 mg CGE /g). These findings highlight specific landraces with high anthocyanin levels, which can serve as potential candidates for the development of functional foods and biofortified maize varieties. This study emphasizes the nutritional and commercial value of NEHR pigmented maize and underscores the importance of their conservation and promotion.

Keywords: Pigmented Maize, Anthocyanin, Landraces, Estimation

An Innovative Idea of Vertical Farming in India

Kunika Khodiyar and Archita Sinha ,

College of Agriculture, Indira Gandhi Krishi Vishwavidhyalaya, Raipur (C.G.), India

Corresponding author's email: architasinha1606@gmail.com

ABSTRACT

Vertical farming is an innovative agricultural technique that involves growing crops in vertically stacked layers, often in controlled indoor environments. This practice allows for large- scale crop production within areas or location where traditional farming is limited due to space, climate or soil conditions. Vertical farming relies on various technologies and is of different types like Hydroponics, Aeroponics, Aquaponics and Soil based using soil in stacked containers. Hydroponics- In this method, plants grow without soil, using a nutrient-rich water solution that directly feeds their roots. This system often involves trays or tubes where water flows over or through the root. Aeroponics- Plants are grown with roots suspended in the air, misted with a nutrient solution. This allows more oxygen to reach the roots, which can speed growth. Aquaponics- A combination of hydroponics and aquaculture (raising fish), where nutrient- rich water from fish tanks is used to feed plants. In turn, plants filter the water, which is then recirculated back to the fish. Soil-Based Vertical Farming - Uses soil as the growing medium in stacked layers, often with lighting and irrigation. These systems aim to replicate natural growth in a controlled environment. Hybrid Systems - Combines elements of two or more systems (e.g., aquaponics and hydroponics) to take advantage of multiple benefits. Benefits of Vertical Farming is Space-efficient for urban area Uses 90% less water than traditional farming, allows for year-round production, cuts down on transport costs and emissions, Reduces or eliminates the use of pesticide, Yields higher, faster crop growth, Energy-efficient with advanced tech, Resilient to climate changes. It aims to address challenges faced by farmers in the region, such as land scarcity, traditional farming limitations, and environmental issues. By adopting vertical farming, it helps to improve crop yield, conserve water, and reduce dependency on large plots of land. They initiative is part of a broader movement to modernize agriculture in the region, making farming more sustainable and economically viable.

Nano technology in Agriculture

Prarthna Pawar and Shatakshi Gautam

College of Agriculture, Raipur

Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G)

Corresponding author's email:pawarprarthna05@gmail.com and shatakshigautam0306@gmail.com)

ABSTRACT

Nanotechnology, an interdisciplinary field converging physics, chemistry, and biology at the nanoscale, is increasingly finding significant relevance in modern agriculture. With the pressing need to enhance crop productivity, nutrient use efficiency, and environmental sustainability, nanotechnology emerges as a transformative approach in addressing long-standing limitations of conventional practices. Extensive literature, including recent advancements outlined in publications such as "Nanotechnology in Agriculture" by Manjunatha et al. (2016) and research featured in Elsevier's Agricultural Nanotechnology series, suggests that the application of engineered nanoparticles offers a promising avenue for precision farming. Particularly, nano-fertilizers and nano-pesticides have demonstrated enhanced efficacy through controlled release mechanisms and improved bioavailability, thereby reducing input costs and environmental contamination. Additionally, nanomaterials such as zinc oxide nanoparticles, silver nanoparticles, and carbon nanotubes have shown potential in plant disease management, pathogen detection, and even enhancing photosynthetic activity. Notably, nanosensors are being developed to monitor soil conditions, crop health, and pest activity in real-time, thereby facilitating data-driven agricultural decisions. Despite its promise, the adoption of nanotechnology in Indian agriculture remains limited due to high development costs, regulatory ambiguity, and limited farmer awareness. Ethical concerns surrounding nanoparticle toxicity and biosafety also warrant rigorous long-term studies. Nevertheless, if integrated thoughtfully with traditional knowledge systems and climate-resilient practices, nanotechnology could catalyze a new era of sustainable and intelligent farming. The literature reviewed underscores the necessity for policy support, interdisciplinary collaboration, and grassroots-level awareness to translate laboratory innovations into field-level impact.

Keywords: Nanotechnology in Agriculture, Nano Use, Advance Agriculture, Sustainable and Intelligent Farming

Promoting Agripreneurship Among Rural Youth for Vikasit Bharat

Nitin Mehetre [1*], Ashwini Jadhav [2], Arun Shelke [3]

[1&2]Department of Agricultural Botany

[3]Department of Agronomy

Samarth Agriculture College Deulgaon Raja, Dist. Buldhana 443204 Maharashtra

Corresponding author's email: nitinmehetre29@gmail.com

ABSTRACT

The Indian government has created the "Viksit Bharat 2047" agenda which aims to transform India into a developed nation by 2047. One important aspect of this plan is the role of agriculture in India's development strategy. This paper focuses on promoting an Agripreneurship Revolution and Exploring the impact of Agripreneurship on rural livelihood to address several challenges faced by Indian agriculture, such as low productivity, limited financial resources, small landholdings, outdated techniques and environmental damage. The plan outlines various government interventions in infrastructure, human potential, culture, economics, society and ecology to achieve the goal. Strategies like promoting agripreneurship in dairy, goatry, poultry, seed production, sericulture, floriculture, mushroom production, fish farming, agriclinic center, biopesticides & chemical pesticide unit, food processing unit, modernizing agricultural markets, supporting agri-startups, encouraging organic farming and empowering smallholders through cooperative projects are essential. There is a need for robust legislative frameworks to tackle structural challenges such as farmer debt, timely crop insurance schemes and regional disparities in rural credit accessibility. Emphasis is given to increasing the interest of educated young people in farming and establishing a trend to boost rural economies, along with the challenges and benefits that come with it. The paper also stresses the importance of ecological sustainability and supports organic farming methods to enhance climate change resistance and support biodiversity conservation. It underscores the urgency to move towards agroecological principles to ensure food security, environmental sustainability and inclusive rural development. By adhering to this roadmap & promoting agripreneurship among rural youth, India can achieve its vision of a prosperous, equitable, and sustainable agricultural sector and contribute significantly to the overall goal of Viksit Bharat.

Keywords: Viksit Bharat, Agri-startups, Agripreneurship, Organic Farming, Seed Production Food Security, Rural Development.

Climate Change Mitigation through Sustainable Agriculture

Prem Kumar Sahu

PhD Research Scholar,

Department of Agriculture Meteorology,

Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.)

Corresponding Author- premsahu8333@gmail.com

ABSTRACT

Agriculture is uniquely positioned at the nexus of climate change, being both a significant contributor to greenhouse gas (GHG) emissions and highly vulnerable to its impacts. This abstract explores the crucial role of sustainable agricultural practices in mitigating climate change while simultaneously enhancing the resilience and productivity of food systems. Conventional agricultural methods, characterized by intensive tillage, synthetic fertilizer overuse, and monoculture, contribute to atmospheric carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O) emissions. Sustainable agriculture offers a paradigm shift, focusing on practices that reduce these emissions, sequester carbon in soils, and promote overall ecosystem health. Key strategies include adopting conservation agriculture (e.g., no-till/reduced tillage, cover cropping), improving nutrient management, optimizing water use efficiency, integrating agroforestry, and enhancing livestock management. These approaches foster soil organic carbon accumulation, reduce energy consumption, minimize nitrogen losses, and increase biodiversity, thereby building more resilient and sustainable agricultural systems capable of adapting to a changing climate while actively contributing to global mitigation efforts.

Keywords: Climate change mitigation, Sustainable agriculture, Carbon sequestration, Greenhouse gas emissions, Climate-smart agriculture, Soil health, Resilient food systems, Agroecology.

Frontiers in Crop Protection for Sustainable Agriculture

Sandeep Patidar

Department of Entomology, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, 313001.

Corresponding author's email: Patidarsandeep839@gmail.com

ABSTRACT

Sustainable agriculture faces mounting challenges from climate change, evolving pest dynamics and the need to reduce environmental impacts while maintaining food security. To evaluate pest and natural enemies' population dynamics, field study was conducted to assess the population dynamics of key insect pests and their natural enemies in relation to prevailing weather parameters across standard meteorological weeks (SMWs). Peak infestation levels were recorded as follows: aphids (2.8/plant on 4st SMW), green stink bugs (2.2/plant on 46th SMW), lady bird beetles (2.4/plant on 48th SMW), pod borer larvae (3.0/plant on 44th SMW), spotted pod borer larvae (6.4/plant on 44th SMW) and pod fly maggots (1.8/plant on 44th SMW). Correlation analysis revealed that maximum temperature had a significant positive association with spotted pod borer larvae populations. In contrast, evening relative humidity was negatively correlated with pod fly maggot and aphid populations. Furthermore, lady bird beetle populations showed a significant positive correlation with maximum temperature and a negative correlation with both morning and evening relative humidity. These findings highlight the influence of key weather variables on pest and natural enemy dynamics, offering valuable insights for the development of weather-based pest forecasting models and integrated pest management strategies.

Keywords: Natural enemies, population dynamics, Integrated Pest Management (IPM).

Evaluation of Post-Harvest Storage Techniques on Shelf Life and Quality of Sweet Potato Tubers

[1]Khushi Sharma and [2]Ritu Sahu

[1]Department of Agronomy, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh 492012

[2]Department of Soil Science, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur,Chhattisgarh 492012

Corresponding author's email: khushi82763@gmail.com

ABSTRACT

Sweet potato (*Ipomoea batatas L.*) is an important tuber crop known for its high carbohydrate content and nutritional value. However, post-harvest losses significantly affect its availability and marketability, especially in rural and tribal regions. This study was designed to assess the impact of different post-harvest storage methods on the shelf life and quality of sweet potato tubers. Three traditional and modern storage techniques were compared: pit storage, zero energy cool chamber (ZECC), and ambient storage. Freshly harvested tubers of the variety 'Rajendra Shakarkand' were stored for 60 days under each condition and periodic evaluations were conducted for weight loss, sprouting percentage, firmness, and visual quality. Results indicated that tubers stored in ZECC retained better firmness and showed the least weight loss (6.4%) compared to pit storage (9,1%) and ambient conditions (12.7%). Sprouting and spoilage were also significantly lower in ZECC. The study concludes that the adoption of low-cost ZECC technology can effectively enhance the shelf life and reduce post-harvest losses of sweet potato tubers, thereby ensuring better income and food security among small and marginal farmers in Chhattisgarh.

Keywords: Sweet potato, Post-harvest, Storage techniques, Zero Energy Cool Chamber

Innovative Strategies for Mitigating Global Warming and Ensuring Climate Resilience

Maria Susan Ekka[1] and Swastika Shrivastava[1]

[1] College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G)

[2] College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur(C.G)

Corresponding author's email: ekkamariasusan83@gmail.com

ABSTRACT

Global warming, a major component of climate change, poses a serious threat to environmental stability and human survival. It refers to the long-term increase in Earth's average surface temperature, primarily caused by the excessive release of greenhouse gases (GHGs) such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). These gases are emitted mainly from human activities including burning of fossil fuels, deforestation, industrialization, and unsustainable agricultural practices. The impacts of global warming are profound, leading to rising sea levels, extreme weather conditions, melting glaciers, loss of biodiversity, reduced agricultural productivity, and increased health risks. To combat this, a multi-dimensional approach combining mitigation and adaptation is essential. Adoption of renewable energy sources like solar, wind, and hydropower is crucial to reduce carbon emissions. Enhancing energy efficiency, promoting afforestation and reforestation, and encouraging low-carbon transportation systems contribute significantly to emission reduction. Climate-smart agriculture practices—such as conservation tillage, integrated pest management, crop diversification, and use of organic inputs—help in reducing the carbon footprint while ensuring food security. Policy support, public awareness, international collaboration, and investment in green technologies are key to successful implementation. Additionally, climate-resilient infrastructure, early warning systems, and effective waste management strategies enhance adaptive capacity in vulnerable regions. In conclusion, global warming demands urgent attention and collective global action. By integrating innovative technologies, sustainable practices, and strong policy measures, we can build a climate-resilient future that ensures environmental safety, economic stability, and social well-being.

Keywords: Global Warming, Climate Change, Renewable Energy, Climate-Smart Agriculture, Carbon Emissions, Sustainability, Climate Resilience

Organic farming in Agriculture

Mahak Bomker* and Janhavi Sahu

College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya , Raipur (C.G)

Corresponding author's email:mahakbomker@gmail.com

ABSTRACT

Organic farming is an ecologically sustainable agricultural practice that avoids the use of synthetic fertilizers, pesticides, genetically modified organisms (GMOs), and growth hormones. In India, organic farming has gained significant attention due to increasing environmental concerns, growing demand for safe and healthy food, and the adverse impacts of conventional agriculture on soil, water, and biodiversity. The traditional Indian farming systems, such as the use of cow dung, compost, green manures, and crop rotation, align closely with modern organic principles, making the transition to organic farming both culturally and technically feasible. The Indian government has introduced several initiatives like the Paramparagat Krishi Vikas Yojana (PKVY) and Mission Organic Value Chain Development for North Eastern Region (MOVCDNER) to promote organic agriculture. States like Sikkim, which became the first fully organic state, have demonstrated the potential for scaling up organic farming nationwide. Despite its benefits—including improved soil health, reduced input costs, environmental conservation, and increased export potential—organic farming in India faces challenges such as lower initial yields, lack of market access, certification barriers, and limited awareness among farmers. However, with growing consumer preference for chemical-free produce and supportive government policies, organic farming holds promise as a viable and sustainable alternative to conventional agriculture in India.

Keywords: Organic farming, sustainable agriculture, India, soil health, certification, PKVY, eco-friendly farming, food security.

Innovative Approaches to Sustainable Farming Systems

Pramod kumar[1] and Hemchand sao[1*]

[1]Department of Agronomy, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.)

*Corresponding author's email: saohemchand999@gmail.com

ABSTRACT

Sustainable agriculture is an integrated system of plant and animal production practices designed to satisfy human food needs while preserving environmental quality, supporting economic viability, and enhancing the quality of life for farmers and society. With the growing concerns over climate change, soil degradation, biodiversity loss, and water scarcity, sustainable agriculture has emerged as a vital approach to secure food production for future generations. It emphasizes the use of eco-friendly technologies, conservation of natural resources, organic inputs, crop diversification, and minimal use of synthetic chemicals. The approach also promotes soil health, reduces greenhouse gas emissions, and supports livelihoods by improving farm productivity and resilience. This paper highlights the principles, practices, challenges, and future prospects of sustainable agriculture, emphasizing its role in achieving global food security and environmental sustainability.

Keywords

Sustainable agriculture, food security, natural resource conservation, climate-resilient farming, organic farming, eco-friendly practices, soil health, biodiversity, sustainable development.

Climate Smart Agriculture: Integrating Sustainable Crop Protection for Resilient Maize Production

Anshul Sharma[1], Arvind Verma[2]

[1]Research Scholar, Maharana Pratap University of Agriculture and Technology, Udaipur

[2]Director Research, Maharana Pratap University of Agriculture and Technology, Udaipur

Corresponding author's email: nshlparashar@gmail.com

ABSTRACT

Climate Smart Agriculture (CSA) is an emerging paradigm that seeks to achieve sustainable food security by enhancing crop productivity, building resilience, and reducing agriculture-related greenhouse gas emissions. Maize (*Zea mays* L.), one of the world's leading cereal crops, is increasingly vulnerable to climate-induced biotic stresses, particularly the invasive Fall Armyworm (*Spodoptera frugiperda*). Unpredictable climatic variations intensify pest outbreaks, extend their geographic ranges, and undermine conventional pest management approaches. To address this, climate-smart crop protection integrates adaptive agronomic practices, ecological pest management and digital tools. Innovative measures, including push-pull technology, bio-intensive integrated pest management (IPM), the deployment of resistant hybrids, pheromone traps and biological control agents, have shown considerable promise in mitigating pest damage under changing climates. Precision agriculture technologies, ICT-based pest surveillance and early warning systems further strengthen timely interventions, minimizing pesticide overuse and protecting beneficial organisms. Embracing CSA principles in maize cultivation enhances system resilience, conserves soil and biodiversity, and secures farmer livelihoods, especially for smallholders in climate-vulnerable regions. However, mainstreaming CSA requires participatory extension models, policy incentives, capacity building and robust stakeholder networks to translate research innovations into scalable field applications. This paper highlights recent progress in climate-smart pest management for maize, outlines critical research gaps and suggests pathways to embed CSA principles in sustainable crop protection frameworks to safeguard maize production against future climate uncertainties.

Keywords: Climate Smart Agriculture, Maize, Fall Armyworm, Integrated Pest Management, Sustainable Crop Protection, Push–Pull Technology, Precision Agriculture.

Agri-Skills for Youth Empowerment

Manvendra Singh

B.Sc (Honors) Agriculture, 3rd Year

Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan - 313001

Corresponding author's email: bhatimanvendrasingh7@gmail.com

ABSTRACT

Agriculture is a key pillar for economic growth and food security, particularly in developing nations. Despite its vast potential, the sector faces an increasing challenge of youth unemployment. To address this, the concept of Agri-skills for youth empowerment has emerged as a crucial strategy. It aims to equip youth with technical knowledge, hands-on training, and entrepreneurial capabilities, thereby transforming agriculture into a modern, profitable, and sustainable career option. The focus lies on skill development in areas like precision farming, organic practices, climate-smart agriculture, post-harvest management, agri-business, and the application of digital tools such as drones, mobile apps, and GIS technologies. These agri-skills not only improve farm productivity but also enhance youth engagement and innovation.

The integration of entrepreneurship training, financial literacy, and market-oriented skills further enables youth to create agri-based enterprises, cooperatives, and service models that generate employment at grassroots levels. Government initiatives, agricultural universities, NGOs, and private sectors play a vital role in promoting such efforts through schemes, training missions, and startup incubators. Building agri-skills among youth is, therefore, essential for rural development, food system transformation, and economic resilience.

In conclusion, empowering youth through agri-skills development can reshape the future of agriculture by making it more technology-driven, inclusive, and sustainable. Strategic incorporation of these programs into education and national development plans is critical to realize this vision.

Digital technologies and agri-innovations for carbon neutrality and environmental regeneration

Manjeet Tripathy

College Of Horticulture, OUAT, Chiplima

Corresponding author's email: tripathymanjeet20040120@gmail.com

ABSTRACT

Digital technologies and agri-innovations are transforming agriculture, enabling farmers to adopt sustainable practices that promote carbon neutrality and environmental regeneration. Precision agriculture, using drones, satellite imaging, and IoT sensors, optimizes crop yields, reduces waste, and minimizes environmental impact. The global precision agriculture market is expected to grow from \$7.8 billion in 2020 to \$12.8 billion by 2025. Regenerative agriculture, agroforestry, and conservation agriculture promote soil carbon sequestration, biodiversity, and ecosystem services. A NOAA study found that regenerative agriculture can sequester up to 3.3 gigatons of CO2 equivalent per year in the US. Digital tools like AI-powered analytics and decision support systems help farmers make informed decisions to reduce greenhouse gas emissions. The integration of digital technologies and agri-innovations can achieve carbon neutrality in agriculture by reducing synthetic fertilizer use, promoting soil health, and enhancing ecosystem resilience. According to the FAO, agriculture accounts for 24% of global greenhouse gas emissions. Digital platforms can facilitate carbon credit monitoring and verification, enabling farmers to participate in carbon markets. As a student, I believe digital technologies and agri-innovations, can revolutionize agriculture and promote sustainability. By leveraging these technologies, farmers can reduce environmental impact while improving crop yields and ecosystem services. Digital platforms provide valuable insights and data that can help policymakers and stakeholders develop more effective sustainability strategies. In conclusion, digital technologies and agri-innovations can transform agriculture, promoting carbon neutrality and environmental regeneration. By adopting sustainable practices and leveraging digital tools, farmers can reduce environmental impact while improving crop yields and ecosystem services. With the potential to sequester millions of tons of CO2, reduce water waste, and promote biodiversity, digital technologies and agri-innovations are essential for a sustainable agricultural future.

Keywords: sustainable practices in agriculture, precision agriculture, carbon neutrality, AI powered analytics and decision support systems, Agri-innovations.

Microbiome Engineering for Sustainable Agriculture

Rohana Kumar Mishra

College Of Horticulture , OUAT , Chiplima

Corresponding author's email: rohan45kanha@gmail.com

ABSTRACT

Microbiome engineering represents an emerging biotechnological tool to directly add, remove, or modify properties of microbial communities for higher specificity and efficacy. The main goal of microbiome engineering is enhancement of plant functions such as biotic/abiotic stresses, plant fitness and productivities, etc. Various ecological-, biochemical-, and molecular-based approaches have come up as a new paradigm for disentangling many microbiome-based agro-management hurdles. The strategic manipulation of plant-associated microbial communities to enhance crop productivity, resilience, and soil health. Recent advances in metagenomics, synthetic biology, and bioinformatics have enabled a deeper understanding of plant-microbe interactions, opening new avenues to design tailored microbial consortia that improve nutrient uptake, suppress pathogens, and mitigate abiotic stress such as drought and salinity. The potential of microbiome-based technologies to revolutionize sustainable farming by reducing dependency on chemical fertilizers and pesticides, increasing climate resilience, and restoring soil biodiversity. The aggregate of microorganisms in the soil environment is a microbiome that emerged as a vital component of sustainable agriculture in the recent past. These beneficial microorganisms perform multiple plant growth-promoting activities including fixation, mineralization, solubilization, and mobilization of nutrients, production of siderophores, antagonistic substances, antibiotics, and release of plant growth-promoting substances, such as auxin and gibberellin hormones, mediated by interactions between host plant roots and microbes in the rhizosphere. Numerous plant species forms symbiotic association with microbes and draw the benefit of mineral nutrient supply with the expense of minimal energy, and their distribution is governed by nature and the number of root exudates, crop species, and cultivars. On the other hand, microorganisms with critical roles in the microbiome can be isolated, formulated, and developed as a new biological product called biofertilizers. Agriculturally, important microbes with Fe- and Zn-solubilizing attributes can be used for the biofortification of micronutrients in different cereal crops. Regardless of the approach to be used, innovations with the use of microbiomes represent the future of sustainable agriculture.

Keywords: microbiome engineering, Biotechnological tools, sustainable agriculture, plant-microbe interaction, biofertilizers, soil health, climate resilience.

Digital Literacy for Rural Women: A Pathway to Equitable Participation in Agri-Value Chains

Shivam Chaubey[1], Kundan[2], Abhishek Pandey[1], Prashant Shukla[1], V. B. Gore[2], Ajay Kumar[1], Shubham Chaudhary[1], Gaurav Kumar[1], Anjani Kumar[1]

[1] Ph.D. Scholar, Division of Agricultural Engineering, ICAR-IARI, New Delhi 110012, India

[2] Ph.D. Scholar, Division of Biochemistry, ICAR-IARI, New Delhi 110012, India

Corresponding author's email: shivamchaubey124@gmail.com

ABSTRACT

In India, rural women play a pivotal role in agriculture, yet they often face systemic barriers—limited access to markets, financial exclusion, and inadequate training—that hinder their full participation in agri-value chains. This study examines how digital literacy initiatives can empower women farmers by bridging these gaps through mobile apps, e-marketplaces, and fintech solutions. By analyzing case studies from states like Kerala (e-Krishi), Andhra Pradesh (Rythu Bandhu), and Uttar Pradesh (Kisan Sakhi), we highlight how digital tools enable women to bypass traditional intermediaries, access real-time market prices, secure microloans via UPI-linked platforms, and participate in online training programs on sustainable farming.

Key findings reveal that smartphone-based apps like Kisan Suvidha and eNAM have increased women's crop profitability by 15–20%, while WhatsApp-based peer networks have strengthened collective bargaining. However, challenges persist, including low digital fluency (only 38% of rural women own smartphones), patriarchal resistance, and unreliable internet connectivity. The study proposes a three-pronged intervention: (1) Community Digital Champions—training local women to mentor peers, (2) Gender-Responsive Design simplifying apps with vernacular voice-commands, and (3) Public-Private Partnerships to subsidize devices and expand rural broadband under the National Digital Agriculture Mission. Empowering women digitally aligns with the conference's vision of empowered youth ensuring equitable growth while enhancing ecological resilience. By integrating digital tools with policy support, India can unlock the untapped potential of 60 million women farmers, advancing SDGs 5 (Gender Equality) and 9 (Industry, Innovation, and Infrastructure).

Keywords: Digital literacy, gender equity, agri-value chains, e-marketplaces, rural women empowerment.

Sustainable Use of Banana Waste for Soil Nutrient

Prerna[1*], Malom Hankar[1], Pradeepto Pal[1], B. Vanlalneihi[1]

[*1]College of Horticulture, Central Agricultural University (Imphal) Thenzawl, Mizoram, India

Corresponding author's email: prernasha95@gmail.com

ABSTRACT

Banana cultivation generates significant volume of organic waste, including peels, pseudostems, leaves, and rejected fruits, which are often discarded without proper management. This study examines the sustainable use of banana waste to improve soil fertility and promote eco-friendly agricultural practices. Banana waste is rich in potassium, phosphorus, calcium, and organic matter which offers a natural and renewable source of nutrients for improvement of soil fertility, structure, and microbial activity. Through methods such as composting, vermicomposting, and biochar production, banana waste can be transformed into effective soil amendments. These processes not only reduce environmental pollution and waste accumulation but also provide a low-cost alternative to chemical fertilizers. The integration of banana waste into soil management systems supports a circular economy approach in agriculture, promoting sustainability and long-term productivity. The paper reviews recent research and case studies that demonstrate the effectiveness of banana waste in improving crop yields, restoring degraded soils, and enhancing soil biodiversity. The findings underscore the potential of banana waste as a valuable resource in sustainable farming, particularly in banana-producing regions where waste availability is high. This approach aligns with This approach aligns with global efforts to reduce agricultural waste, enhance soil health, and support environmentally responsible farming practices and United Nations Sustainable Development Goals *viz*., SDG 2: Zero Hunger, SDG 9: Industry, Innovation, and Infrastructure, SDG 12: Responsible Consumption and Production, SDG 13: Climate Action and SDG 15: Life on Land.

Keywords: Banana waste, soil fertility, circular economy, SDG's

Eco-Feed: Fruit Waste for Future Farms

[1]Hiran Raajan P, *[2]Dr.K.R.Ramesh

[1] *UG scholar, Department of Horticulture, Faculty of Agriculture, Annamalai Nagar, Annamalai University, Chidambaram, Cuddalore, Tamil Nadu, India-608 002.*

*[2]Professor, Forest college and Research Institute, Tamil Nadu Agricultural University, Mettupalyam, Coimbatore, Tamil Nadu,India-641 301

Corresponding authors e-mail: rameshforest99@gmail.com

ABSTRACT

In India, an alarming 30–40% of fruit produced annually is wasted, amounting to approximately 74 million tonnes of food loss each year. This substantial waste not only exacerbates environmental challenges but also represents an untapped resource that can be effectively utilized for sustainable agricultural solutions. One promising approach to address this issue is transforming fruit waste into high-quality animal feed, creating a circular economy that benefits both livestock and the environment. Fruit waste, including overripe, damaged, or unsellable produce, is often discarded, despite being rich in essential nutrients, fibers, and minerals. These nutrients make fruit waste a valuable alternative to conventional animal feed ingredients, such as grains and soy, which are commonly used in livestock diets. By processing fruit waste into digestible and nutritious feed products, we can reduce the volume of waste, lower the environmental impact of food production, and enhance the overall health and productivity of livestock. The utilization of fruit waste for animal feed offers several significant advantages. It reduces the dependency on traditional feed crops, which require extensive land, water, and resources to cultivate. Additionally, utilizing fruit waste helps divert organic material from landfills, reducing methane emissions and the overall environmental burden. This process also contributes to lowering greenhouse gas emissions, supporting a more sustainable approach to agriculture. Moreover, fruit waste-based animal feed can offer a cost-effective solution for farmers, particularly in regions where fruit production is abundant but frequently goes unused, either due to surplus or market inefficiencies.

This abstract highlights the process of converting fruit waste into animal feed, detailing the steps involved from waste collection to processing techniques. Methods such as drying, fermentation, and extrusion are employed to enhance the nutritional value, digestibility, and preservation of the waste, making it suitable for inclusion in livestock diets. Once processed, the fruit waste-based feed can be integrated into the feeding regimes of various animals, including poultry, cattle, and swine, ensuring a balanced and sustainable approach to livestock nutrition. Ultimately, this approach offers a promising pathway toward more sustainable agricultural practices by reducing food waste, conserving resources, and improving food systems.

Assessment of Waterlogging Stress Tolerance in Onion Genotypes

[1*]Amol Pawar, [2]Sushant Sukumar Patil, [3]Mayur Patil, [4]Pandit Trupti Rajesh,

[1,2,3] Department of Agronomy, Lovely Professional University, Punjab, India

[4]Department of Entomology, Lovely Professional University, Punjab, India

Correspondence Email: amolrp4@gmail.com

ABSTRACT

Eight onion genotypes were examined in this study; four of the tolerant varieties (Acc 1666, Acc 1630, W 355, Bhima Dark Red) and four of the sensitive kinds (Bhima Red, Bhima Raj, Bhima Shubra, and Bhima Super) were examined. The experiment was carried out in the Kharif season of 2023 at ICAR-DOGR in Pune, India. At harvest, morphological, physiological, pre- and post-waterlogging treatment, recovery phase, and biochemical data were evaluated at harvest. The findings demonstrated that under stressful conditions, tolerant genotypes—specifically, Acc 1666—maintained better rates of survival, plant heights, and leaf areas. When compared to sensitive genotypes such as Bhima Super, Acc 1666 showed the least amount of yield drop .Under waterlogging, tolerant genotypes showed higher amounts of protein, phenolic content, and antioxidants, suggesting improved stress tolerance. Following treatment, all genotypes showed a fall in the Membrane Stability Index (MSI), with tolerant genotypes exhibiting lesser decreases. These results emphasize how crucial it is to choose onion types that can withstand waterlogging when growing them in flood-prone locations in order to improve crop performance and yield stability.

Impact of Abiotic Variation and Planting Schedule on Pollinator Activity and Onion Seed Yield

Pandit Trupti Rajesh[1*], Sunil Dwivedi[2], V. Karuppaiah[3]

[1*]Ph.D. scholar, Department of Entomology, Lovely Professional University, Punjab, India

[2]Associate Professor, Department of Entomology, Lovely Professional University, Punjab, India

[3]Senior scientist, Department of Entomology, ICAR-DOGR, Rajgurunagar, Pune, Maharashtra

Corresponding authors e-mail: truptipandit143@gmail.com

ABSTRACT

Onion (*Allium cepa L.*) is an entomophilous crop highly dependent on insect pollinators, especially *Apis* spp. and dipteran flies, for successful seed production. However, pollination success is often influenced by fluctuating abiotic conditions, which can alter pollinator foraging behaviour and floral synchrony. This study was undertaken to assess the interactive effects of abiotic variations namely temperature, relative humidity, light intensity, and wind speed—and different planting dates on pollinator visitation rates and subsequent seed yield in onion. Field experiments were conducted across three staggered planting windows during the late kharif to rabi season, with continuous monitoring of floral phenology, pollinator activity, and microclimatic conditions during anthesis. Nectar secretion, pollen viability, and stigma receptivity were also evaluated to understand floral rewards and their alignment with pollinator availability. Results revealed that early-planted onion plots experienced optimal overlap between peak flowering and maximum pollinator abundance under favorable environmental conditions, resulting in significantly higher seed set and quality. In contrast, delayed planting was associated with reduced pollinator visits, pollen sterility due to heat stress, and poor seed yield. The findings suggest that precise manipulation of planting time, synchronized with local climatic trends and pollinator behavior, can enhance pollination efficiency and seed productivity. This study highlights the need for climate-resilient crop management strategies integrating pollinator ecology for sustainable onion seed production under changing agro-climatic conditions.

Keywords: Stress, Behaviour, *Apis* species, Climate, Foraging, Pollen, Nectar

Morpho-Physiological and Yield Responses of Onion Varieties to Salinity Levels

1* Mayur Patil, 2 Amol R Pawar, 3 Sushant Sukumar Patil, T. R. Pandit.

1,2 Ph.D. scholar, department of agronomy, lovely professional university.

3 Assistant professor, Department of agronomy, lovely professional university.

4 Ph.D. scholar, department of entomology, lovely professional university.

Corresponding authors e-mail: patilmayur5739@gmail.com

ABSTRACT

A pot experiment was conducted during the 2023-24 Rabi season at Lovely professional university, Punjab to assess the effects of soil salinity (with electrical conductivity levels of <2.0, 4.0, 6.0, and 8.0 dS m^{-1}) on the growth, yield, and quality of five onion (*Allium cepa* L.) varieties: Pusa red, Pusa ratan, Panch ganga, Pusa Madhavi, N 2-4-1. The experiment followed a factorial completely randomized design with three replications. Results demonstrated a significant decline in plant growth and yield attributes with increasing salinity. For instance, at the highest salinity level (8.0 dS m^{-1}), mean plant height reduced by 56%, bulb fresh weight by 71%, bulb dry weight by 67%, and bulb volume by 63% compared to the control (<2.0 dS m^{-1}). Among the varieties, ‘Pusa Madhavi’ showed comparatively better tolerance by maintaining higher plant height (49.33 cm), fresh bulb weight (37.49 g), and bulb dry yield (3.90 g) under low salinity. These responses suggest that salinity imposes osmotic and ionic stresses, severely diminishing onion performance, although varietal differences in tolerance are evident. The findings underline the importance of identifying salt-tolerant varieties and optimizing irrigation practices to sustain onion yield in saline environments.

Eco-friendly Fractionation of Lignocellulosic Biomass for Production of Agro-Energy Products

Ajay Kumar[1*], Prince Dwivedi[1], Kundan[2], and Gore V.B.[2]

[1]Division of Agricultural Engineering, ICAR - IARI, New Delhi - 110012

[1]Division of Biochemistry, ICAR - IARI, New Delhi – 110012

[*Corresponding Author: ajay_12390@iari.res.in]

ABSTRACT

The industrial reliance on fossil fuels for energy, polymers, and chemicals has led to environmental degradation, resource depletion, and energy insecurity. To address these challenges, a transition toward a circular bioeconomy is essential. This study explores the eco-friendly fractionation of lignocellulosic biomass for the production of sustainable agro-energy products. Lignocellulosic wastes, including rice straw, sugarcane bagasse, and forestry residues, represent an abundant yet underutilized resource, with global availability exceeding 2 billion tons annually. Due to their high lignin content (10–40%), much of this biomass is either burnt or left to decay, contributing to air pollution and loss of valuable energy-rich material. The energy content of these organic materials is estimated to be around 14-46 MJ per kg at 10 % moisture content; however, only 20 % of residues is used for energy purposes. This study aims to find a versatile and efficient pretreatment method to enhance sugar yields from biomass, optimizing enzymatic saccharification and microbial fermentation processes at the pilot scale. The project also focuses on the co-production of value-added products, such as antimicrobial compounds and biopesticides, to reduce the overall cost of bioethanol production and increase economic viability. A circular bioeconomy framework will be proposed to promote sustainable waste management, resource optimization, and integration of renewable biomass into the agro-industrial value chain. The environmental impact, energy efficiency, and economic feasibility of the process will be critically evaluated. By converting agricultural waste into biofuels and bioproducts, this study supports cleaner energy alternatives, reduces open-field burning, and contributes to sustainable agriculture. The expected outcomes will offer a replicable model for transforming agricultural residues into marketable agro-energy solutions, thus aligning with global goals for energy security, environmental sustainability, and rural development.

Keywords: Circular bioeconomy, Agro-waste valorization, Sustainable pretreatment

Molecular Analysis of Divergence in Genes Contributing towards Drought Stress Tolerance in Soybean [*Glycine max* (L) Merrill]

G.H. Ranade, D.B. Kunjir, Dr. V.P. Chimote

State Level Biotechnology Centre, Post Graduate Institute, Mahatma Phule Krishi Vidhyapeeth, Rahuri, Ahilyanagar, Maharashtra

[*Corresponding Author's email: gauriranade911@gmail.com]

ABSTRACT

Soybean (Glycine max), the world's leading oilseed crop, is a vital source of plant-based protein, fats, and essential nutrients, offering numerous health benefits and contributing to soil enrichment through nitrogen fixation. However, soybean is highly sensitive to drought, an increasingly significant threat due to rising global temperatures and changing precipitation patterns. Drought can reduce yields by over 40%, particularly when stress occurs during critical growth phases. The research focused on 7 soybean genotypes, including NRC 37 X EC 602288, KDS 1201 X EC 333901, KDS 1173 X EC 602288, JS 2098 X EC 333901, JS 2098 X EC 602288, JS 2098 X TGX 709-50E, KDS 1201 X TGX 709-50E. Among these, TGX 709-50E and EC 333901 are known for their delayed wilting abilities. The genotypes NRC classified as drought sensitive; genotype, JS 20-98 as intermediate-tolerant. The markers used were SSR and Gene Specific marker. This study investigates the genetic basis of drought tolerance in soybean genotypes with varying drought responses, focusing on seven key drought-related genes and SSR markers. Genomic DNA was extracted from soybean seedlings and amplified using 12 candidate gene-specific primers, revealing the amplification of genes known for their roles in drought stress adaptation. SSR marker analysis across revealed significant polymorphism, with 15 out of 17 primers amplifying polymorphic markers, producing up to six alleles per locus. This study provides valuable insights into the genetic complexity of drought tolerance in soybeans, highlighting the importance of multiple gene interactions and polymorphic markers in contributing to drought resilience.

Effect of Nano Urea and Nano DAP on Growth, Yield and Quality of Chilli (*Capsicum annuum* L.)

N. M. Maske[1]*, M. A. Ajabe[1], B. G. Mhaske[1], P.S.Chate[1] and A.V. Narote[1]

[1]MGM Nanasaheb Kadam College of Agriculture, Gandheli, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani- 431 402, Maharashtra, India.

ABSTRACT

A field experiment was conducted during Kharif 2023–24 at the Research Farm of MGM Nanasaheb Kadam College of Agriculture, Gandheli, to evaluate the efficacy of Nano Urea and Nano DAP on chilli (Capsicum annuum L.) cultivation. The study employed a randomized block design with nine treatments and three replications, integrating recommended dose of fertilizer (RDF) with varying concentrations of nano nutrients applied at 30 and 45 days after transplanting (DAT). Results showed that RDF combined with Nano DAP @ 0.4% (T_9) significantly enhanced agronomic attributes including plant height (74.99 cm), number of leaves (291.67), fruit length (7.47 cm), fruit girth (2.59 cm), and total chlorophyll content (2.34 mg g^{-1}). T_9 also recorded the highest green fruit yield (25.61 t ha^{-1}), total soluble solids (4.62 °Brix), and ascorbic acid content (139.41 mg/100 g). These findings highlight the potential of nano fertilizers to improve nutrient efficiency, crop performance, and fruit quality in chilli. Adoption of Nano DAP with RDF can contribute towards sustainable intensification and resource optimization in vegetable production systems.

Society for Community Mobilization for Sustainable Development (Mobilization)

Headquarter: ICAR-Indian Agricultural Research Institute, New Delhi-110012

ABOUT THE SOCIETY

MOBILIZATION Society was established in 2003 as a non-profit professional society aimed at sensitizing and mobilizing development partners and community for sustainable development. The Society has successfully mobilized researchers, academicians, planners, grass-root mobilizers, students to create conducive intellectual atmosphere for introspective deliberations. Nine national seminars organized in collaboration with renowned institutions like IIT-Delhi, ICAR-IVRI, Bareilly, GBPAU&T, Pantnagar etc., to address the emerging problems experienced by the agrarian mass. The Society remained collaborator of two International Conference organized at Andaman in December 2016 and New Delhi in February 2017. The recognition of the society in the efforts for strengthening the forum for scientific communication is growing among the related professionals and concerned agricultural stakeholders rapidly and presently has more than 1800 Life Members.

JOURNAL

Society publishes Quarterly Journal of Community Mobilization and Sustainable Development (print ISSN 2230– 9047; online ISSN 2231–6736) having NAAS rating of 5.67 (Journal ID J158). The Mobilization journal is available on the website www.mobilization.org.in and has been registered with www.indianjournals.com for national and global abstracting and indexing.

AWARDS & HONOURS

MOBILIZATION envisages reorienting the young professionals and researchers for imbibing the values of community participation in research, training and extension endeavours. The society instituted awards for researchers, educationalists, teachers, trainers, extension professionals, students, innovative farmers and NGOs in recognition of their contributions for the society.

AWARDS

- **Fellow Mobilization Award**
- **Best Community Mobilizer Award**
- **Young Scientist Award**
- **Young Women Scientist Award**
- **Outstanding Research Scholar Award (For Ph.D.)**
- **Outstanding Research Scholar Award (For M.Sc.)**
- **S.P. Goel Award**
- **Agro-Industry Award**
- **Award for NGO**
- **Innovative Farmer Award**
- **Innovative Women Farmer Award**
- **Best KVK Professional Award**
- **Best Extension Professional Award**
- **Best KVK Award**

Visit us at **www.mobilization.org.in**
E-mail: **jpscatat@gmail.com**

Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya

(Established in 2008)
ISO 9001-2008
Life time International Accreditation Organization (IAO) awarded

The University represents a well knit and action oriented network of research and education centres operating in agriculture and allied fields in Madhya Pradesh with Four College of Agriculture, one College of Horticulture, 22 Krishi Vigyan Kendra, 5 Zonal Agriculture Research Station

Research/Extension

- 52 Crop varieties developed
- Largest National producer of Breeder Seed
- National Award for Best Krishi Vigyan Kendra, Jhabua and Datia
- 11 ICAR awards to KVK and Scientists

Infrastructure:

- State of Art University Library and Constituents Colleges Library.
- State of Art Smart Class room
- State of art Bio-Technology centre
- Well equipped and furnished Boys and Girls Hostel
- Placement Cell

Courses Offered

- **Bachelor of Science in Agriculture (Hons.)**
- **Bachelor of Sciences in Horticulture (Hons.)**
- **Dual Degree programme with Dalhousie University, Canada**

- **Master of Science in Agriculture [M.Sc. (Ag.)]** in 11 disciplines
- **Master of Science in Horticulture [M.Sc. (Hort.)]** in 4 disciplines
- **Doctor of Philosophy (Ph.D.)** in 9 disciplines

Centre of Excellence

Ravine management	Organic cotton
Kadaknath	Honey bee
Climate Change	Apiculture

Entrepreneurship Development

- Agri-business Incubation Centre
- World Bank & ICAR funded NAHEP
- 19 Experiential Learning Units

RAJMATA VIJAYARAJE SCINDIA KRISHI VISHWA VIDYALAYA, GWALIOR (M. P.)

Affiliation	:	Indian Council of Agriculture Research, New Delhi
Website	:	www.rvskvv.net
Address	:	Raja Pancham Singh Marg,Gwalior-474 002 (M.P.) India
Phone	:	0751-2970502, Fax: 0751-2970504
E-mail	:	vc@rvskvv.net and registrar@rvskvv.net

Rani Lakshmi Bai Central Agricultural University, Jhansi-284003, UP (India)

(Established on 5th March, 2014 by the act of Parliament as Institution of National Importance)

Steps towards Rainbow Revolution & Bright Future in Agriculture……….

IN THE SERVICE OF THE NATION THROUGH PURSUE A CAREER IN

- The University has two colleges located at the headquarter in Jhansi, Uttar Pradesh namely College of Agriculture and College of Horticulture & Forestry and two upcoming colleges namely College of Veterinary & Animal Sciences and College of Fisheries located at Datia campus, Madhya Pradesh.
- B.Sc. (Hons) Agriculture, B.Sc. (Hons) Horticulture and B.Sc. (Hons) Forestry: 4-years undergraduate programmes at Jhansi campus. B.VSc. & AH Veterinary & Animal Science, B.FSc. Fisheries at upcoming Datia campus.
- M.Sc. (Agriculture) in eleven disciplines, namely; Genetics & Plant Breeding, Plant Pathology, Agronomy, Soil Sciences, Entomology and Agricultural Extension Education: 2-Years degree programmes and two upcoming Inter-institutional and Inter-disciplinary Master's Programmes in Agricultural Biotechnology & Seed Science & Technology. M.Sc. (Horticulture) in three disciplines, namely; Fruit Science, Vegetable Science and Floriculture & Landscaping: 2-Years degree programmes. M.Sc. (Forestry) in two disciplines, namely; Silviculture & Agroforestry and Forest Product and Utilization: 2-Years degree programmes.
- Doctoral Programme in Ph.D. Genetics & Plant Breeding, Ph.D. Agronomy, Ph.D. Plant Pathology, Ph.D. (Horticulture) Fruit Science, Ph.D. Forestry (Silviculture & Agroforestry)

JOIN THE INSTITUTION OF NATIONAL IMPORTANCE

ADMISSION THROUGH ALL INDIA COMMON UNIVERSITY ENTRANCE TEST (CUET) CONDUCTED BY ICAR, NEW DELHI

Research activities

- Three well developed research farms in Jhansi, Datia and Niwari along with modern implements.
- Well equipped Central Research laboratory facilities, with high end equipments.
- Augmentation of agricultural productivity in Bundelkhand through basic and strategic research with focus on pulses, oilseeds, millets, fruits, vegetables, flowers, value addition, natural resource management and social science.
- Developed technologies have potential to increase agricultural productivity and income of small and marginal farmers in the region.

Extension Education Activities

- FLDs, training and ICT tools for transfer of technologies in 14 districts of Bundelkhand region in UP and MP
- Dissemination of knowledge, agri-practices and technology for crop protection and soil fertility management through Mobile Plant Health Clinic at the doorsteps of farmers, Promotion of science based Natural farming in the Bundelkhand
- Drone technology for enhancing efficiency of Agri-inputs, less labor intensive and cost effective manner
- Promotion and diversification of industrialized agriculture through development of technical skills.

Others Features

- Well furnished library, e-library and classrooms to nurture the students for their all round development.
- Establishment of state-of-art infrastructure facilities in academic and administrative blocks, laboratories, instructional units/ blocks for enhanced learning.
- Emphasis on Experiential Learning, Student READY and NSS to discover new passion.
- Green & Clean campus fulfilling green building norms, Placement cell, Media cell, Smart Classrooms, Sports & Gym, 24*7 Wi-Fi, Hygienic Mess, CCTV camera surveillance in the whole campus, Geyser, Air, Water coolers and proper waste disposal system.

Inspiring Academic community for Innovations & Inventions for the development of Emerging technology, Employability and Enterprise

Chaudhary Charan Singh Haryana Agricultural University

Hisar–125 004, Haryana, INDIA

(An A+ Accredited University by NAEAB, ICAR, New Delhi)

Inspiring Agripreneurs

Prof. B.R. Kamboj
Vice-Chancellor
CCSHAU, Hisar

A Premier Institution for

Carrier Opportunities in

AGRICULTURE and ALLIED SECTORS

The University offers (Degree Programmes)

9 Under Graduate | **47** Masters | **42** Ph.D.

Prestigious Academic Establishment of High Repute

- Full Fledged University Since 1970
- Quality Research, Teaching and Extension
- State of the Art Infrastructure
- High-tech laboratories
- World Class Sports Facilities
- Wi-Fi connected campus
- One of the most beautiful campuses in India with a lot of biodiversity both in terms of flora and fauna.
- Research on Natural farming
- All the hostels have solar water system
- 7 Community Radio Stations in various districts

- Twice Recipient of ICAR Best Institution Award
- First Stop for International Students
- First Recipient of Haryana Kisan Ratna Award
- Among the Top Ranked Agricultural Universities of the Country
- Best ABIC of the country Award 2021
- All India Champion of Agriculture Sports Meet 2017 and 2023

Constituent Colleges

- ✓ College of Agriculture, Hisar
- ✓ College of Agriculture, Bawal
- ✓ College of Agriculture, Kaul
- ✓ College of Basic Sciences and Humanities
- ✓ College of Biotechnology
- ✓ Indira Chakravorty College of Community Sciences
- ✓ College of Agricultural Engineering &Technology
- ✓ College of Fisheries Science
- ✓ Institute of Business Management and Agripreneurship, Gurugram

The faculty of this university have served on various coveted positions such as Director General (ICAR), Chairman (ASRB), Advisor (Planning Commission), Vice-Chancellors, Deputy Director General (ICRISAT), Deputy Director Generals (ICAR), Directors of National Institutes etc. Alumni of this university are working all over the world and are holding important positions in administration of various sectors.

www.hau.ac.in

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SARDARKRUSHINAGAR DANTIWADA AGRICULTURAL UNIVERSITY
SARDARKRUSHINAGAR- 385506 DIST. BANASKANTHA (GUJARAT, INDIA)

Sardarkrushinagar Dantiwada Agricultural University (SDAU) came into existence after quadruplicating of erstwhile Gujarat Agricultural University on 01 May, 2004 with jurisdiction covering seven districts namely; Banaskantha, Sabarkantha, Aravalli, Patan, Mehsana, Gandhinagar, and Kachchh.

Vision:- To increase the income of the farmers and other people who are directly or indirectly dependent on agriculture.

Mission:- Prolong agricultural sustainability by ensuring enhanced safe food and nutritional security without harming the nature base and pristine environment.

Goal:- Well trained human resources and target oriented innovations/technologies for assuring safe food and nutritional security with precise focus on economic well-being and environment sustainability.

Our Strength

- Polytechnics - 5
- Colleges - 9
- Research Stations - 26
- KVKs - 3

Various Courses

Diploma Courses

- Agriculture
- Horticulture
- Nutrition & Community Science

UG Degree Courses

- B. Sc. (Hons.) Agriculture
- B. Sc. (Hons.) Horticulture
- B. Tech. (Food Technology)
- B. Tech. (Bio Technology)
- B. Tech. (RE & EE)
- B. Sc. (F.N. & D.)
- B. Sc. (Community Science)

PG Degree Courses

- M. Sc. (Agriculture)
- M. Sc. (Horticulture)
- M. Tech. (Agril. Engg.)
- M.Sc. (Community Science)
- MBA in Agri-Business Management

Doctoral Degree Courses (Ph. D.)

- Agriculture Faculty
- Horticulture Faculty
- Agril. Engg. & Tech. Faculty
- Community Science Faculty

Facilities at SDAU

- Latest Laboratories
- Smart Classrooms
- Separate Boys & Girls Hostels
- Wi-Fi Campus
- Central Library
- Computer Lab
- NCC & NSS
- National Standard Sports Facilities
- Gymnasium & Swimming Pool
- Auditorium
- Guest House
- Reading & Recreation Hall in Hostels
- Central Examination Hall
- Counselling & Placement Cell

For more detail please contact us on

www. sdau.edu.in registrar@sdau.edu.in (02748)278226 (02748)278234

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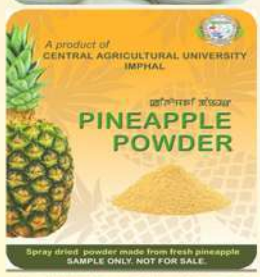
Central Agricultural University, Imphal



- **Year of establishment : 1993**
- **13 constituent colleges with 6 KVKs and 6 MTTCs & VTCs spread across 7 North Eastern States, offering 10 UG, 48 PG, and 34 Ph.D programs in Agriculture and Allied sciences**
- **Designated as Center of Natural Farming under NMNF by MoA&FW, GoI**
- **Launched B.Sc. (Hons) Natural Farming in 2023**
- **2,982 students with a 1:1.38 male-to-female ratio from all 28 states with successful graduation of 17 international students.**
- **128 alumnus working as ARS scientists**
- **Skill mapping under NEP-2020 with publication of Compendium of Skill Sets manual & Policy documents on**
  - **Futuristic Agricultural Education for Viksit Bharat - 2047**
  - **Early Childhood care and Nutrition which has been adopted by Govt of Meghalaya**
  - **Strategies for Achieving 30 trillion Economy by 2047**
- **Exploring new dimensions in agricultural innovation—from drones and bio-resources to traditional knowledge and food technologies by collaborations with Regional, National & International Institutions**
- **Released 8 region-specific rice varieties, 1 groundnut, 1 soybean & 1 cassava variety**
- **Secured 32 patents, developed 38 prototypes, 2 copyrights and commercialized multiple technologies**
- **Established a BSL-II lab for transboundary disease, 5G Lab and 3D Printing Laboratory**
- **Only University in the country implementing 60 FPO's**
- **Nurtured 96 startups across the NEH region**
- **Mobile-based Agro Advisory System connecting over 44,000 farmers across 53 districts and 2,000+ villages in the region with 1.48 lakh advisories issued so far**

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पूर्णतः सहकारी स्वामित्व
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IFFCO BAZAR

BIO-STIMULANT

Seaweed Based Bio-stimulant

- Validated by 43 ICAR-Research Institutes & State Agri. Universities
- Helps in reduction of chemical fertilizer by 25%
- Crop yield increased 15 - 25%
- Reached over 30.6 Million Acres of land
- Tested on 19 different crops at different agro climatic zone
- Developed and Sourced from CSIR-CSMCRI

For more information visit our website

शेतकरी देवो भवः

VASANTRAO NAIK MARATHWADA KRISHI VIDYAPEETH

Parbhani – 431 402 (Maharashtra) INDIA.

Year of Establishment : 1972

(ICAR-NAEAB Accredited with 'A' Grade)

Sixteen Constituent Colleges

- College of Agriculture, Parbhani (UG/PG/Ph.D.)
- College of Agriculture, Latur (UG/PG)
- College of Agriculture, Badnapur (UG/PG)
- College of Agriculture, Ambejogai (UG)
- College of Agriculture, Dharashiv (UG)
- College of Agri., Golegaon (Hingoli) (UG)
- College of Agriculture, Jirewadi (Beed) (UG)
- College of Agri., Lihakhedi (C.Sambhajinagar) (UG)
- Colleges of Agriculture, Nanded (UG)
- College of Horticulture, Parbhani (UG)
- College of Agril. Engg & Technology, Parbhani (UG/PG/Ph.D.)
- College of Food Technology, Parbhani (UG/PG/Ph.D.)
- College of Community Science, Parbhani (UG/PG/Ph.D.)
- VD College of Agril. Biotechnology, Latur (UG/PG)
- College of Agri-Business Management, Jirewadi (Beed) (UG)
- PG Institute of Agril. Business Management, Chakur (Latur) (PG)

- Total 59 Colleges (16 Constituent & 43 Affiliated) offers UG,PG, Ph.D. Programs.
- Total 57 Agril. Technical Schools (51 Affiliated & 6 Constituent) offers Diploma programs.

ADMISSION OPEN

Academic Excellence

- Dynamic Curriculum aligned with NEP 2020 fostering innovation, skill development & entrepreneurship
- Advanced Laboratories viz., Plant & Soil Health, Drone, AI, ML, Robotics
- RPTO Centre & 6-Month Professional Certificate Course in AgriDrone Technology
- Nationally & Internationally Trained Faculties
- Strong Alumni, Placement & Career Guidance Cell.

Global Exposure & Collaborations

- 25 Faculty members & 51 PG Students trained USA, Australia, Spain, Hungary, Thailand, Canada, Brazil, Malaysia, Nepal & More
- MoUs with 9 International Institutes : Western Sydney University (Australia), Universitat Politecnicade, Valencia (Spain); Washington State University (USA); Belarus State Uni. Of Informatics; University of Florida (USA); Kansas State University (USA); GIZ, ICRISAT, Purdue University (USA).
- MoUs with 40+ National Reputed Institutes for research, education & extension

Research Achievements

- 23 AICRPs & 19 State funded Research Schemes
- Externally funded projects : DST (2), NASF (10), CM fund (8), RKVY (4), IFFCO (1)
- Handsome CSR Funding & Strong Industrial Collaborations.
- MoUs with 250+ FPOs for quality seed production and participatory research.
- International Collaboration Research with Purdue University (USA), GIZ(Germany) , AIT (Thailand).
- Developed 158 Varieties / Hybrids, 58 Farm Implements,
- Released 1146 Technologies / Recommendations.

National-International Recognitions

- ISO 14001:2015 ISO 21001:2018 ISO 50001:2018
- Ranked 33rd in IIRF 2025
- International Green University Award 2023 (USA)
- Vasantrao Naik Agricultural Outstanding Contribution Award 2025
- Awarded Best AICRP Research Centres : Pearl Millet, Oilseed, Safflower, Cotton, Pulses Agril. Meteorology & Dryland in the Country.

For More Information www.vnmkv.ac.in Contact : 02452-229755

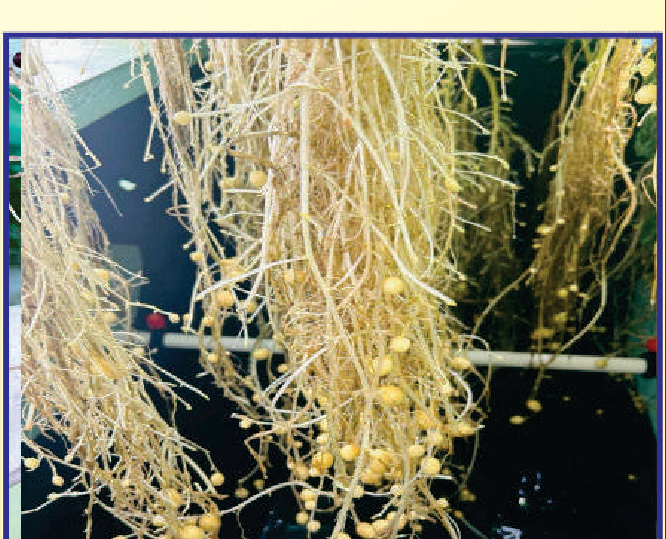
राजमाता विजयाराजे सिंधिया कृषि विश्वविद्यालय ग्वालियर (म.प्र.)

जैव प्रौद्योगिकी केन्द्र

ऐरोपोनिक्स (मृदा रहित खेती)

ऐरोपोनिक्स तकनीक के माध्यम से टिश्यू कल्चर द्वारा रोग मुक्त आलू के बीजों/कंदो का उत्पादन

- ऐरोपोनिक तकनीक पौधों की जड़ों को बिना मिट्टी के हवा में लटकाकर पोषक तत्वों का वाष्प के रूप में छिड़काव किया जाता है।
- ऐरोपोनिक प्रणाली में पौधों की जड़ो को हवा मे पोषक तत्वों के घोल का छिड़काव किया जाता है।
- पारंपरिक खेती की तुलना में ऐरोपोनिक पद्धति में 90% तक कम पानी की आवश्यकता होती है
- आलू के बीज से रोग मुक्त पौधे एवं 10 प्रतिशत अधिक उत्पादन
- इस विधि से बीजोत्पादन उन क्षेत्रों में भी किया जा सकता है जहाँ पर जुताई योग्य मिट्टी उपलब्ध नहीं है ।



FSII is an association of research based plant science industry committed to deliver quality seeds for farmers.

Alliance for Agri Innovation, a special interest group of FSII, promotes technology innovations in agriculture.

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Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences (KSNUAHS), Shivamogga

Main Campus Iruvakki- 577 412 (Accredited by ICAR & UGC)

Dr. R. C. Jagadeesha
Vice Chancellor

A unique integrated University in the State having Agriculture, Horticulture and Forestry Sciences in its jurisdiction *viz.*, Shivamogga, Chikkamagaluru, Udupi, Dakshina Kannada, Kodagu, Davangere and Chitradurga districts of Karnataka.

1. Educational Institutions & Courses offered

A) College of Agriculture, Shivamogga, **B)** College of Horticulture, Mudigere **C)** College of Horticulture, Hiriyur, **D)** College of Forestry, Ponnampet (A++ ICRFE accredited) and **E)** Two Diploma Agriculture Colleges at Kathalagere and Brahmavara.

Under Graduate Degree

- B.Sc. (Hons.) Agriculture
- B.Sc. (Hons.) Horticulture
- B.Sc. (Hons.) Forestry

Post Graduate Degree

M.Sc. Agriculture

- Agricultural Economics (2023-24)
- Agricultural Extension Education (2012-13)
- Agricultural Microbiology (2023-24)
- Agricultural Statistics (2023-24)
- Agronomy (2012-13)
- Entomology (2002-03)
- Food Science and Nutrition (2023-24)
- Genetics and Plant Breeding (2012-13)
- Horticulture (2018-19)
- Microbiology (2023-24)
- Molecular Biology and Biotechnology (2023-24),
- Plant Pathology (2012-13)
- Soil Science (2002-03)

M.Sc. Horticulture

- Floriculture and Landscaping (2010-11)
- Plantation, Spices and Medicinal and Aromatic Crops (2011-12)
- Fruit Science (2010-11)
- Vegetable Science (2013-14)
- Postharvest Management (2023-24)

M.Sc. Forestry

- Silviculture and Agroforestry (2010-11)
- Forest Biology and Tree improvement (2015-16)
- Natural Resource Management (2015-16)

C. Doctoral Degree

Ph.D. Agriculture

- Agronomy (2013-14)
- Entomology(2013-14)
- Genetics and Plant Breeding(2013-14)
- Soil Science(2013-14)
- Plant Pathology(2013-14)

Ph.D. Forestry

- Ph. D. in Silviculture and Agroforestry (2019-20)

D. Certificate Courses (52 weeks)

- Diploma in Agricultural Extension Services for Input Dealers

E. Other Certificate Courses

- High tech Mushroom production technology for sustainable livelihood
- Bakery and Confectionery (Biscuits and Cakes) Comprehensive Horticulture Nursery Management
- Landscape Gardening
- Protected cultivation of High valued vegetable crops

2. Research

University has 14 Research stations *viz.,* one Main Agricultural and Horticultural Research Station at Iruvakki, four Zonal Agricultural and Horticultural Research Station at Shivamogga, Hiriyur, Mudigere, Brahmavara and nine Agricultural and Horticultural Research Station at Kathalagere, Ullala, Thirthahalli, Ponnampet, Sringeri, Bavikere, Honnavile, Madikeri and Kademadkal.

3. Extension

- University has four ICAR-KVKs at Shivamogga, Chitradurga, Chickkamagaluru and Udupi. Two Extension Education Units at Kathalagere and Ponnampet and two Extension Units at Thirthahalli and Sringeri
- University reaches approximately 4 lakh farmers annually through capacity building, on-farm testing, Front-Line Demonstrations, Method Demonstrations, Vocational and Skill oriented training programmes, *etc*.,
- University is publishing bi-monthly *Negila Miditha* magazine for stakeholders.
- Regularly organizing Krishi-Totagarika Mela exhibiting recent advances in agricultural technologies to farmers and other stakeholders.

4. Achievements

- A total of 3809 students have been graduated in Agriculture (986), Horticulture (1278) and Forestry (608) of which 2872 are Under Graduates, 840 Master's Degree and 97 Ph.D. A total of 583 students have obtained Diploma (Agriculture) from the University.
- University has awarded 126, 123 & 41 Gold Medals to 66 UG, 118 PG and 35 Ph. D. graduates, respectively.
- Students have secured 114 & 14 ICAR JRFs & SRF, respectively.
- University has 88 MoUs with national & international institutions for overall development of stakeholders.
- Students & faculty have visited institutions abroad Under IDP project funded by World Bank and ICAR.
- **Patents:** For an invention entitled "Method of in vitro and rogenesis for production of double haploids in Chill (Capsicum annuum) (Patent number 468204)" and Mini Hand operated Groundnut Sheller for 20 years (Patent number 488359) and three patents are filed.
- **Technologies Developed:** 15 varieties (Paddy 12 numbers, Tobacco, Arecanut & Cowpea, one each)
- **20 Farm Machineries: 98 Technologies in Crop Production/Protection, Horticulture, Fisheries & Food Sciences and Nutrition have been Developed**
- Produced & distributed 529 tons of quality seeds & planting materials and 388 tonnes bio-agents and bio-fertilizers to farmers to keep ecosystem eco-friendly
- Developed and commercialized "Sahyadri Noni herbal dip tea technology" and "Sahyadri Siri Coffee Leaf Beverage Instant Dip Sachet technology".
- **Published more than 1700 scientific articles in reputed journals**
- **One District one Product (ODOP): Operating in three districts on Pineapple at Shivamogga , Spices at Mudigere and Groundnut at Hiriyur**
- University has 1544 projects worth Rs.196 crores funded from national/international organizations

For further information please contact: The Registrar, KSNUAHS, Shivamogga Mob: 94808 38958
Email: registrar@uahs.edu.in www.uahs.edu.in

COLLEGE OF VETERINARY SCIENCES AND ANIMAL HUSBANDRY (CENTRAL AGRICULTURAL UNIVERSITY)

SELESHI, AIZAWL, MIZORAM: 796015

UG course (BVSc & AH)

Eligibility:

- ☐ Pass with a minimum of 50% in Physics, Chemistry, Biology/Biotechnology & English
- ☐ 47.5% for SC/ST/PWD/In-service categories
- ☐ Minimum age of 17 years and maximum 25 years

15 PG courses (MVSc)

Courses offered: The PG program facilitates both theoretical and practical applications in Veterinary Anatomy, Veterinary Physiology, Animal Nutrition, Livestock Production & Management, Animal Husbandry Extension, Animal Genetics & Breeding, Veterinary Microbiology, Veterinary Pathology, Veterinary Parasitology, Livestock Products Technology, Veterinary Biochemistry, Veterinary Medicine, Veterinary Public Health & Epidemiology, Animal Reproduction, Gynecology & Obstetrics and Veterinary Surgery & Radiology.

11 PhD courses

PhD program imparts best training to conduct advanced research by strengthening Biochemical, Physiological, Nutritional, Medical, Anatomical aspects of Veterinary Science.

Courses offered: Veterinary Anatomy, Veterinary Biochemistry, Veterinary Medicine, Animal Nutrition, Veterinary Microbiology, Veterinary Pathology, Veterinary Surgery & Radiology, Livestock Production and Management, Animal Reproduction Gynecology & Obstetrics, Veterinary Public Health & Epidemiology and Veterinary Parasitology.

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AGRIVISION 2025

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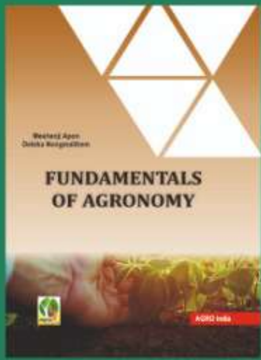

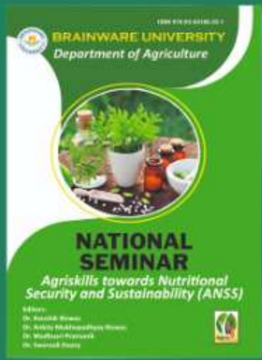

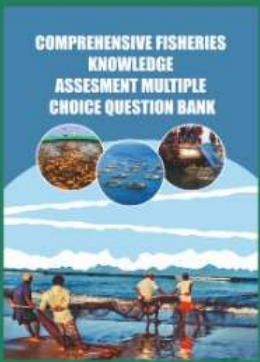

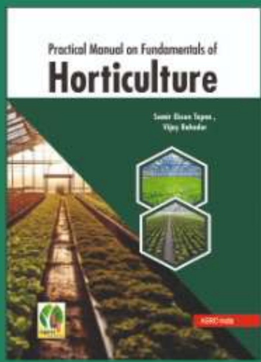

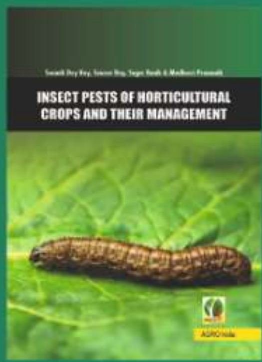

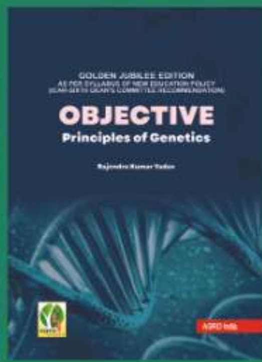

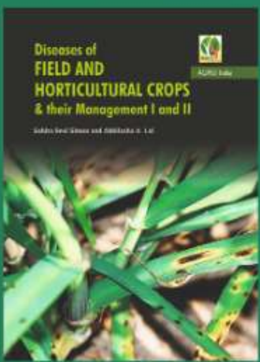

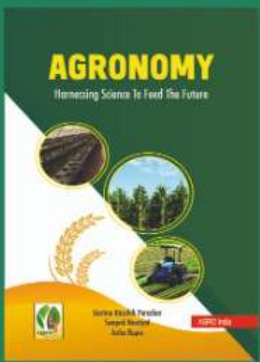

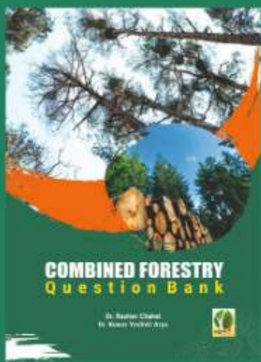

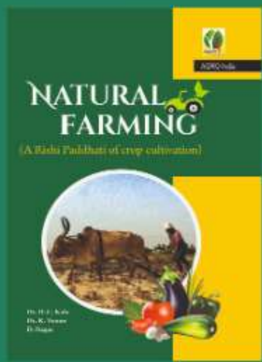

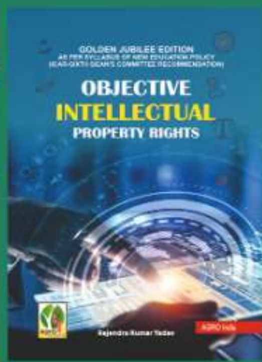

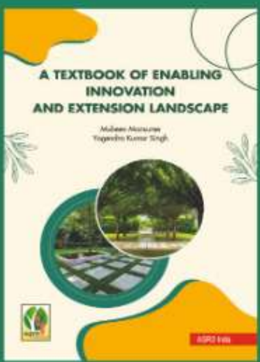

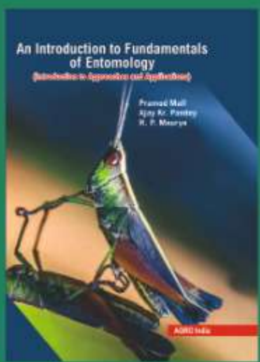

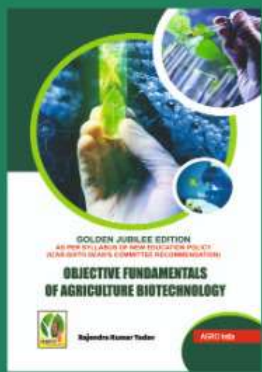

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