

SOUVENIR & ABSTRACTS

AGRIVISION-2026

FIRST ZONAL CONVENTION-EASTERN BHARAT

cum

NATIONAL CONFERENCE

on

"पूर्वोदय कृषि संगम: युवाओं द्वारा कौशल, नवाचार एवं उद्यमिता विकास"

"Purvodaya Krishi Sangam: Skill, Innovation and Entrepreneurship Development by Youth"

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Supported By

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Dr. P. S. Pandey

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No._____/RPCAU (VC)

Date :_13/05/2026__



Message

Dr. Rajendra Prasad Central Agricultural University (RPCAU), Pusa, carries forward a rich legacy of agricultural education, research, and innovation that dates back to the establishment of the Imperial Agricultural Research Institute at Pusa in 1905. Over the decades, this historic institution has played a pioneering role in shaping the agricultural landscape of the country. As an Institution of National Importance, RPCAU remains steadfast in its commitment to advancing scientific knowledge, promoting sustainable agriculture, and empowering the farming community through education, research, and extension. It gives me immense pleasure to extend my heartfelt greetings and best wishes to all delegates, academicians, scientists, researchers, students, entrepreneurs, and progressive farmers participating in the First Zonal Convention – Eastern Bharat cum National Conference, AGRIVISION-2026, organized by Vidyarthi Kalyan Nyas in collaboration with Dr. Rajendra Prasad Central Agricultural University, Pusa.

The theme of this important convention, **"Purvodaya Krishi Sangam: Skill, Innovation and Entrepreneurship Development by Youth,"** is both timely and transformative. Eastern India possesses immense untapped agricultural potential, and the active participation of youth through skill development, technological innovation, and entrepreneurial initiatives will be instrumental in unlocking this potential and building a resilient, self-reliant agricultural economy. At RPCAU, we have consistently pursued excellence in agricultural education, cutting-edge research, and impactful extension activities. Our steady rise in national rankings, along with achievements in patents, copyrights, geographical indications, and technology commercialization, reflects our commitment to innovation and societal advancement. Equally significant are our efforts toward value-based education, youth empowerment, leadership development, and community engagement, all of which contribute to nurturing future-ready agricultural professionals capable of addressing challenges related to food security, climate change, natural resource management, and rural prosperity.

I am confident that AGRIVISION-2026 will provide a vibrant platform for meaningful deliberations on emerging agricultural technologies, climate-resilient farming systems, agribusiness opportunities, and policy innovations for inclusive and sustainable development. I encourage all participants, particularly the youth, to engage wholeheartedly in the discussions, share their ideas, and forge collaborations that will help shape the future of Indian agriculture. I appreciate Vidyarthi Kalyan Nyas and all the organizers for their vision, dedication, and tireless efforts in organizing this landmark event. I wish the First Zonal Convention – Eastern Bharat cum National Conference, AGRIVISION-2026, grand success and hope that it will inspire a new generation of agricultural leaders and innovators.

(P. S. Pandey)

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दिनांक/Date : 11.05.26



Message

It gives me immense pleasure to write this message for the souvenir of the "***First Zonal Convention–Eastern Bharat cum National Conference, AGRIVISION–2026,"*** scheduled to be held during May 16-17, 2026 by the Vidyarthi Kalyan Nyas in collaboration with Dr. Rajendra Prasad Central Agricultural University. The focal theme of the conference, "Purvodaya Krishi Sangam: Skill, Innovation and Entrepreneurship Development by Youth," is highly relevant in the present agricultural scenario, as it encompasses climate-resilient agriculture, agricultural entrepreneurship, AI and digital technologies, crop protection, women empowerment, and nutritional security. Such academic and professional gatherings provide an excellent platform for interaction among students, researchers, scientists, entrepreneurs, and policy makers to exchange ideas and develop practical solutions for the advancement of Indian agriculture.

Agriculture continues to be the backbone of our economy, and it is imperative that we promote sustainable and climate-resilient agricultural practices for ensuring food and nutritional security, environmental conservation, and the prosperity of farming communities. Sustainable agriculture demands the efficient utilization of natural resources, conservation of biodiversity, adoption of modern technologies, and encouragement of innovation-driven entrepreneurship. Conferences like AGRIVISION–2026 play a significant role in inspiring young minds to contribute meaningfully toward the transformation of the agricultural sector through research, skill development, and technological interventions.

I encourage all participants to make the best use of this opportunity for learning, networking, and sharing knowledge that can contribute toward building a prosperous and resilient agricultural ecosystem. I extend my heartfelt congratulations and best wishes to the organizers and participants of AGRIVISION–2026 for the grand success of the convention. I am confident that this significant gathering will provide an enriching platform for meaningful deliberations, knowledge sharing, and valuable learning experiences for all stakeholders.

(D.R. Singh)
Vice-Chancellor

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MESSAGE



It gives me immense pleasure to extend my heartfelt greetings and best wishes to all participants of the "First Zonal Convention – Eastern Bharat cum National Conference, AGRIVISION-2026." is scheduled to be held during May 16–17, 2026 by Vidyarthi Kalyan Nyas in collaboration with Dr. Rajendra Prasad Central Agricultural University, Pusa. The conference theme, "Purvodaya Krishi Sangam: Skill, Innovation and Entrepreneurship Development by Youth," reflects the growing importance of youth participation in strengthening Indian agriculture through innovation, entrepreneurship, and sustainable development.

Agriculture continues to be the backbone of our nation's economy, and empowering young minds with knowledge, skills, and technological expertise is essential for ensuring a prosperous and resilient agricultural future. In this transformation, agricultural education, research, extension services, and digital technologies play a vital role in bridging scientific advancements with farming communities.

Today, agriculture is rapidly evolving through climate-resilient practices, artificial intelligence, precision farming, agri-startups, and market-oriented innovations. Such initiatives provide an excellent platform for students, researchers, scientists, entrepreneurs, and policy makers to exchange ideas, foster collaborations, and explore practical solutions for contemporary agricultural challenges.

I encourage all participants to actively engage in the technical sessions, discussions, and interactive activities during this conference and make the best use of this valuable opportunity for learning and collaboration.

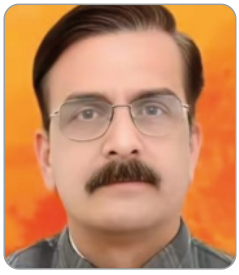
I congratulate the organizing team of First Zonal Convention – Eastern Bharat cum National Conference, AGRIVISION-2026 for this commendable initiative and wish the conference grand success. May this convention inspire new ideas, strengthen partnerships, and contribute meaningfully toward building a sustainable and prosperous agricultural ecosystem for the nation.

With best wishes,

(Inderjeet Singh)

प्रोफेसर रघुराज किशोर तिवारी
(राष्ट्रीय अध्यक्ष अभाविप)
PROF. RAGHURAJ KISHOR TIWARI
(NATIONAL PRESIDENT ABVP)

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Message

It is with immense pride and heartfelt joy that I extend my warmest greetings to all participants, organizers, and stakeholders of the First Zonal Convention – Eastern Bharat cum National Conference, AGRIVISION-2026, scheduled for May 16–17, 2026 is organized by Vidyarthi Kalyan Nyas in collaboration with Dr. Rajendra Prasad Central Agricultural University, Pusa. The focal theme of the convention is "Purvodaya Krishi Sangam: Skill, Innovation and Entrepreneurship Development by Youth" resonates deeply with the vision of our Hon'ble Prime Minister. The future of Indian agriculture lies in the hands of our youth, who must lead the way in natural farming, AI-driven technologies, and climate-resilient practices.

Since its inception in 2015, Agrivision has evolved into a dynamic movement dedicated to the holistic empowerment of students in Agriculture and allied sciences, including Veterinary, Dairy, Horticulture, Fishery, and Forestry. Our mission is to bridge the gap between traditional agricultural education and the demands of modern industry, with a steadfast commitment to integrating digital tools, advanced technologies, and skill development into agricultural learning, championing reforms such as professional degree recognition for agricultural courses and timely recruitment in the sector, and promoting self-reliance and dignity for agricultural graduates.

I urge every participant to engage wholeheartedly in the technical sessions, share innovative ideas, and collaborate in shaping a roadmap for sustainable rural development. Let this convention become a crucible of creativity and a catalyst for enhanced farmer incomes, resilient ecosystems, and a vibrant agricultural future.

I extend my heartfelt appreciation to the organizing committees of Vidyarthi Kalyan Nyas and RPCAU, Pusa, for their tireless dedication. I am confident that this convention will emerge as a resounding success and a beacon of hope for a prosperous.

(Prof. Raghuraj Kishore Tiwari)

दक्षिण बिहार केन्द्रीय विश्वविद्यालय

Central University of South Bihar

(A Central University Established By an Act of Parliament)

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MESSAGE

I am happy to know that the *First Zonal Convention– Eastern Bharat cum National Conference, AGRIVISION-2026* being organized by Vidyarthi Kalyan Nyas in collaboration with Dr. Rajendra Prasad Central Agricultural University, Pusa, during May 16–17, 2026. The focal theme of this convention is "Purvodaya Krishi Sangam: Skill, Innovation and Entrepreneurship Development by Youth".

I extend my warmest greetings and best wishes to all the participants of this First Zonal Convention– Eastern Bharat cum National Conference and I am confident that this convention will provide a great platform to discuss various innovations, entrepreneurship, sustainable agriculture, and youth-led development in the agricultural sector. Agrivision is committed to promoting sustainable and farmer-centric agricultural practices through research, education, innovation, and extension activities. We recognize that agriculture is the backbone of our economy, and climate-resilient and farmer-centric practices are essential for ensuring food security, rural livelihoods, and inclusive growth.

I urge all participants to actively engage in the discussions and workshops and share their ideas and experiences. This convention provides a great opportunity to learn from each other and work towards developing farmer-centric, technology-driven, and sustainable agricultural systems that can significantly benefit our farming community and society at large. As an agricultural student, you are the future of our agricultural sector, and your role in promoting innovation, entrepreneurship, sustainability, and rural development is immensely significant. I hope this convention will inspire you to take up upcoming challenges and contribute to the growth of our nation.

I wish the organizers and participants of First Zonal Convention-Eastern Bharat cum National Conference, AGRIVISION-2026 all the success, and I am confident that this convention will be a great learning experience for all.

Thank you

कामेश्वर नाथ सिंह

(Prof. Kameshwar Nath Singh)

Place : Gaya

Date : 15.05.2026

Lead Papers

Climate Resilient Agricultural Practices in Bihar: Towards Sustainable, Resilient and Climate-Smart Agriculture

Ratnesh Kumar Jha, Abdus Sattar, Sudhanand Prasad Lal, Purbasha Priyadarshani Padhi, Shreya Anand, Sarathi Saha, Digvijay Singh & Manju Devi

Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar

Abstract

Climate change has emerged as one of the greatest threats to global agriculture and food systems, particularly in developing countries where agriculture is highly dependent on climate-sensitive natural resources. Rising temperatures, erratic rainfall, recurrent floods, droughts, heat waves and extreme weather events are adversely affecting agricultural productivity, food security and rural livelihoods. Bihar, one of India's most agriculture-dependent states, represents a highly fragile agro-ecosystem vulnerable to both floods and droughts. North Bihar frequently experiences severe floods due to Himalayan river systems, while South Bihar suffers from recurring droughts and moisture stress. In this context, Climate Resilient Agriculture (CRA) has emerged as a crucial pathway for ensuring sustainable agricultural development, livelihood security and ecological stability. This lead paper highlights the climate change scenario at global, national and state levels and presents the experiences and achievements of the Climate Resilient Agriculture Programme implemented by Dr. Rajendra Prasad Central Agricultural University (RPCAU), Pusa across 11 districts in Bihar. The project facilitated the development of intervention measures such as Water-smart, Nutrient-smart, Carbon-smart, Energy-smart, Weather-smart and Knowledge-smart using a participatory approach. The main interventions adopted by the programme included Direct Seeded Rice (DSR), Alternate Wetting and Drying (AWD), raised bed planting, laser land leveling, zero tillage, crop diversification, residue management, biochar production, and solar-powered irrigation systems. The project led to notable advancements in terms of increased agricultural output, water use efficiency, energy savings, carbon emissions reduction, and adoption of technologies. DSR and laser land leveling proved more productive and profitable, with a high level of irrigation efficiency than the existing methods.

Keywords: Climate change, Climate resilient agriculture, Bihar, Direct Seeded Rice, Sustainable agriculture, Climate adaptation, Water-smart agriculture, Climate-smart technologies

1 Introduction

The problem of climate change is being viewed as one of the major problems facing human beings in the 21st century. The problem of climate change can be seen affecting many areas such as the economy and the agricultural sector. Agriculture is highly dependent on climatic variables such as temperature, rainfall, humidity and solar radiation, making farming systems particularly sensitive to climate variability and extreme weather events. Global warming, erratic precipitation patterns, prolonged droughts, floods, heat stress and changing pest dynamics are already affecting agricultural productivity and food systems worldwide. The Intergovernmental Panel on Climate Change (IPCC) has projected that the global average temperature may increase substantially by the end of this century if greenhouse gas emissions continue at current levels (IPCC, 2021). Climate risks are becoming increasingly complex due to interactions between climatic and non-climatic vulnerabilities. India, with its large agrarian population and dependence on monsoon rainfall, is highly vulnerable to climate change. Indian agriculture is dominated by small and marginal farmers who possess limited adaptive capacity and are highly dependent on natural resources. Increasing climatic uncertainties threaten crop productivity, water availability, soil fertility and livelihood security.

Among Indian states, Bihar represents one of the most climate-sensitive agro-ecological regions, where agriculture is highly vulnerable to climatic variability and extreme weather events. Rising temperatures, erratic rainfall, recurrent floods, droughts and increasing heat waves are posing serious threats to agricultural sustainability, food security and rural livelihoods. This issue affects the smaller and marginal farmers to an even greater degree, as they account for almost 97% of the total farmers in the state of Bihar (Anand et al., 2025). Since these farmers are largely dependent upon the climate-sensitive natural resources available to them along with the lack of technological and institutional support, their exposure to such climate-related risks becomes extremely high. The state of Bihar is characterized by rainfall-based agriculture and farming on a small-scale. Floods in the northern part of Bihar and occasional droughts in the southern part often lead to disruptions in agriculture and make the farmers vulnerable to various climate change-related threats. In order to mitigate the adverse impacts of climate change, Bihar is considered as one of the first states in India to adopt climate-resilience strategies for agricultural development. An important milestone was achieved in February 2016, when scientists and agricultural experts interacted and presented

field-based evidence on climate-resilient crop varieties, conservation agriculture and precision resource management practices. These scientific consultations laid the foundation for developing a comprehensive strategy aimed at strengthening farmers' resilience against climate shocks while improving productivity and resource-use efficiency. Following extensive consultations with leading international and national institutions including Borlaug Institute for South Asia CIMMYT, BISA, CGIAR centres, ICAR-Research Complex for Eastern Region ICAR-RCER, Bihar Agricultural University (BAU) and Dr. Rajendra Prasad Central Agricultural University (RPCAU), the Government of Bihar formally launched the Climate Resilient Agriculture (CRA) Programme across all 38 districts in December 2020.(Sattar et al., 2026) Prior to its state-wide expansion, the programme was initiated as a pilot intervention in eight climate-vulnerable districts—Nawada, Nalanda, Munger, Banka, Bhagalpur, Madhubani, Gaya and Khagaria—in November 2019 (Fig. 1).

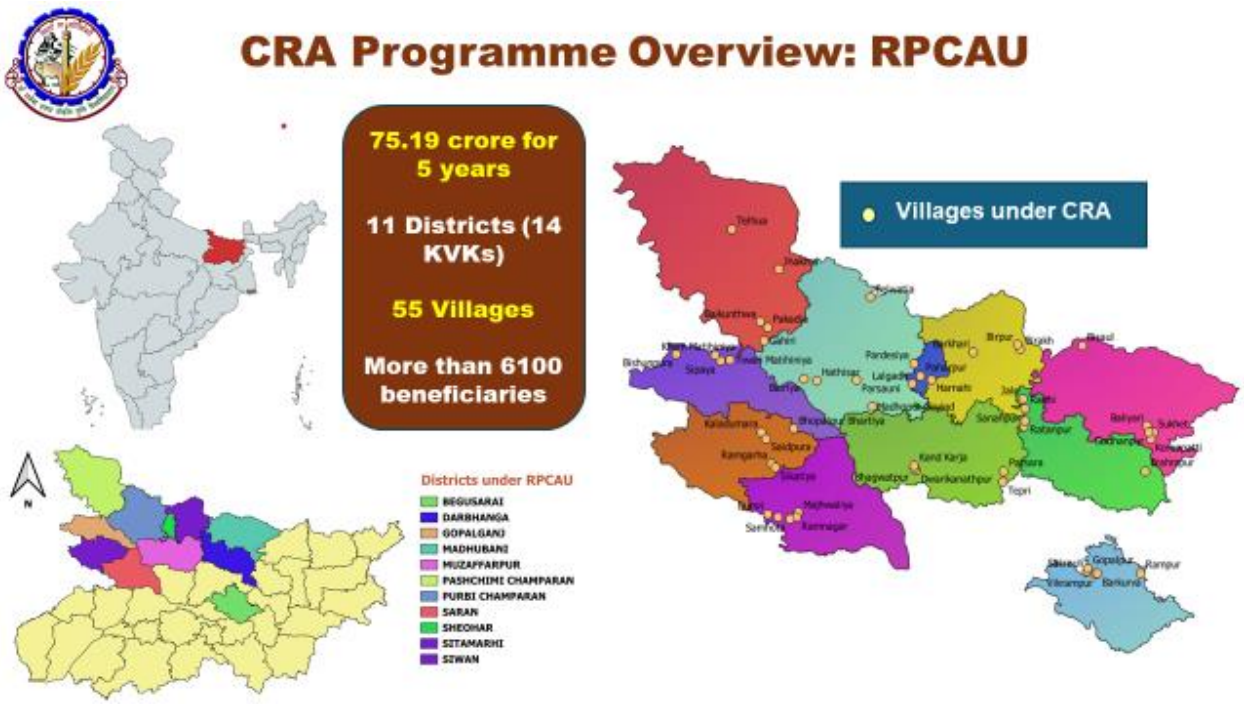


Fig 1: Implementing partners and associated districts under the Climate-Resilient Agriculture (CRA) Programme in Bihar

The CRA Programme was conceptualized to promote sustainable agricultural intensification through climate-smart technologies capable of improving productivity, conserving natural resources and strengthening farmers' resilience under changing climatic conditions. The programme emphasized participatory approaches, farmer-centric innovations and institutional convergence to enhance adaptive capacity at the grassroots level.

2. Climate Resilient Agriculture: Concept and Strategic Importance

Climate Resilient Agriculture (CRA) refers to agricultural systems and management approaches that enhance productivity, strengthen adaptive capacity and reduce vulnerability to climate variability while ensuring environmental sustainability and livelihood security. The concept emphasizes sustainable intensification through efficient utilization of land, water, energy and biological resources while minimizing greenhouse gas emissions and ecological degradation. Globally, climate-resilient and climate-smart agricultural approaches are increasingly recognized as essential for ensuring food security under changing climatic conditions. International organizations such as FAO, CGIAR and the World Bank have emphasized the need for integrated approaches that simultaneously address productivity enhancement, adaptation and mitigation objectives. In India, climate resilience has become an important component of national agricultural policy frameworks including the National Action Plan on Climate Change (NAPCC) and the National Mission for Sustainable Agriculture (NMSA).For Bihar, climate resilient agriculture assumes particular significance because of the state's high exposure to floods, droughts and climatic uncertainties. Sustainable management of water, soil and energy resources is critical for improving agricultural resilience and reducing production risks among smallholder farmers. In this context, technologies promoting water-use efficiency, conservation agriculture, renewable energy utilization and climate-informed farming practices offer significant potential for strengthening agricultural sustainability.

3. Climate Resilient Agriculture Programme in Bihar

Climate Resilient Agriculture Programme, carried out by the Dr. Rajendra Prasad Central Agricultural University, can be seen as an important institutional effort that was made with the purpose of building resilience of farming systems in the face of climate change. The Climate

Resilient Agriculture Programme facilitated the adoption of climate-smart agriculture practices, which fell into several categories, including water-smart, nutrient-smart, carbon-smart, energy-smart, weather-smart, and knowledge-smart technologies. Important interventions included in the climate-resilient programme were direct seeded rice (DSR), alternate wetting and drying (AWD), laser land leveling, raised bed planting, zero tillage, crop diversification, residue management, biochar production, community-based irrigation systems and solar-powered irrigation technology. These interventions were implemented through participatory demonstrations, farmer trainings, capacity-building programmes and field-level extension activities. The programme covered multiple climate-vulnerable districts of Bihar and emphasized convergence among research institutions, extension agencies, local governance systems and farming communities. The integrated implementation of climate-smart technologies contributed toward sustainable agricultural intensification, resource conservation and resilience enhancement in vulnerable agro-ecological regions.

4. Climate-Smart Technologies and Field Experiences

From all the climate-smart interventions being advocated under the CRA programme, water-saving and resource conserving technologies seemed quite promising for increasing agricultural productivity and efficiency along with building resilience during climate stress situations. Among the interventions, Direct Seeded Rice (DSR) appeared quite promising for the production of rice-based systems. In-field observations showed that DSR significantly reduced labour, irrigation requirements, and cultivation cost in comparison to the traditionally transplanted system. The technique allowed crop establishment during the delay in the onset of monsoons and helped reduce methane emissions linked to puddled rice cultivation. Grain yields from DSR averaged at 37.25 q ha^{-1} compared to 34.44 q ha^{-1} from conventional practices, indicating about 8 percent yield increase. Economic evaluation also proved that net economic returns were much higher in case of DSR cultivation system. Another intervention, Alternate Wetting and Drying (AWD), also seemed quite effective for efficient water use in rice production. It resulted in less water usage while not affecting the productivity of crops. Some of the other environmental benefits included improved root development, efficient nutrient use and reduced methane emissions. Profitability under AWD system was also higher compared to continuous ponding (Annual report, 2024).

Laser land leveling and raised bed planting also emerged as important resource-conserving technologies under the programme. Laser land leveling helped in increasing irrigation efficiency by helping with even water distribution and eliminating water stagnation in the fields. This technology contributed greatly to reduction in water usage during irrigation, weed problem and costs of cultivation while boosting crop yields. Raised bed planting technology proved highly beneficial in pigeonpea farming. Raised bed planting boosted the yield of pigeon pea in situations of excess rainfall and water logging. The project further included conservation-based practices such as zero tillage, crop diversification, management of residues and bio-char production. Sustainable management of crop residues through mulching, composting and incorporating straw in the field enhanced soil organic carbon content while minimizing the environmental pollution caused due to burning of residues. Crop diversification became one of the important impacts of CRA in Bihar. The program promoted farmers to shift from traditional crop cultivation involving just rice to growing various other crops like pulses, oil seeds, millets, maize and other high value crops.

The findings indicate that substantial changes occurred in the cropping pattern after implementation of CRA interventions. In the diversified farming system, nearly 24 per cent of the cultivated area shifted towards crops other than rice, including maize, soybean, arhar, millet, and sorghum. In contrast, conventional farming systems remained heavily dependent on rice cultivation, with only about 9 per cent of the area diversified into other crops Field experiences across programme districts demonstrated encouraging improvements in crop productivity, irrigation efficiency, energy conservation and farmer awareness regarding climate-smart technologies. Increasing adoption of DSR, laser land leveling and water-smart interventions reflected growing farmer acceptance and the scalability potential of climate resilient agriculture in Bihar.

5. Impact of (CRA) Programme on Farmers' Livelihoods in Bihar

Impact of Direct Seeded Rice (DSR)

The relative yield performance of different rice varieties under Direct Seeded Rice (DSR) and Transplanted Rice (TP) revealed the superiority of DSR across all tested cultivars. Among the varieties, *R. Masuri-1* recorded the highest DSR yield (43.35 q ha^{-1}) compared to 40.16 q ha^{-1} under TP, while *R. Neelam* exhibited the maximum yield advantage of DSR over TP with a 9.02%

increase. On average, DSR produced 37.25 q ha^{-1} against 34.44 q ha^{-1} under TP, resulting in an overall yield improvement of 8.03%. The findings indicate that DSR not only ensured comparable productivity but also enhanced yield performance under climate-resilient crop management practices.

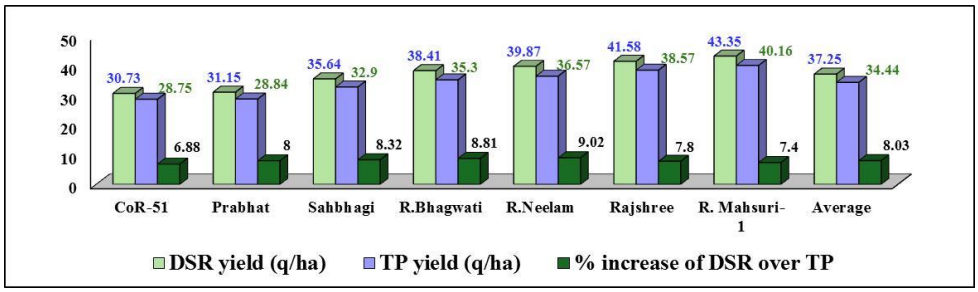


Fig. 2: Relative yield performance (q/ha) under Direct Seeded Rice (DSR) & Transplanted Rice (TP)

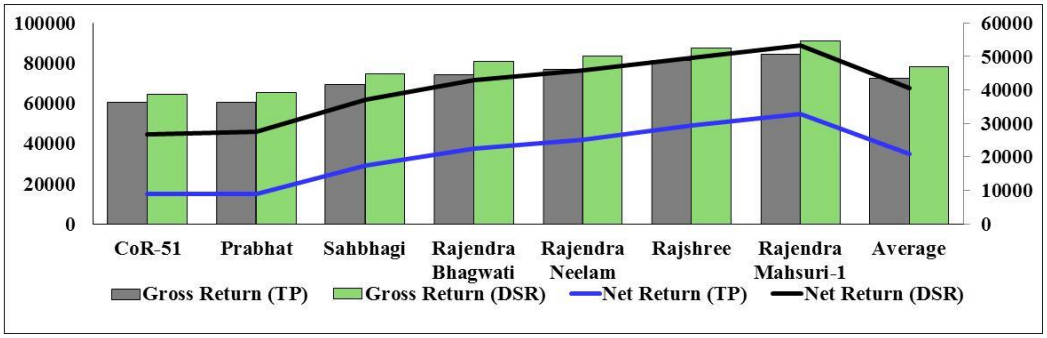


Fig. 3: Relative yield performance (q/ha) under Direct Seeded Rice (DSR) & Transplanted Rice (TP)

Impact of Laser Land Leveling

Laser Land Leveling (LLL) significantly improved irrigation efficiency and crop performance compared to mechanically levelled (ML) fields. In laser leveled field number of irrigation (flood irrigation) reduced by 50% (1) as compared to unleveled fields (2), weed population reduced by 75% in LLL field as compare to ML field, about 17.7% improved yield of LLL field over ML field in Variety CoR-51.

Table 2: Improved irrigation efficiency and crop performance under LLL compared to mechanically levelled (ML) fields

Parameter	Laser Leveled	Mechanically Leveled	Change (%)
Weed Population (No. m^{-2})	1	4	-75
Number of Irrigations	1	2	-50
Yield (q ha^{-1})	35.91	30.52	17.66

Uniform land leveling facilitated efficient water distribution, reduced weed infestation, and minimized irrigation requirement, thereby improving productivity and resource-use efficiency.

Raised Bed Planting and Crop Diversification

Raised Bed Planting (RBP) in pigeon pea showed superior performance over broadcasting method.

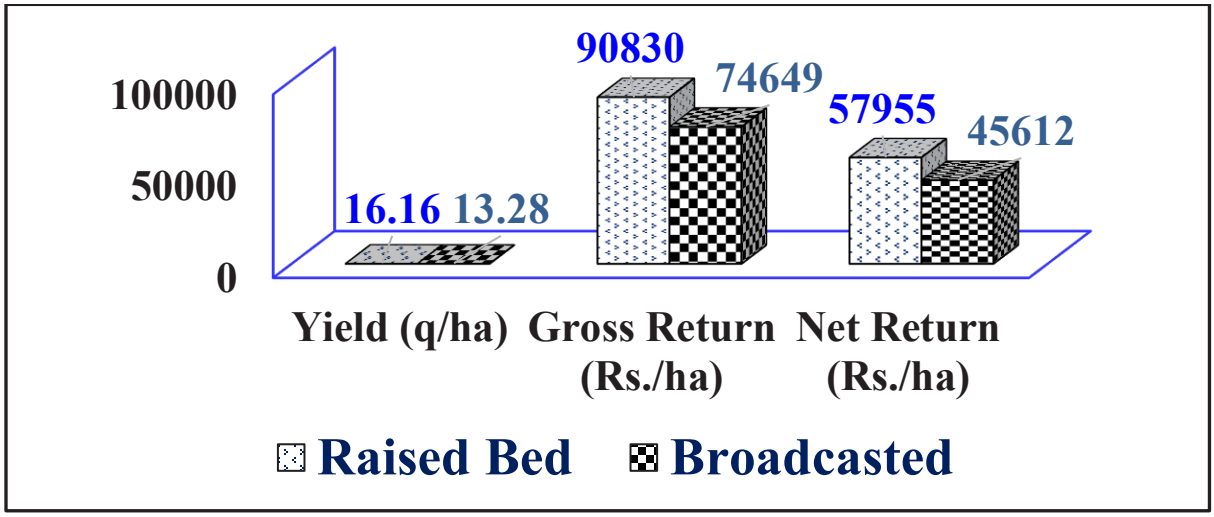


Fig. 4: Yield increase under RBP in pigeon pea

An increased yield of 21.68% under RBP showed the efficiency of improved planting geometries and soil water management.

Crop diversification

Another success in the CRA scheme was the cropping diversification, where approximately 24% of land had been diversified into other crops under the CRA scheme in comparison with just 9% in traditional systems. Diversification enhanced resilience against climate-induced crop failure and improved farm income stability.

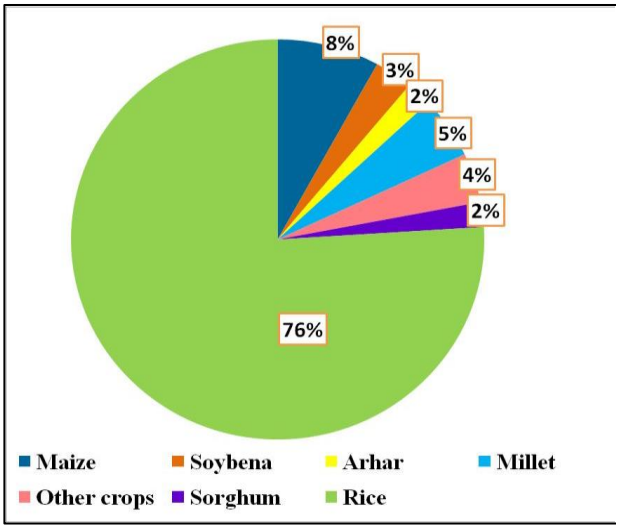


Fig. 5a: 24% area diversified with other crops

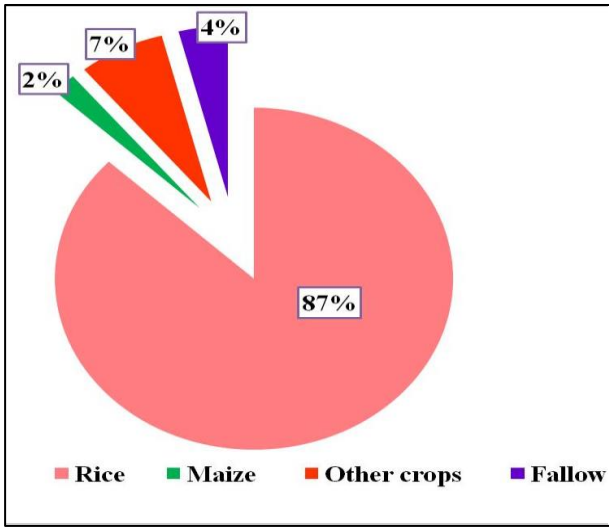


Fig. 5b: 9% area diversified with other crops

Water-Smart Agriculture and Resource Conservation

Water-saving technologies implemented under CRA covered about 1410 ha annually and contributed substantially to water conservation.

Table 3: Water-saving technologies implemented under CRA

Technological interventions	Area (ha)/ year	Total water saving (ha cm)
Direct seeded Rice	380	0.566
Raised bed planting Maize	310	0.112
Raised bed planting Pigeonpea	28	0.112
Maize with Pigeonpea Intercropping	6	0.063
Zero Tillage wheat	331.6	0.265
Raised bed Planting Wheat	130	0.339
Zero Tillage Lentil	112.4	0.070
Zero Tillage of Green gram	112	0.054
TOTAL	**1410**	**1.579**

These interventions improved irrigation efficiency and reduced dependence on groundwater extraction.

Energy and Carbon Savings

Climate-smart agricultural practices significantly reduced diesel consumption and greenhouse gas emissions.

Table 4: Energy consumption and carbon saving through Climate-smart agricultural practices

Parameters	**Area (ha)**	**Before Interventions**		**After interventions**		**Energy / carbon saving (%)**
Energy smart (fuel-Diesel)	1410	**Total consumption (l)**	**Rate of Consumption (l/ha)**	**Total consumption (l)**	**Rate of Consumption (l/ha)**	
		2,53,729.5	179.95	84,600	60	200
Carbon Smart (Gas emission)	1410	**Total emission (kg)**	**Rate of emission (kg/ha)**	**Total emission (kg)**	**Rate of emission (kg/ha)**	
		6,79,972.50	482.25	2,26,728	160.8	200
Nutrient Smart	Soil health improved					
Knowledge Smart	Training/travelling seminar					

(Capacity Buiiding)		

The reduction in fuel consumption and emissions indicates that CRA interventions promoted low-carbon agriculture while improving farm profitability.

Impact on Cropping Intensity and Technology Adoption

The CRA programme significantly enhanced adoption of climate-smart technologies and farm mechanization. Expansion of DSR and laser land leveling was observed not only among CRA farmers but also among non-CRA farmers, indicating strong horizontal spread of technologies.

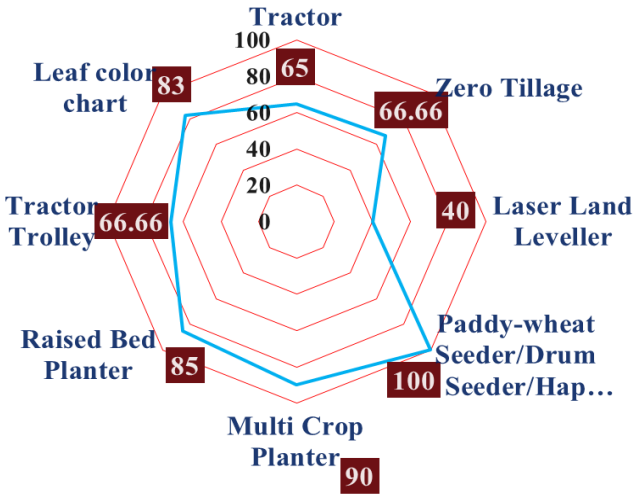


Fig. 7: Increase in Adoption Percentage of technology/farm implements under CRA Programme

Cropping intensity also increased substantially due to assured irrigation, timely sowing, and improved resource management. Water harvesting and recharge structures enabled wheat cultivation in areas where sowing was previously not possible due to moisture constraints.

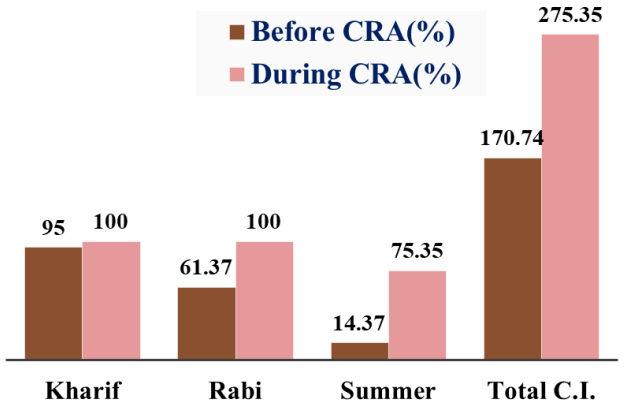


Fig. 8: Cropping Intensity before and after CRA Programme

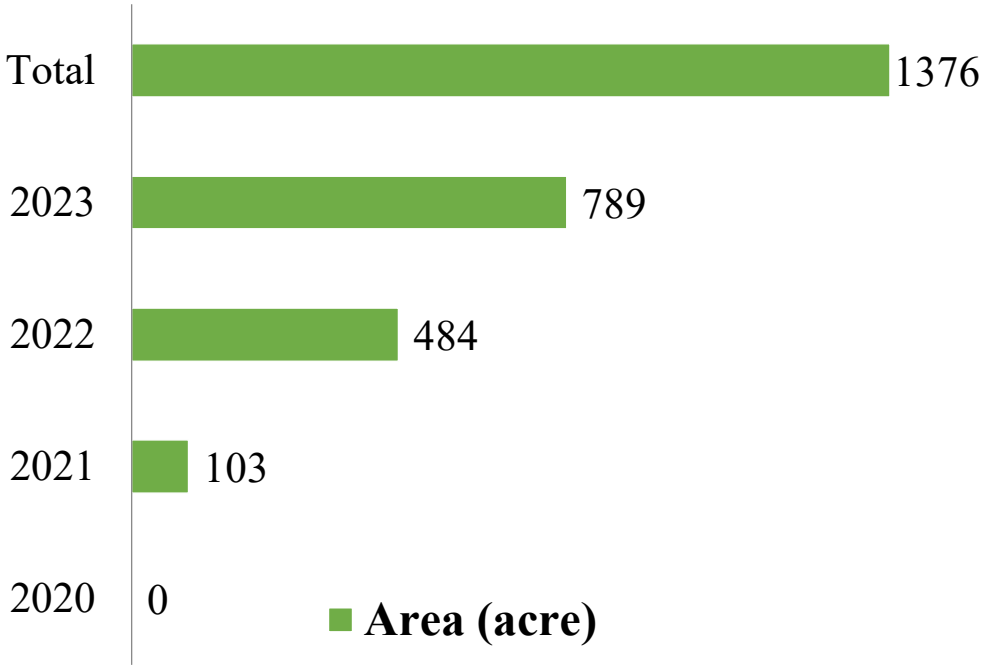


Fig. 9: Expansion of DSR among non-CRA farmers of CRA Villages

6. Emerging Outcomes and Lessons Learned

The introduction of climate-smart interventions under the CRA programme witnessed great achievements in terms of productivity, efficiency in resource utilization, and environmental sustainability within the CRA programme districts. There were marked improvements in rice productivity under the climate-smart interventions compared to traditional farmer methods, whereas intercropping techniques and enhanced agronomic methods were found effective in enhancing yields. The water-smart interventions introduced under the CRA programme witnessed remarkable success in irrigation efficiency and water conservation. Reduced usage of diesel, lesser fuel demands, and reduced carbon emissions were seen as evidence of the environmental sustainability offered by renewable energy and resource-efficient technologies. The project also stressed the significance of participatory extension methods, institutional convergence, and location-specific innovations for fostering climate resilience. The lessons learned from the field showed that climate-smart technologies could not only increase production and profitability but also promote environmental sustainability if implemented with the help of suitable institutions and farmer-focused extension systems. The case study interventions also proved the adaptability of climate-smart agriculture in vulnerable situations. The water harvesting and groundwater recharge facilities constructed in the drought-prone regions made irrigation more accessible and allowed crop cultivation even after experiencing extended dry spells. Likewise, climate-smart agronomic practices like early transplantation of paddy enabled farmers to reduce flood damage to their crops in vulnerable regions.

7. Challenges in Scaling Climate Resilient Agriculture

Despite the promising results of the CRA Programme, there are various issues that have continued to impede the widespread application of climate resilient technologies in Bihar. Small land holdings limit mechanization and effective resource management. The inadequacy of irrigation facilities and agricultural equipment, coupled with the financial limitations of small farmers, has also inhibited the uptake of climate-smart technologies. Information dissemination, weak market linkages, and institutional coordination remain some of the issues influencing climate change adaptation efforts. Poor understanding of conservation agriculture, renewable energy systems, and resource management practices in most areas is another factor limiting the application of climate-smart technologies. Overcoming these barriers necessitates an integrated policy approach,

institutional capacity building, and extension services that enhance access, affordability, and knowledge of climate-smart technologies.

8. Policy Implications and Future Strategies

The scaling up of climate resilient agriculture in Bihar will need to adopt a holistic approach that combines different measures at technology, institutions, and policy levels. Enhanced efforts to build capacity in terms of improving climate information services and increasing weather forecasting initiatives would play an important role in preparing farmers against any climatic adversities. Water-smart technology options, use of renewable energy, and crop diversification that is climate-resilient are some key measures that need to be emphasized. Promoting custom hiring centres, decentralized renewable energy systems, climate-smart village approaches can enhance accessibility of technologies among smallholder farmers. Capacity building and skill development among farmers, rural youth and extension personnel should receive greater policy attention for improving awareness and adoption of climate-smart technologies. The involvement of Farmer Producer Organizations (FPOs), agri-entrepreneurs and rural youth can further accelerate the dissemination and commercialization of climate-resilient innovations. Future strategies should also emphasize digital agriculture, climate advisory services, carbon-smart farming systems and community-based adaptation approaches for strengthening agricultural resilience under changing climatic conditions.

9. Conclusion

Climate change poses a serious threat to agricultural sustainability, food security and rural livelihoods, particularly in climate-vulnerable states such as Bihar. Increasing climatic variability, recurrent floods, droughts and extreme weather events are adversely affecting agricultural production systems and threatening the livelihoods of millions of small and marginal farmers. In this context, the Climate Resilient Agriculture Programme implemented by Dr. Rajendra Prasad Central Agricultural University demonstrates that climate-smart interventions can substantially improve productivity, profitability, water-use efficiency and resilience while simultaneously reducing environmental stress and greenhouse gas emissions. Technologies such as Direct Seeded Rice, Alternate Wetting and Drying, laser land leveling, residue management, conservation agriculture and solar-powered irrigation systems have shown considerable potential for

strengthening agricultural resilience in Bihar. It is clear that climate resilient agriculture is more than just an adaptation approach; it is a means to achieve a sustainable food system, ecological sustainability, and resilient livelihoods amid climate change. It is crucial that such technologies be scaled through proper institutional convergence, policy support, science and technology innovations, and farmer-led initiatives.

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Role of Horticultural Crop Production in Atmanirbhar Bharat

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Horticulture plays a crucial role in achieving food security, employment generation, rural development, entrepreneurship, export promotion, and sustainable resource utilization. Among agricultural sectors, horticulture has emerged as one of the fastest growing and most profitable sectors in India. Horticulture contributes over 30% of the agricultural GDP. This sector has become a major economic engine, with production reaching 362.08 million tonnes in 2024–25, consistently surpassing food grain production despite using only about 13% of the total cropped area (DAFW, 2026). Horticultural crops include fruits, vegetables, flowers, spices, plantation crops, medicinal and aromatic plants, mushrooms, and ornamental plants. These crops contribute significantly to nutritional security, farm income enhancement, agro-industrial development, and foreign exchange earnings. With increasing demand for high-value crops, climate-smart technologies, protected cultivation, precision farming, and value addition, horticulture has become a powerful engine for achieving self-reliance in rural and national economies.

India is one of the largest producers of fruits and vegetables in the world. Diverse agro-climatic conditions enable cultivation of a wide range of horticultural crops throughout the year. Horticulture occupies a comparatively smaller area than field crops but generates much higher productivity and income per unit area. The sector contributes substantially to, agricultural GDP, livelihood security, nutritional security, rural employment, women empowerment, export earnings, agro-processing industries and sustainability. Horticulture has shifted Indian agriculture from subsistence farming toward commercial and market-oriented production systems.

Role of Horticulture in Atmanirbhar Bharat

1. Enhancing Farmers' Income

Enhancing farmers' income is one of the major goals of agricultural development in India and an important objective of the vision of Atmanirbhar Bharat. Horticultural crop production has emerged as a highly effective pathway for increasing farm profitability, improving rural livelihoods, and strengthening the agricultural economy. Compared to traditional cereal-based farming systems, horticulture provides significantly higher returns per unit area, generates year-round income, and creates opportunities for value addition and entrepreneurship. Horticulture includes fruits, vegetables, flowers, spices, plantation crops, medicinal and aromatic plants, mushrooms, and ornamental crops. The sector contributes substantially to agricultural GDP and offers immense potential for income enhancement, especially for small and marginal farmers. Horticultural crops provide higher returns compared to cereal crops due to their greater market value and demand. Cultivation of fruits, vegetables, flowers, spices, and medicinal plants helps farmers earn better income from small and marginal landholdings. Higher profitability strengthens rural livelihoods and supports the goal of economic self-reliance.

2. Employment Generation

Horticultural crop production is one of the most important sectors for employment generation in India. Under the vision of Atmanirbhar Bharat, horticulture plays a vital role in creating sustainable livelihood opportunities, reducing rural unemployment, promoting entrepreneurship, and strengthening the rural economy. Compared to many traditional field crops, horticulture is more labour-intensive and requires continuous human involvement in production, harvesting, processing, packaging, transportation, and marketing activities. The horticulture sector includes fruits, vegetables, flowers, spices, plantation crops, medicinal and aromatic plants, mushrooms, and ornamental crops. Expansion of horticulture not only creates direct employment in farming but also generates indirect employment through agro-based industries, supply chains, export activities, and agribusiness enterprises. Horticulture is labour-intensive and creates large-scale employment opportunities in nursery raising, crop production, processing, transportation and export and retail sectors. The sector provides employment to rural youth, women, and skilled workers. Establishment of nurseries, tissue culture labs, cold storage units, and food processing industries further expands employment opportunities.

3. Nutritional Security

Horticultural crop production plays a fundamental role in ensuring nutritional security, which is an essential component of human health, sustainable development, and the vision of Atmanirbhar Bharat. Nutritional security means ensuring the availability, accessibility, and consumption of balanced and nutritious food required for healthy living. Horticultural crops such as fruits, vegetables, spices, nuts, mushrooms, and medicinal plants are rich sources of vitamins, minerals, antioxidants, proteins, dietary fiber, and other essential nutrients. In India, malnutrition, micronutrient deficiencies, and imbalanced diets remain major public health concerns. Horticulture provides a sustainable solution to these challenges by increasing the availability of diverse and nutrient-rich foods. The sector not only improves food quality but also contributes to better health and nutritionally rich produce. Nutritious crops such as amla, papaya, citrus, leafy vegetables, and drumstick improve health and enhance immunity.

4. Export Promotion

Horticultural crop production plays a crucial role in promoting agricultural exports and strengthening India's economy under the vision of Atmanirbhar Bharat. India possesses immense potential for exporting horticultural commodities due to its diverse agro-climatic conditions, rich biodiversity, availability of quality produce, and year-round production capability. Fruits, vegetables, spices, flowers, medicinal plants, and processed horticultural products contribute significantly to foreign exchange earnings and global trade. Export promotion in horticulture not only increases national income but also enhances farmers' profitability, creates employment opportunities, encourages value addition, and strengthens agro-based industries. With rising global demand for fresh, nutritious, organic, and processed foods, horticulture has emerged as one of the most promising sectors for expanding India's agricultural exports.

Export promotion through horticultural crop production is a vital component of Atmanirbhar Bharat. Horticultural exports strengthen the economy by generating foreign exchange, increasing farmers' income, creating employment opportunities, and promoting agro-industrial development. The sector encourages adoption of modern technologies, quality production systems, and value addition practices. With improved infrastructure, strong policy support, advanced post-harvest management, and international market integration, horticulture can significantly enhance India's global competitiveness and contribute to building a self-reliant,

prosperous, and export-oriented agricultural economy. Export-oriented horticulture increases foreign exchange earnings and strengthens India's position in international markets. Quality production, residue-free cultivation, organic farming, and post-harvest management help Indian products compete globally. Promotion of GI-tagged horticultural crops such as Jardalu mango, Alphonso mango, and Kashmir saffron further enhances export potential.

5. Development of Agro-Based Industries

Horticultural crop production plays a significant role in the development of agro-based industries in India. Under the vision of Atmanirbhar Bharat, agro-based industries are essential for generating employment, promoting value addition, reducing post-harvest losses, increasing farmers' income, and strengthening the rural economy. Horticulture provides a continuous supply of raw materials for various industries related to food processing, pharmaceuticals, cosmetics, beverages, floriculture, and export-oriented enterprises. Agro-based industries convert raw horticultural produce into value-added products with higher market value and longer shelf life. These industries help establish strong linkages between agriculture, industry, and markets, thereby promoting rural industrialization and economic self-reliance. Horticultural production supports numerous agro-industries such as value addition and processing (fruits, vegetables, spices, etc.) and floriculture and landscaping industries

6. Promotion of Entrepreneurship and Startups

Horticulture has emerged as one of the most promising sectors for entrepreneurship and startup development in India. Under the vision of Atmanirbhar Bharat, promotion of horticulture-based enterprises can create self-employment opportunities, strengthen rural economies, encourage innovation, and reduce dependence on traditional agriculture. The increasing demand for fruits, vegetables, flowers, spices, medicinal plants, and processed products has opened new avenues for agri-business and startup ecosystems. Horticulture is highly suitable for entrepreneurship because it requires comparatively lower land area, offers higher returns per unit area, supports value addition, and provides opportunities across the production, processing, and marketing chain. Horticulture offers excellent opportunities for agri-startups and entrepreneurship in areas such as:

- Protected cultivation
- Hydroponics and vertical farming

- Mushroom cultivation
- Organic farming
- Nursery management
- Tissue culture production
- Precision farming
- Drone and IoT-based crop management
- Food processing and branding

Young entrepreneurs are increasingly adopting innovative horticultural technologies, creating self-employment and rural business ecosystems.

7. Efficient Utilization of Natural Resources

Efficient utilization of natural resources is one of the most important aspects of sustainable agricultural development. In the context of Atmanirbhar Bharat, horticultural crop production plays a vital role in conserving and utilizing natural resources such as land, water, soil, nutrients, biodiversity, and energy in an efficient and sustainable manner. Modern horticulture integrates scientific management practices, precision technologies, and climate-smart approaches to maximize productivity while minimizing resource wastage. Horticultural crops are generally high-value crops that provide greater economic returns per unit area and per unit of water used. Adoption of advanced production technologies in horticulture helps achieve higher productivity with lower environmental impact, thereby promoting sustainable agriculture and long-term resource conservation. Modern horticulture promotes efficient utilization of land, water, nutrients, and other inputs through precision farming, protected cultivation, fertigation and water management.

8. Empowerment of Small and Marginal Farmers

Small and marginal farmers constitute the backbone of Indian agriculture. A majority of farmers in India possess small landholdings, limited resources, and restricted access to advanced technologies and markets. In such conditions, horticultural crop production has emerged as a highly effective approach for improving livelihoods, enhancing income, and promoting sustainable rural development. Under the vision of Atmanirbhar Bharat, horticulture plays a vital role in empowering small and marginal farmers by transforming agriculture into a profitable and market-oriented enterprise. Horticultural crops such as fruits, vegetables, flowers, spices,

medicinal plants, and plantation crops provide higher returns per unit area compared to traditional cereal crops. The sector creates opportunities for diversification, value addition, employment generation, and entrepreneurship, thereby strengthening the economic condition of rural households. Small landholders can earn substantial income through intensive horticultural production systems such as:

- High-density orcharding
- Intercropping
- Kitchen gardening
- Integrated farming systems
- Protected vegetable cultivation

Horticulture helps diversify farm income and reduces dependence on traditional low-value crops.

9. Women Empowerment

Women play a vital role in Indian agriculture and contribute significantly to horticultural crop production. Under the vision of Atmanirbhar Bharat, women empowerment through horticulture has become an important pathway for achieving sustainable rural development, economic self-reliance, nutritional security, and social equality. Horticulture provides numerous opportunities for women to participate in income-generating activities, entrepreneurship, value addition, and agribusiness enterprises. Horticultural activities such as nursery raising, vegetable cultivation, floriculture, mushroom production, post-harvest handling, food processing, and medicinal plant cultivation are highly suitable for women because they require skill, precision, and continuous management. Participation in horticulture not only enhances women's economic status but also improves household nutrition, decision-making capacity, and overall social empowerment. With proper training, infrastructure, financial support, and market linkage, horticulture can significantly strengthen women empowerment and contribute to the realization of Atmanirbhar Bharat through inclusive and sustainable rural development.]

10. Reduction of Post-Harvest Losses Through Infrastructure Development

Post-harvest losses are one of the major challenges in horticultural crop production in India. Fruits, vegetables, flowers, mushrooms, and other horticultural commodities are highly perishable in nature and require proper handling, storage, transportation, and processing after

harvest. Under the vision of Atmanirbhar Bharat, reduction of post-harvest losses through infrastructure development is essential for improving farmers' income, ensuring food and nutritional security, strengthening agro-based industries, and promoting sustainable agricultural growth. Post-harvest losses occur due to improper harvesting, inadequate storage facilities, poor transportation systems, lack of processing units, and weak market infrastructure. Development of modern post-harvest infrastructure helps maintain quality, reduce spoilage, extend shelf life, and increase market value of horticultural produce.

Modern infrastructure such as cold storage, pack houses, refrigerated transport, processing units, and smart supply chain systems helps preserve quality, extend shelf life, reduce wastage, and improve farmers' income. Efficient post-harvest management not only enhances economic returns but also strengthens food security, nutritional availability, export competitiveness, and rural employment. With proper investment, technological advancement, and policy support, infrastructure development can transform the horticulture sector into a more resilient, profitable, and self-reliant component of the Indian economy.

11. Climate Resilience and Sustainable Agriculture

Climate change has emerged as one of the greatest challenges to global agriculture. Rising temperatures, irregular rainfall, droughts, floods, cyclones, heat waves, and increasing pest and disease incidences are adversely affecting crop productivity and food security. In this context, horticultural crop production plays a vital role in promoting climate resilience and sustainable agriculture under the vision of Atmanirbhar Bharat. Horticulture provides opportunities for efficient resource management, biodiversity conservation, carbon sequestration, and adoption of climate-smart technologies that enhance agricultural sustainability. Horticultural crops such as fruits, vegetables, spices, flowers, medicinal plants, and plantation crops contribute significantly to environmental stability while improving farmers' income, nutritional security, and livelihood resilience. Modern horticulture integrates sustainable production systems, precision technologies, organic practices, and efficient resource utilization to cope with changing climatic conditions. With proper technological support, infrastructure development, and policy interventions, horticulture can significantly contribute to the realization of Atmanirbhar Bharat by building a resilient, sustainable, and self-reliant agricultural sector.

12. Government Initiatives Supporting Horticulture for Atmanirbhar Bharat

Government initiatives supporting horticulture have played a transformative role in strengthening India's agricultural economy and promoting the vision of Atmanirbhar Bharat. Schemes such as MIDH, NHM, PMKSY, AIF, PM-FME, and Operation Greens have improved horticultural production, irrigation efficiency, infrastructure development, processing, marketing, and export promotion. These initiatives encourage adoption of modern technologies, climate-resilient practices, value addition, and entrepreneurship, thereby enhancing farmers' income and generating rural employment. With continued policy support, infrastructure development, technological innovation, and farmer empowerment, horticulture will continue to emerge as a strong pillar of self-reliant and sustainable agricultural growth in India. Several government schemes promote horticultural development in India such as Mission for Integrated Development of Horticulture (MIDH), PM Formalisation of Micro Food Processing Enterprises (PM-FME), Pradhan Mantri Krishi Sinchai Yojana (PMKSY), Agriculture Infrastructure Fund (AIF), Startup India and Agri-Entrepreneurship Programs, etc. These initiatives support production, infrastructure, processing, marketing, and export promotion.

Challenges in Horticultural Development

Horticultural development in India faces several challenges related to production, infrastructure, marketing, environmental, and technological accessibility. Issues such as small landholdings, climate change, pest and disease incidence, post-harvest losses, weak market linkages, and inadequate infrastructure affect the growth and profitability of the sector. However, through modern technologies, infrastructure development, policy support, skill enhancement, and market reforms, these challenges can be effectively addressed. Strengthening the horticulture sector is essential for enhancing farmers' income, promoting nutritional security, generating employment, and achieving the vision of Atmanirbhar Bharat through sustainable and self-reliant agricultural development. Despite immense potential, the sector faces several challenges such as small landholdings, limited access to quality planting material, climate change impacts, pest and disease incidence, post-harvest losses, lack of cold chain infrastructure, market price fluctuations, inadequate processing facilities. Addressing these challenges through technology, infrastructure, policy support, and farmer training is essential for achieving self-reliance.

Future prospects

The future of horticultural crop production in India is highly promising due to increasing demand for nutritious food, technological advancement, export opportunities, and government support. Horticulture is gradually transforming from traditional cultivation into a modern, technology-driven, market-oriented, and climate-resilient enterprise. In the context of Atmanirbhar Bharat, the horticulture sector has immense potential to strengthen the rural economy, generate employment, and enhance India's global competitiveness. The future of horticulture in India is highly promising due to, rising demand for nutritious food, urbanization and changing dietary habits, export opportunities, technological advancements, digital agriculture and IoT application, protected cultivation and precision farming, growth of food processing industries. Integration of smart technologies, climate-resilient practices, and value-chain development will further strengthen the role of horticulture in Atmanirbhar Bharat.

Conclusion

Horticultural crop production has emerged as one of the most dynamic and promising sectors of Indian agriculture and plays a crucial role in realizing the vision of Atmanirbhar Bharat. The sector contributes significantly to farmers' income enhancement, employment generation, nutritional security, women empowerment, entrepreneurship development, export promotion, agro-industrial growth, climate resilience, and sustainable utilization of natural resources. Due to its high productivity, profitability, and diversification potential, horticulture is transforming Indian agriculture from subsistence farming into a modern, market-oriented, and technology-driven enterprise. The development of horticulture not only strengthens food and nutritional security but also promotes rural livelihoods through value addition, processing industries, protected cultivation, precision farming, and smart agricultural technologies. Horticulture-based enterprises such as nursery management, floriculture, mushroom cultivation, organic farming, food processing, and export-oriented production provide immense opportunities for youth, women, small farmers, and agri-entrepreneurs. In addition, sustainable horticultural practices such as micro-irrigation, integrated nutrient management, organic farming, and climate-smart production systems contribute to environmental conservation and long-term agricultural sustainability. Government initiatives including MIDH, PMKSY, PM-FME, Agriculture Infrastructure Fund, Operation Greens, and Startup India have played a transformative role in strengthening horticultural infrastructure, promoting innovation, reducing post-harvest losses, and improving market access. However, challenges such as climate change,

small landholdings, inadequate infrastructure, post-harvest losses, market fluctuations, pest and disease incidence, and limited access to technology still need focused attention. With continued investment in research, infrastructure development, digital agriculture, cold chain systems, skill development, and market integration, horticulture has the potential to become a major pillar of economic growth and rural prosperity in India. Strengthening the horticulture sector will play a decisive role in building a prosperous, healthy, sustainable, and self-reliant India under the vision of Atmanirbhar Bharat.

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Artificial Intelligence and Digital Technologies for Agricultural Revolution

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1. Background

Agriculture is the prime need of human being for food without which no one can alive. Agriculture is still a profession low profit, human drudgery and dignity in society. The farm mechanization has little bit improve the situation especially in power requirement, however, the monitoring the crop is still completely manual. The crop monitoring includes the judgment by farmers regarding the various requirements such as irrigation, insecticide, pesticide, fertilizer, weeding, etc. The human judgments are completely based on the experience and carries error in judgment which results in crop damage, wastage of resources and money.

Digitization has made revolution in all sectors and made human life comfortable, easier and economical. Digitalization of agricultural activities can judge the exact requirement of the plant with the help of sensors and artificial intelligence for reducing the input cost and enhancing the yield. Further, receiving the requirement of plants on mobile through Internet of Things (IoTs) and automation for management will reduce the time delay. Hence, it can be very much cleared that the application of sensors, artificial intelligence, Machine learning, Internet of Things, automation, etc, cover under the digital agriculture which reduces the cost of input, enhances the yield and hence increases the farmers' profitability.

2. Application of viable principle/methodology in digital technology

Some of the important methods/technology/applications which can be utilized for digital agriculture are elaborated below:

2.1 Sensors and digitalization

The sensor is a device which can measure the physical parameters and can be utilize for decision making. For example, soil moisture meter can measure the real time moisture content of the field and helpful in deciding the irrigation requirement. Digitalization is highly important to utilize the sensor reading in any binary system such as computer or microcontrollers.

2.2 Automation

Automation has played very significant role in enhancing the speed of operation as well as timely operation. It saves the human time and energy which is much valuable. Measuring parameters using sensors is one job and analyzing the measured value through logical based system is second one. Further, acting up on the measured value is the real utilization of sensor measurement. There may be two way of acting, manual or automation. For an example, automatic irrigation system works on the principle of data measured by soil moisture meter. A logic has been fed in the system to switch on the irrigation system if value of moisture meter less than a certain value and off if achieve another defined value.

2.3 Application of Machine learning and deep learning in agriculture

Machine learning and deep learning, two subsets of artificial intelligence, have numerous applications in agriculture, transforming the way of cultivating crops, managing farms and caring live stokes. Machine learning models analyse historical data on weather patterns, soil conditions, and crop types, playing an important role in crop management. This information help the farmers to make data driven decisions so that they can precisely schedule cultural activities such as planting, harvesting, irrigation, and pest control without delay. Consequently, farmers can use their finite resources wisely and can predict future crop yield with high degree of accuracy.

Deep learning provides the ability in agricultural machinery to "see" and "understand" their surroundings through computer vision. These techniques are employed

in weed and pest detection, disease detection, food quality inspection and livestock management. By using computer vision and neural networks, cameras mounted on agricultural machinery can identify and differentiate between crops and unwanted plants, enabling targeted herbicide application and thus reducing its application rate. Moreover, in livestock farming, deep learning techniques helps in disease recognition, optimizing feeding schedules, and monitoring animal health.

2.4 Artificial intelligence

Artificial intelligence is the engineering and technology of making intelligent machines through computer programs. It is a computer technology that enables computers to learn from past records and make decisions like human. The expert systems are the good example where there is an inference engine which collects the write information from knowledge base. The expert system is to be developed by a computer programmer with the help of knowledge experts and can be utilize by a non-expert. The use of artificial intelligence in agriculture is the need of hours where expertise play important role for precise utilization of inputs such as fertilizer, irrigation, pesticide/insecticide etc. Machine is already introduced in the farm which needs to be intelligent to replace the human. For example, an expert system which can judge and suggest the plants requirement based in available soil type, moisture content, weather condition, etc.

2.5 Internet of things

Internet of Things has become the life line of general people. This has significant role in agriculture and allied sectors also. This can mainly be utilized in passing the information from field to mobile hand set which remains in the farmers hand all the time. For an example, any information of crop such as irrigation requirement, fertigation, diseases attack, etc. can be available on mobile application within no time. Not only that, if farmers started the irrigation pumps and may get the information regarding the completion of job. All the sensors data can be called on the mobile and judgment can be taken from anywhere without visiting the field.

3. Application of above methodology for viable technology

3.1 Agricultural drones for spraying and surveillances

Drone is playing important role in agriculture especially in spraying which requires less time and energy. The efficacy of the drone spray is also reported high because of better coverage due to smaller droplets. Operation of drone in autonomous mode has further improves the better application on precise location through the GPS. Various application of drone spraying is shown in Fig. 1.

Furthermore, the surveillance through drone has multiple solutions such as water logging condition, crop health, crop damage and all other requirements as and when needed. The remedial application in the form of spray can also be applied on the effected location with the help of GPS.



Application in paddy



Application in pigeon pea



Application in wheat



Application on mango tree

Fig. 1: Various application of drone for spraying

3.2 IoT based JioKrishi Digital Platform/System

IoT based JioKrishi Digital Platform/System is being installed at farmer's field to assess the efficacy of real-time information such as weather, soil data, water need prediction, irrigation/fertigation management on the mobile of the registered user. In this system, the sensors are installed to measure the soil and weather parameter and analyses through a pre-installed decision support system about the different application needed for different crop in nearby locality.

Registered farmers get advisories on the crops (weather condition, irrigation need, pest attack warning, disease warning, nutrition need etc.) through this digital platform on their mobiles. The view of the installed platform and screen short of the various output screens are shown in Fig. 1 and 2, respectively.



Fig.2: View of Installed IoT based JioKrishi platform/system

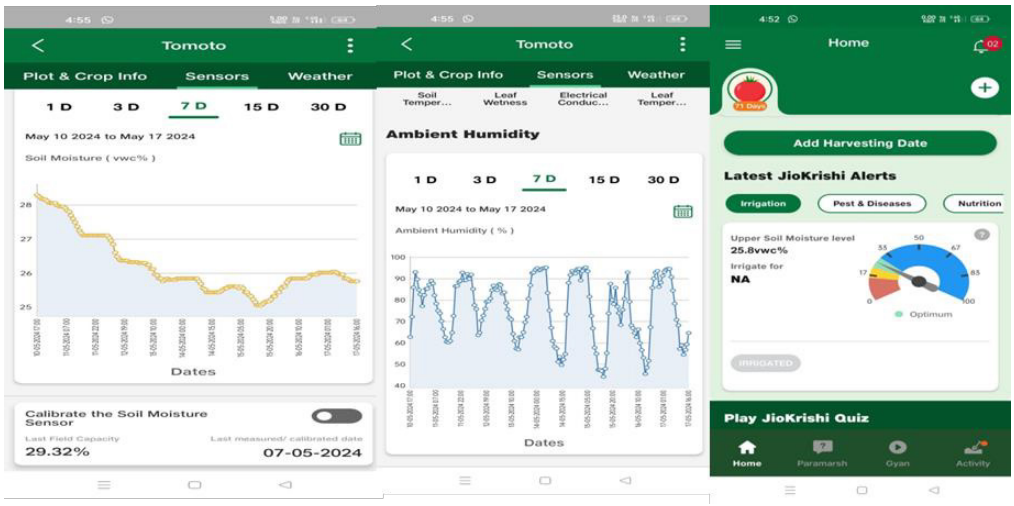


Fig. 3: Screenshot of the various output screens of mobile application

3.3 IoT – based Decision Support System for Disease Forecasting

IoT-based integrated decision support system (DSS) records the real time soil and crop microclimate data. The data gets stored in the cloud database, analysed by the system and a relevant real time crop management practice is suggested to the stakeholder. Primarily, the device and the integrated sensors module record data on temperature, relative humidity, windspeed, wind direction, rainfall, light intensity, soil temperature, moisture level, canopy temperature and vapor pressure deficit. It forecasts various disease incidence, irrigation scheduling, spray scheduling, etc based on the real time data recordings. The Decision Support System module is getting verified with the prevailing disease-pest incidence and the microclimatological parameters. This device fosters the smart horticulture practice through forecasting which facilitates smart crop management. A view of IoT based smart DSS for disease forecasting installed in Banana orchard of RPCAU



Fig. 4: View of IoT based smart DSS installed in Banana orchard of RPCAU

3.5 Digital display of depth and its automatic control

A digital depth display and microcontroller based automatic depth control system for tractor mounted implements is developed (Fig.5) to operate the tractor at required depth of operation. The real time depth of operation, as measured by sensor was temporarily saved as SMD in the microcontroller. Then controller checks that if SMD is more/less than desired limit as set by the operator digitally, the controller sends a signal to rotate the stepper motor by one step for reducing/increasing the depth of operation and then repeat the process from sensing of depth.

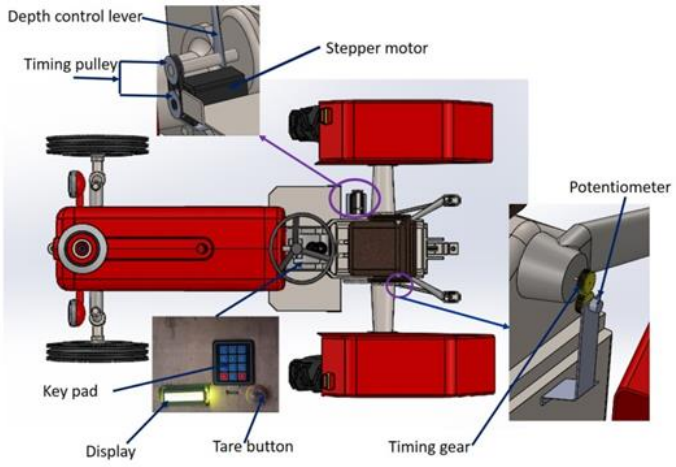


Fig.5: View of instrumentation system mounted on tractor

4. Conclusions

In an era where global population growth and climate change are exerting enormous pressure on agricultural systems, cutting-edge technologies such as artificial intelligence, the Internet of Things (IoT) and sensor fusion technologies are offering innovative solutions to problems such as labor shortages, accurate weather forecasting, soil and crop health monitoring etc. Based on the discussion on various technologies and tools available, it can be concluded that the application of digital agriculture is the need of hour to make the agricultural system simple, comfort and profitable. It is sure that with the application of these technologies, agriculture system will also be a preferred profession and younger generation will attract towards the agriculture. Obviously, this will initiate the capacity building of human in these technologies and organisation responsible in this area has already started the courses to develop trained man power under the headings of digital agriculture.

Crop Improvement: Conventional vs Modern

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Introduction:

Cultivation of crops is started 10,000 years ago at that time the main motive was to domestication of plant for the consumption only because at that time there was no much more population and more environmental hazards that time humans was depended only on the wild relatives.(Rashid *et al.,* 2017) As the time passed the problem come in existence like low yielding, attack of diseases and pest and the and the continuously increasing population size. Crop improvement is a multi-disciplinary scientific endeavor aimed at enhancing the genetic potential of crops plants to achieve higher yield, productivity, better nutritional quality, resistance to biotic and abiotic factors and greater adaptability to diverse agro-climatic conditions(Allard, 1999; Acquaah, 2012). Crop improvement involves the deliberate manipulation of plant genetic architecture through selection, hybridization, mutation, biotechnology, and genome engineering to develop cultivars possessing desirable agronomic traits (Moose and Mumm, 2008). However, it was not possible to cope with the demand of food by using conventional methods of cultivation. There was need to develop new approaches to improve the quality and quantity of yield. As the global world, population is rapidly and alarmingly increasing, new methods have been introduced for better production, improved nutrient content and disease resistant crops. Since start, man has been trying to manipulate different ideas and techniques to save the crops from different diseases by using conventional methods. Unfortunately, conventional methods are no more serviceable towards the current needs. According to Godfray *et al.* 2010) the total food production must be increased by 70% by the year 2050 to fulfil the need of continuously increasing population size and consumption of food for that the conventional methods are not sufficient so in this era of technologies biotechnology opens new horizons in the in the field of science. It is a viable option which can provide improved genotypes that can survive in extreme condition and can give more profit. Incorporation of biotechnology in the crop improvement the multiple approaches are included for the crop improvement like as, Transformation, mutagenesis and recombinant DNA technology, Genetic engineering, molecular breeding, Marker assisted selection, Marker assisted back crossing, genomic selection and CRISPR cas etc.

This chapter will be focused on the comparison of the conventional and modern crop improvement which include the conventional breeding methods and the modern tools and technologies for the crop improvement.

Historical development of crop improvement:

The origin of crop improvement dates back approximately 10,000 years, when early humans transitioned from nomadic hunting-gathering societies to settled agricultural communities (Harlan, 1992). The history of the crop improvement and the plant breeding may be regarded to have progressed through five distinct phases that are briefly discuss blow.

S.no	Phase	Description
1	***First Phase (Domestication)***	Prehistoric humans brought wild plant species under human cultivation. Started began over 11000 years ago. Domestication may be regarded as the most basic method of crop improvement . Still in practice To planned and introduced into a new location of a plant species from another part of the world is an integral part of plant breeding and crop improvement is an integral part of plant breeding and crop improvement today.
2	***Second Phase (Selection)***	Practiced to exploid the natural genetic variation existing in the crop species. Van Mons, Knight, Cooper, Le Couter and Shireff, around 1840, used selection methods, including individual plant selection and progeny test, to develop some useful cereals varieties. Types of selection a) Pure line selection b) Mass selection c) Clonal selection d) Progeny selection
3	***Third Phase (Hybridization)***	Hybridization is major phase for the crop improvement The main feature of this phase of plant breeding is the planned and controlled hybridization between diverse selected genotypes/ varieties to create new and more desirable combinations among the existing gene/alleles. There are two of hybridization occurs **Distinct hybridization** *(hybridization between two distinct species belonging to the same genus or different genera)* **Somatic hybridization** *(Fusion between protoplasts)*
4	***Fourth Phase (Creating Novel Genetic Variations)***	The objective of this phase of creating novel genetic variations not known/ available in crop species. New alleles of exiting genes were created by ***inducing mutations*** using radiation like *X rays, Gama rays,* etc. or chemical mutagens like ethymethane sulphonate etc. ***Somaclonal variations, polyploidy*** was another way to create genetic variations.

5	***Fifth Phase (Genetic Engineering)***	This phase coupled with the development of recombinant DNA technology and genetic engineering which aims at the isolation and cloning of specific useful genes of various organism, and their transfer and expression into plants. This phase has revolutionized the opportunities, in crop improvement since it permits the transfer into the crop plants of genes from any organism or even synthetic genes.

Conventional key methods for the crop improvement:

Conventional crop improvement refers to traditional breeding approaches that rely primarily on phenotypic selection and sexual hybridization to manipulate genetic variability (Acquaah, 2012). The required characters are attained from closely related individuals and incorporated into new cultivars using hybridization (Al-Khayri *et al.,* 2016). Variability in conventional breeding is created through hybridization. Selection based on phenotype is done to identify the most important genotype. Conventional breeding is a longer process and usually takes more than 10 years to release a new cultivar (Bharti and Chimata 2019). Conventional breeding methods, such as hybridization, selection, and mutation breeding, have been the backbone of crop improvement for centuries (E. Akpo *et al.,* 2021). This section highlights the historical significance of these approaches and their ongoing relevance in the development of improved crop varieties with enhanced productivity and resistance to diseases and pests (Eeba B *et al.,* 2012).

Sno	Breeding method	Features and Varieties developed
1	***Pure line***	Pure line selection is a progress in plant breeding where the best individual plant progeny is identified and isolated from a single self-pollinated homozygous plant. Developed by **Danish biologist Johannsen in 1903**. By this method the genetically identical offspring produced and the variation is due to environmental conditions. **Example:** In wheat **NP4** and **NP5** improved by this method
2	***Mass selection***	Mass selection is used for the improvement of local verities, purification of existing pure line varieties, and production of new varieties from heterogeneous local and races. In this method individual plats are carefully chosen based on observable characteristics from a mixed population. This method gives wide adaptability, cost-effective and simple , genetic variability retention. Example: **Tinpakhia, basri and Jaunpur** in maize; **pusa moti, bajri-28-25, bichpuri local and bajra -207** in pearl millet.
3	***Pedigree***	Pedigree method was first outlined by **Love in 1927**. In this method the from F2 generation onwards, individual plants are selected and their progenies are evaluated. In entire process records of the ancestry of selected plant are maintained, which denotes parent to offspring relationships.

		Example: wheat varieties such as **K65, WL711, K68, NP52**, **NP80-5**, and **NP120** emerged through the pedigree approach (Briggs & Shebeski, 1971)
4	***Back crossing***	The backcross involves crossing a hybrid (either the F1 or a segregating generation) with one of its parents. Subsequently, the progeny resulting from this cross are repeatedly backcrossed to the same parent as the F1 hybrid (Aleksoski, 2018) This method has several advantages like as the transfer of the traits, genetic background maintenance, speeding up the breeding programmes and it give more precision. Example: Rust resistance in wheat **(Kalyan Sona)**: Rust resistance was successfully transferred to the wheat variety Kalyan Sona from diverse sources such as **Robin, HS 19**, and **Bluebird.**
5	***Mutation breeding***	Artificial mutations are induced using physical mutagens or chemical mutagens to create novel genetic variability. Mutation breeding has several advantages like as, Creation of novel variability, Improvement without altering genetic background, Useful for oligogenic traits
6	***Polyploidy breeding***	Manipulation of chromosome number to develop polyploid crops with enhanced Vigor and adaptability. **Examples:Hexaploid wheat, Triploid watermelon, Triticale**

Reasons for the shifting on modern methods for crop improvement:

Conventional breeding is over-dependent on phenotypic expressions of cultivars for identifying superior ones. Thus, selected cultivars are not free from errors as phenotypes are highly influenced by genotype by environment interactions (Lema 2018). Conventional breeding is applied science and it leans towards experiences, observations and skills of breeders for judgment (Allard 1961). Conventional selection is dependent on phenotypic expression; only dominant gene are expressed on. Thus, case of conventional breeding only dominant genes can be selected. In traditional breeding, phenotypic selection is difficult because of presence of masking effects. Multiple alleles are difficult to select because their phenotypic expression varies. Although constant breeding is conducted through conventional breeding the results has not bee n effective as they are largely affected by genotype by environment (G*E) interaction. Conventional breeding is more dependent on skills, and subjective analysis of breeder (Lamichhane and Thappa, 2022)

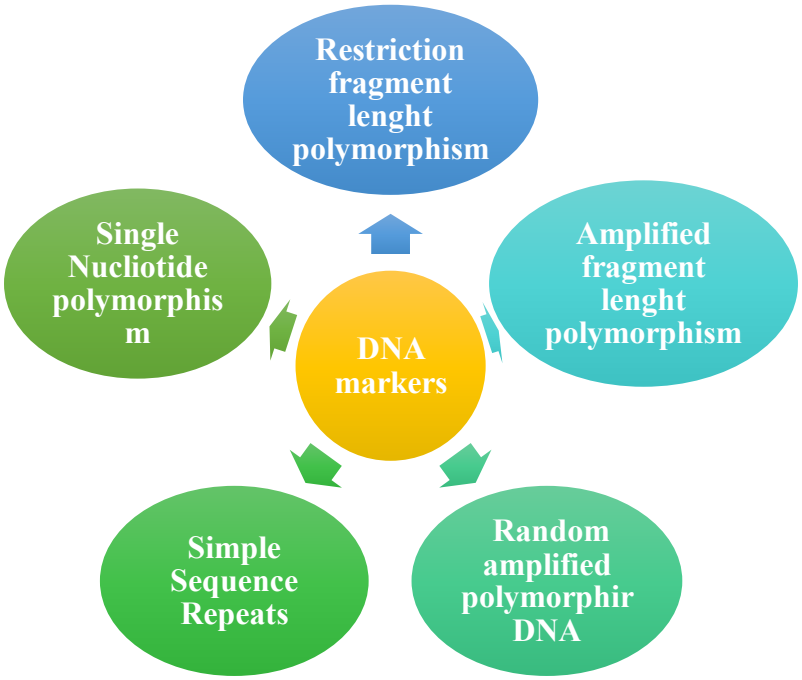
Modern methods for the crop improvement:

For last 20 years modern technologies are being amalgamated with conventional breeding practices. With time the breeding objectives of plants are moving beyond the limits to improve crop yield only. More unique traits like weed resistant, improved nutrition and responsiveness to soil and microbial community are studied robustly. To overcome these unusual goals, conventional breeding is used in combination with other branches of science for thorough study of genomics

(Fu 2015). technologies like Genomic selection, Environics and High Throughput Phenotyping (HTP) are practiced to improve genetic gain of cultivars. These new technologies gave rise to modern breeding. Genomics, Environics and Phenomics are considered to be parts of modern plant breeding triangle (Crossa *et al.,* 2017). Conventional breeding has been using many genetic and molecular techniques that have accelerated the speed of crop enhancement. These modern techniques have been widely used in staple crops like rice, wheat, sorghum, maize, etc. (Ricroch *et al.,* 2014). In order to make breeding programs more effective, efficient and swift, other branches of biology are being integrated into it. As a result, modern specific approaches are being developed for breeding of various plants. Some of these modern breeding methods include:

Marker Assisted selection:

MAS is the method which uses various DNA markers for determining the genomic regions responsible for the expression of desired traits in the plant phenotypes. By the marker the breeding programmes becomes very easily because by these markers the duration of releasing variety has been reduced. Uses of DNA markers are quite popular because they do not harm the phenotypic expression of plant and are affected neither by growing environment not by inheritance (Ashraf *et al.,* 2012). Marker assisted selection is more useful in selecting traits like grains yield, flower colours, seed character, etc. which are expressed only in late reproductive stage, through use of DNA markers such traits can be identified in a genotype even at early stage of plant development. It is most efficient approach while selecting traits that are less heritable, expressive and tedious. However, the method is only effective is case of selecting few quantitive traits which controls notable amount of variation in a population (Shu and Wu, 2016). By the marker assisted back crossing in variety ***PBW 343*** now known as ***Unnat PBW 343*** developed in wheat**.**



Genomic Selection:

Genomic selection (GS) is an advanced breeding approach that selects superior individuals based on genomic estimated breeding values using genome-wide molecular markers. Compared with conventional breeding and marker-assisted selection, GS enables faster and more accurate improvement of complex traits such as grain yield. Unlike linkage analysis and GWAS, GS focuses on predicting the performance of future progenies rather than identifying individual QTLs. It is particularly effective in capturing small-effect genes controlling economically important quantitative traits and serves as a cost-efficient alternative to extensive phenotyping for complex trait improvement (Wang *et al.,* 2018; Robertsen *et al.,* 2019; Sweeney *et al.,* 2019).

Hight thoughtput phenotyping:

High-throughput phenotyping (HTP) has emerged as a transformative and precision-driven platform in modern plant breeding, enabling comprehensive dissection of genotype–phenotype interactions under diverse environmental conditions (Moreira *et al.,* 2020). Unlike conventional visual phenotyping, which is labour-intensive, subjective, and limited in scalability, HTP facilitates rapid, non-destructive, and real-time monitoring of dynamic phenotypic variations across extremely large breeding populations. Advanced HTP platforms are capable of recording temporal shifts in plant architecture, physiological responses, growth kinetics, and stress-adaptive traits in hundreds of thousands of plants within a single day, thereby substantially enhancing phenotyping efficiency and resolution (Rebetzke *et al.,* 2018). The integration of automated sensing systems, robotics, artificial intelligence, and machine learning algorithms has enabled HTP to generate highly precise, reproducible, and multidimensional datasets while significantly minimizing human intervention and experimental bias (Mir *et al.,* 2019). Furthermore, HTP systems employ a wide spectrum of sophisticated imaging technologies, including hyperspectral imaging, thermal imaging, fluorescence imaging, LiDAR, RGB imaging, and multispectral sensors, to capture spatiotemporal variations in crop performance across different developmental stages and environmental scenarios (Pasala and Pandey, 2020). Consequently, HTP has become an indispensable tool for accelerating genomic-assisted breeding, stress physiology studies, and climate-resilient crop improvement programmes by bridging the critical gap between large-scale genotypic data and complex phenotypic expression. For the high throughput phenotyping there are various tools which are listed below:

HTP Tools	Principle/Application	Major Traits Measured
RGB Imaging Sensors	Standard digital imaging using visible spectrum cameras	*Plant height, canopy cover, biomass, leaf area, color, growth dynamics*
Multispectral Imaging	Captures reflectance at specific wavelengths	*Chlorophyll content, nutrient status, NDVI, stress responses*
Hyperspectral Imaging	Acquires continuous spectral information across hundreds of bands	*Disease detection, biochemical composition, photosynthetic efficiency*
Thermal Infrared Imaging	Measures canopy temperature and transpiration patterns	*Drought tolerance, stomatal conductance, heat stress*
Fluorescence Imaging	Detects chlorophyll fluorescence signals	*Photosynthetic efficiency, early stress detection*

LiDAR (Light Detection and Ranging)	Laser-based 3D sensing technology	*Plant architecture, canopy structure, biomass estimation*
3D Imaging Systems	Reconstruction of plant morphology using stereo vision or structured light	*Plant height, leaf angle, organ morphology*
RGB-D Cameras	Combines RGB imaging with depth sensing	*Canopy architecture and volumetric measurements*
Near-Infrared (NIR) Sensors	Detects near-infrared reflectance	*Water content, physiological status*
Unmanned Aerial Vehicles (UAVs/Drones)	Aerial phenotyping platforms carrying multiple sensors	*Field-scale monitoring, growth dynamics, stress mapping*
Ground-Based Phenotyping Platforms	Tractor-mounted or robotic systems	*High-resolution field phenotyping*
Conveyor-Based Phenotyping Systems	Automated movement of plants through imaging chambers	*Controlled-environment phenotyping*
Robotic Phenotyping Systems	Autonomous robots integrated with sensors and AI	*Precision trait acquisition in field and greenhouse*
Satellite Remote Sensing	Large-scale remote crop monitoring	*Crop vigor, stress, productivity*
Machine Learning (ML) Algorithms	Automated feature extraction and predictive analysis	*Trait prediction and classification*
Deep Learning (DL) Models	AI-based image recognition and phenotypic prediction	*Disease identification, yield prediction*
Computer Vision Techniques	Image segmentation and object detection	*Organ counting, canopy analysis*
Internet of Things (IoT) Sensors	Real-time environmental monitoring	*Soil moisture, temperature, humidity*
Environmental Sensors	Monitor microclimatic variables	*Genotype × Environment interactions*
Cloud Computing and Big Data Analytics	Large-scale data storage and processing	*Multi-dimensional phenotypic analysis*
GIS and Spatial Mapping Tools	Spatial variability analysis	*Precision agriculture and field variability mapping*

CRISPR Cas editing:

The CRISPR/Cas9 system is a high-throughput discovery system in cutting-edge genomics, with recent studies reporting extensive use of Cas9 in gene transformation, drug delivery, and knockout mutations based on NHEJ-mediated DSBs (Ahmar *et al.,* 2012). The system detects foreign particles in bacteria and with the use of restriction enzymes these nucleic acids are dissolved (Chen *et al.,* 2019). Mechanism of CRISPE-Cas9 happens in three different steps. At first, the invading foreign DNA is recognized and a spacer sequence from foreign DNA is integrated into host CRISPR array for immunological memory. Then, Cas9 protein is formed and the CRISPR array is transcribed to precursor CRISPR RNA (crRNA). The non-coding pre-crRNA is hybridized to form mature CRISPR RNA (crRNA). Finally, with the help of crRNA and Cas9 protein foreign

nucleotides are identified and cleaved with the help of enzymes. During 2013 the molecular breeding with CRISPR initiated in rice and tobacco. Crop improvement through CRISPR is done either by addition of important genes in plants or removal of harmful genes in rice grain shape affects quality of grains. Gene regulators GW2, GW5 and GW6 have negative effect on grain size. These regulators are disrupted with the use of CRISPR to improve grain quality (Xu *et al.,* 2016). Also, CRISPR introduces disease resistance in plants not only by integrating dominant genes but also by disrupting host susceptibility against biotic stresses. For example, Bacterial blight in rice is caused by *Xanthomonas oryzae* pv. Oryzae. The bacterium initiates the transcription of SWEET genes that increases disease proneness. However, through CRISPR technologies scientists have modified the promoter region of SWEET 11, SWEET 13 and SWEET 14 genes which develops broad-spectrum disease resistance in rice (Oliva *et al.,* 2019).

Comparison on the conventional and modern plant breeding methods:

Conventional Plant breeding	Modern plant breeding
The breeding method is based more on phenotype which created unreliability in determining pure lines of genes	It is genotype-based method of plant breeding which is more accurate in determining the pure gene line.
It is more time consuming to release a new variety	It is comparatively less time consuming to release a new variety.
Variability in conventional breeding is created through hybridization.	Newly used technologies like genomic selection, Enviromics, and high throughput phenotyping are practiced to improve genetic gain of cultivars.
Generally, dominant genes are only selected. The selection of recessive alleles needs to undergo a long procedure.	The recessive alleles can be selected thorough the use of markers and identification of specific sited of gene which is quite shorter procedure than of the conventional.
It is less effective since it depends more on skills, arts, and subjective analysis of breeder. This makes the result less reliable.	Modern plant breeding is more effective and trusted since it is based on scientific research and findings
Conventional plant breeding demands less technical skills and scientific knowledge	In the same place, modern plant breeders are required with more technical skills and genetic science knowledge.
It is less expensive as it can be carried with local techniques and tools.	It is highly expensive as it requires high tech machineries and methodologies.

Conclusion

Crop improvement has evolved from the early domestication and conventional selection of wild plant species to highly advanced molecular and genome-assisted breeding approaches aimed at ensuring global food and nutritional security. Although conventional breeding methods such as selection, hybridization, mutation breeding, and backcrossing have significantly contributed to the development of improved crop varieties, their effectiveness is limited by long breeding cycles, environmental influences, and low precision in the selection of complex quantitative traits. The increasing global population, climate change, emergence of new pests and diseases, and depletion of natural resources have necessitated the adoption of modern biotechnological interventions for rapid and precise genetic enhancement of crops. Consequently, advanced approaches including marker-assisted selection, genomic selection, high-throughput phenotyping, artificial intelligence-based phenomics, and CRISPR/Cas-mediated genome editing have revolutionized crop improvement by accelerating genetic gain, improving selection accuracy, and enabling targeted manipulation of economically important traits. The integration of genomics, phenomics, bioinformatics, and precision breeding technologies is now transforming agriculture into a data-driven and climate-resilient system capable of developing high-yielding, stress-tolerant, and nutritionally enriched crop cultivars for sustainable agricultural production in the future.

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Transforming Aquaculture Systems for Food Security and Aatmanirbhar Bharat

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1. Introduction

Being the fastest growing food-producing sector aquaculture production has increased dramatically over the past five decades reaching 80.0 million tonnes of food fish harvested (FAO, 2018). To maintain per capita fish consumption till 2030, the production of aquaculture needs more. In relation to more production in limited area with less impact of climate change further intensification is needed for sustainable and innovative aquaculture (Godfray et al., 2010). The population of the world is continuously growing and the demand of food are increasing as well. Huge quantities of food are supplied from the capture fisheries (wild fish) from throughout the world. Thus, now a day climate change is creating an adverse impact on fishery production and affecting the livelihood of the fishermen and the availability of food. The fish diversity, habitat destruction and availability of natural food are affected due to rising sea temperatures and fish populations are moving to cooler regions which are disturbing the original place where they have been traditionally caught. Climate changes results in rising temperature that also affect the physiology of fish and bleached coral reefs. Rising temperature and deterioration of coral reefs that is not affecting only fishes, but that is also affecting other part of the ecosystem.

Considering the capture fishery, aquaculture also has a major role in the world, it is not only the protein source for human beings but it also can minimize the burden of capture fishery (natural or wild stock). According to FAO, 2018 it was predicted that 2/3 of seafood consumed universally by 2030 so it can be prevented by focusing on aquaculture. Increasing climate change and continuously growing population to prevent their impact the aquaculture offers environmental mitigation and adaptation opportunities**.** NOAA Fisheries, 2022, the requirement of feed for seaweed and shellfish is little or nothing as compared to fish and the fish require two to eight times less feed than cattle, poultry, and swine which makes climate-smart protein relative to their livestock counterparts.

The impact of climate change in an area of many food-producing resources has been observed throughout the world. Highly populated country such as India which is more vulnerable to climate change and have huge population dependent on fish farming so there is having extreme load on natural resources. The increasing population contributed to climate change due to deforestation (Riphah, 2015) and increasing innovative technology which releases GHGs (greenhouse gases) accumulated in the surrounding environment such as methane, nitrous oxide, fluorinated gases, and carbon dioxide. Among all agricultural food-producing practices, the fisheries one has major significance. The aquatic animal and their farming are much more sensitive to climate alteration.

Aquaculture species will need to adapt or adjust to their continuing global warming or rising temperature as studied by Hoffmann and Sgro (2011). There has been cumulative evidence viz. few aquatic animals can manage increasing temperature by acclimatization through phenotypic plasticity (Salinas et al., 2013). Climate change on the populations who are dependent on fish farming for their livelihood and aquaculture industries need to undoubtedly adopt innovative farming technologies that should be environmentally sensitive. There is another way could be beneficial towards climate resilience that is the implementation of Climate-Smart Aquaculture which gives structure to the resilient system and helps to increase sustainable aquaculture production and incomes, adaptation towards climate alteration and climate change mitigation. Thus the main aim of this article is how enhance sustainable aquaculture production, incomes, adaptation and mitigation towards climate change.

2. New technologies for sustainable production

Technical innovation will also provide some adaptation options, such as the breeding of saline-resistant aquaculture species to confront sea level rise, the development of storm-resistant fish farming systems (e.g. sturdier fish cages) and the strategy to adopt an integrated approach in the farming system. In addition, the perception of scientific invention in integrated fish farming given some possible innovative technologies named re-circulatory aquaculture system, aquaponics, biofloc technology (BFT), cage and pen culture system and integrated multi-trophic aquaculture (IMTA) which have capability to increase the aquaculture production under controlled condition.

2.1. Resilience Fish species for changing climate

Sustainable and ecologically sensitive aquaculture farming is critical in the period of global climate change to fulfill the higher demand for animal protein sources. To the development of aquaculture industries and management strategies for increasing the farmer income through the increasing production the climate smart aquaculture can be implemented in an era of climate change. Climate-smart aquaculture involves climate-resilient species that have a great ability to tolerate high salinity, eurythermal and hypoxic conditions. Some air-breathing fishes such as *Pangasius*, *Channa* species, *Clarias* species, *Heteropneutes fossilis* etc. which are having great market value and have the potential to increase local economies.

There are few species have tolerance capacity in a wide range of salinity and can be used as a climate resilient species which named *Etroplus suratensis* (pearl spot), *Rachycentron canadum*, *Lates calcarifer* (Asian sea bass), and *Mugil cephalus* can be cultured in cages. However some freshwater fishes can be cultured in cages *Heteropneustes fossilis* (Stinging catfish), *Pangasius sp*., *Channa sp*., *Labeo rohita*, *Cirrhinus mrigala*. These species have the ability to withstand in adverse climatic conditions or evolutionary ecology as well as it can be cultured in innovative farming techniques under climate-smart aquaculture like cage and Pen culture systems, Re-circulating aquaculture systems, Biofloc aquaculture systems, IMTA and Aquaponics.

2.2. Re-circulatory Aquaculture System (RAS)

In order to produce more food from the same area of land while reducing the environmental impacts requires more sustainable intensification methods for upholding the food security. (Godfray et al., 2010). The ability to maintain optimal and constant water quality conditions throughout the culture period led to gain more attention for aquafarmers. In this context, Recirculatory Aquaculture System (RAS), which requires limited resource for greater production and provides environment sustainability, has gained significant importance. RAS is used for fish production in indoor tank-based systems where water exchange is limited and the use of biofiltration is required to reduce ionized and unionized ammonia level (Timmons et al., 2005). They can also provide some degree of biosecurity through measures to isolate the stock from the external environment. This system filters the water through a series of biological and mechanical filtration systems and makes it clean for recycling back through fish culture tanks and more than 90% of the water is re-circulated through the culture units (Sugita et al., 2005). In contrast with the conventional method of growing fish outdoors unit, this system rears fish at very high densities in indoor tanks with a "controlled" environment. The major pre-requisite for RAS is clean water,

dissolved oxygen, and optimal temperatures for ensuring proper growth and environment sustainability. Keeping in view of all these, the present review aims to highlight the advantages, challenges and future opportunities of RAS.

Table 1: Major design parameters to benefit RAS

Parameters	Comments
Biosecurity	A risk assessment needs to be carried out that considers factors such as species, potential pathogens, disease susceptibility, location and potential routes of infection. This will lead to decisions on disinfection and other biosecurity measures.
Salinity	This will depend on the requirements of the species, but marine systems have inherently more complex water chemistry and less efficient biofiltration.
Production plan	The use of multiple batches involving staggered stocking and harvesting schedules is normal in RAS to optimise use of resources and maintain reasonably stable biomass
Water flow rates	These may be calculated in relation to biomass has been stocked as to provide a consistent supply of water per minute per kg or stock. Consideration of water velocities in relation to body length can be a useful design parameter
Water quality targets	Typical parameters include suspended solids, dissolved oxygen and carbon dioxide, ammonia, nitrite and nitrate, pH, alkalinity, salinity and temperature need to be set at the design stage to help define performance requirements for treatment equipment
Waste treatment and disposal	The major waste stream from RAS is organic solids which frequently need dewatering and other treatment prior to disposal

In spite of the fact that Recirculatory Aquaculture System (RAS) allows increasing the fish production by many folds using limited resources, the major challenges affecting this industry includes poor management, lack of knowledge about the technology, high investment and occurrence of diseases and pathogens. Several researches are being carried out to improve technical aspect in recirculating loop, efficient use of system byproducts and finding an alternative source of energy. Recent advancement in RAS such as denitrification reactors, sludge thickening technologies and ozone treatments results in minimal use of water, waste discharge and energy use. With greater knowledge about the system and understanding the interaction between its components, this technology has the potential to bring revolution in aquaculture sector in further days to come.

2.3. Biofloc Aquaculture System

The floc bacteria have a main role in keeping the good quality of water in this system and reduce the obnoxious gasses (by nitrification process) which are released from ammonia nitrogen in some hour (Hopkins *et al*., 1995; Hargreaves, 2006). According to Hu *et al*., 2012 revealed that the biofloc system has the advantage of reducing the release of nitrous oxide which is a main greenhouse gas (GHG), this gas is released during the denitrification process, typical in aquaculture systems with a global warming potential 310 times greater than that of carbon dioxide (CO2) over hundred years.

Some ontogenic studies have been done and recorded the thermal history of broodstock and early life stages of fishes at different temperatures and found that stimulated gonadal development at high temperatures (Pankhurst and Munday, 2011). In climate smart aquaculture the broodstock tank or ponds are highly recommended. Biofloc system is another way to culture broodstock with zero or minimal exchange of water and it provides microorganism aggregate as a protein supplement which has the potential to stimulate gonadal development and highest spawning percentage. Biofloc system also reduced the major feed cost (Ogello et al., 2021). Unlike finfish, the earlier studies also revealed the improved reproductive performance of shrimp which is cultured under biofloc (Cardona et al., 2016). It can also be used for the mass production of live feed organisms such as rotifers, copepods, cladocerans, and artemia for the feed of finfish and shellfish fry and fingerlings.

Thus, BFT has emerged as a promising and sustainable aquaculture technique with significant economic and environmental benefits. However, there are still challenges and opportunities for improvement in BFT systems. One area of future research is the optimization of carbon sources for biofloc production. Specific carbon sources can stimulate particular microbial populations, affecting the nutritional properties of the biofloc and fish performance. Therefore, developing strategies for selecting and managing carbon sources are necessary to improve biofloc quality and quantity. Another critical challenge is managing microbial populations. Imbalances in the microbial community can lead to the accumulation of toxic compounds like nitrate and ammonia, leading to negative impacts on fish health and water quality. Therefore, controlling microbial populations and maintaining a balanced community is essential for the successful implementation of BFT. Effective monitoring tools for BFT systems are also necessary to ensure stable and consistent production. Currently, there are limited techniques available to monitor the

microbial community in real-time and detect changes in water quality. Developing accurate and reliable monitoring tools is essential for the successful implementation of BFT. Finally, scaling up BFT systems to commercial production levels is another challenge. Optimizing system design, management practices, and developing economically viable production models are necessary for the successful commercialization of BFT systems.

2.4. Integrated multi-trophic Aquaculture (IMTA)

It is the Integrated farming system of aquaculture species in different trophic levels with the synergistic interaction between the farming species. This is the complementary ecosystem function which permits waste or uneaten feed of one species to recapture by another one or transformed into fertilizers for other crops and takes advantage by the interaction among themselves (Chopin et al., 2001, 2008; Troell et al. 2003; Neori et al. 2004). This farming system was developed or designed to minimize the ecological impact on cages in sea areas (Troell, 2009). The IMTA has three major components one is important culture species which may be finfish or shrimp, the second one is organic extractive such as shellfish (Mollusca/ herbivores) and the final third one is inorganic extractive aquaculture species like as seaweed. In marine ecology, climate change will have major implications and subsequently, aquaculture. De Silva & Soto, 2009 pointed that the species-specific effects have been recorded in marine area and it need to, expend species production as a form of insurance in relation to adaptation prospects under several climatic condition.

Due to diversify nature of IMTA it should be implemented, in some areas of the world where 'incidental IMTA' occurs, and in the nearest location of farms culturing different species (Duarte et al., 2003), the regional aquaculture industries may have greater potential for Resilience. Climate change causes ocean acidification that creates a deleterious impact on Mollusca (shellfish) such as forming thin shells in oysters resulting in low market value and a negative impact on growth, survival, and calcite biomineralization. So IMTA implementation is the way to longer adaptation of bivalve culture. It is suggested that bivalves use a combination of IMTA and genetic breeding strategies to achieve trans-generational acclimatization and increase their resilience to climate change (Tan & Zheng, 2020).

It is however noteworthy that if background levels of dissolved nutrients are too low, overall seaweed production will be limited regardless of local nutrient enhancement from fish

farms (Troell et al., 2003). The same situation would affect particulate matter availability for bivalves as well. Hydrodynamics, including current strength and direction will affect the success of IMTA systems, as this influences the distribution of nutrients and organic particles from the point sources. As the distribution of farm effluents could determine the appropriate orientation and location of the extractive species within the IMTA systems, any offshore IMTA enterprise, especially when natural dissolved nutrient concentrations and particle load are limited at the particular site, should be carefully located. Offshore sites, where prevailing horizontal and vertical currents would transport nutrients and particles away from the reach of the extractive species should be avoided. In general, sites with (1) anthropogenic-induced eutrophication through larger river inputs, (2) atmospheric depositions, (3) upwelling, as well as (4) locations presenting natural eutrophication should be sought after. All these influences can increase nutrient concentrations in offshore waters, stimulating growth of bivalves and seaweeds, i.e., independently from fed aquaculture nutrient enrichment (Buck and Buchholz, 2004; Buck, 2008). For example, the offshore test site for mussel and seaweed cultivation at Roter Sand (17 nautical miles off the coast of Bremerhaven) is in the vicinity of the estuaries of the rivers Elbe and Weser and, therefore, influenced by the river-run nutrient load (Buck, 2007). However, it is important to also understand how such environments may affect fed species, as these may not be optimal for fish growth.

2.5. Aquaponics

It is the type of re-circulatory aquaculture system that allows the production of fish as well as plants and this technique became widespread earlier. Aquaponics is based on integrated multi-trophic recirculating aquaculture, the fertile water from the culture fish tank is used for the farming of vegetable plants, or in other ways it is the transfer of the minerals from fish culture tank to hydroponics. It also decreases the use of water (Rakocy, 2012; Turcios and Papenbrock, 2014). Aquaponics is an innovative idea and it is one of the re-circulatory systems integrated with ornamental fish as well as cultivated crops such as vegetables, medicinal herbs, etc. that creates surplus profits and allows shelter for fish. According to Campos et al., (2020) in India, some of the ornamental fishes are prone to climate change and said that it would create species-specific impairments in metabolic pathways. It is the technique having associated activities of fish culture and vegetable farming in closed and controlled conditions. The losses from irregular weather patterns can be avoided from this process and also can increase food production.

2.6. Cage and Pen Aquaculture System

Cage culture is the fish farming system that can be installed in an open water body or some quantity of water area enclosed from all sides with the HDPE net having some preferred mess size depending on the size of fish species to be cultured. Climate change adaptation to increase fish production, the setup of cages in open water resources is another way and it can be implemented under different climatic conditions. Food web or preferred food items for fish are being destroyed due to climate change in the natural water body which is decreasing the productivity and quality of fish. For the installation of a cage, some criteria should be necessary for increasing the production of fish such as selection of site, candidate species (suitable species), size and materials of the cage, health management and good feed conversion ratio feed. Considering the changing climate the selection of fish species is very important aspect or climate resilience fish species should have tolerance capacity under low oxygen, high temperature, wide fluctuation of salinity, regional preference and great market demand. Some of the climate-resilient species named *Mugil cephalus*, *Pangasianodon hypophthalmus* (Pangas), *Lates calcarifer* (Asian seabass), *Rachycentron canadum* (cobia), and *Etroplus suratensis* (Pearl spot) are cultured in cages. However in freshwater cages *Heteropneustes fossilis* (stinging catfish) *Pangasius sp*., *Labeo rohita*, *Cirrhinus mrigala*, *Channa sp*.

Pen culture is also a type of enclosure culture system the only difference it has a fixed bottom and is installed in a low-depth area and it has the advantage of facilitating the natural food base for the fish. Some of the research institute has established or undertaken climate-resilient pen culture system in Assam, West Bengal, and Kerala wetland for the conservation and farming of commercially important high-valued fishes. Climate resilient cage and pen systems (CRPS and CRCS) used HDPE nets to bear flood and wind action for farming resilient indigenous fish species.

2.7. In-Pond Raceway System

The flow through raceway production systems is evolved from earthen ponds. Earthen ponds were then replaced with a wooden or concrete structure to avoid the soil erosion that happens in earthen raceways (Fornshell et al., 2012). Then also the major disadvantages of raceway were the demand for a huge volume of water and the release of organically rich water to nature (Masser, 2012). Hence, an advanced raceway system named In-pond raceway system (IPRS) has been developed by the U.S. Soybean Export Council (USSEC) as a technique for increasing fish production with reduced environmental effects. It is an effective intensive aquaculture practice for

regions with high water consumption and limited land resources (Li et al., 2019). In general, the IPRS system integrates the benefits of four aquaculture technologies: recirculation systems, raceway models, cage farming and pond aquaculture systems. The principle of IPRS is to aggregate fed fish into cells or "raceways" inside a pond and provide them with a continuous circulation of water to maintain optimum water quality and improve feed management. It also can minimise the loading of solid waste in the pond by concentrating and eliminating it from the downstream end of the raceway units. As in the case of other intensive culture practices, IPRS also has the threat of disease and in addition, the system needs electricity backups for continuous and smooth running.

2.7. *Neo female technology*

It is another farming technique by the culture of either all females or male in systems which have higher demand, growth rate, and food conversion ratio. There are some fish species are suitable for mono-sex culture such as for all female carp, salmon and all male *Macrobrachium resenbergii* (Male grow faster than female) tilapia which have recorded higher growth. Neo female technology, it is produced from sex reversal of male which produce all male offspring, this technique basically done through RNA interference methods and removal of androgenic gland (Amir, 2013). It has several advantages such as production raised two fold, higher growth and better food conversion ratio.

However, the leading aquaculture fish species show sexual dimorphism for traits such as growth, age at sexual maturity etc. in which one sex outperforms the other, increasing the need for controlling sex-ratio in the farming system. Despite the huge contribution of aquaculture to global fish production, it is facing a lot of challenges, for example, maintaining the genetic purity of the fish species and balancing the sex-ratio in the culture system. Many of these difficulties arise due to a lack of deep understanding of fish genetics, or to the duplicated genome of cultured species, or to the unavailability of high-quality reference genomes and information on sex determination mechanisms (crucial for monosex production and establishing appropriate breeding programme). It is thereby needed to go over the possible strategies for identifying sex-determining gene/s using modern genome sequencing and computational technologies so as to anticipate that developments in genome sequencing technologies will help to address the biological complexities and challenges

that exist in commercial aquaculture and will be of value for the future growth of the aquaculture industry in the world.

3. Conclusion

Climate change is certainly not a forthcoming event, but it is a current issue what the entire world is witnessing. The major action points include the adoption of methodologies to reduce the already happened unprecedented changes and the other one is to avoid further addition to the already existing negative impacts. Aquaculture being one among the topmost contributor and fastest-growing food sector; the scientific interventions in the concept of integrated farming has resulted in many viable advanced technologies such as Integrated multi-trophic aquaculture (IMTA), aquaponics, biofloc technology, recirculatory aquaculture systems (RAS) and raceways so as to adopt the best method of culture, taking into account the need as well as the sustainability.

In spite of several advantages, the system of aquafarming practices likely BFT, RAS, aquaponics etc. is yet to reach to the large section of the people mostly because of lack of expertise, higher initial investment and high operating cost of running. Most of the systems are limited to developed countries currently using for either brood stock management or in nursery rearing. Researches are being carried out by the scientists to minimize the operational cost and find suitable species for production. Thorough research and deeper understanding are required to understand the micro ecosystem of the practices and interaction of various component of this species to face the challenges in the future.

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THEME: -1

Climate Resilient Agriculture, Aquaculture and Livestock Farming

Climate-Resilient Potato Seed Production through Apical Rooted Cuttings in Bihar

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ABSTRACT

Potatoes, considered the third most important food crop globally, are a major crop for both food security and income generation in many tropical countries. Traditional seed potato production systems have been copied over the decades with minimal success. The prevalence of soil-borne and viral diseases build-up over several generations of seed propagation coupled with prolonged seed storage at warm ambient temperatures are major constraints of potato. Poor farmers bear the high transportation costs and pay high seed prices. To make matters worse, the high price does not guarantee high quality, thus making it difficult for small and marginal farmers to invest such a large sum in seed purchases, which accounts for nearly half of the total cost of production. The amount of potato tuber seed produced is a small fraction of the actual seed requirements, the cost is prohibitive, and seeds of the desired cultivars are often not available at the right time. Seed importation fills a small gap in the seed requirements of wealthier farmers in some countries. ARC technology is a way to produce high-quality seed potatoes, which would benefit major potato production areas. ARC technology allows seed producers to produce large quantities of seed potatoes from a relatively small piece of land. This is achieved through strict field hygiene and intensive pest and disease control. They have a faster regeneration potential and are true-to-type. It is critical to maintain the mother plants in a juvenile simple rounded leaf state, and then the apical cuttings would develop into excellent ARC for transplanting into the field. Potato apical rooted cuttings (ARC) have been developed using tissue culture techniques. Originating from juvenile simple rounded leaf mother plants, it is a significant new way of transplanting and field growing seed potatoes under field conditions in tropical and sub-tropical regions. Mini tuber production of ARC has been achieved in both substrate and aeroponic systems. ARC mini tubers of ARC have resistant to biotic and biotic stresses. These high-quality ARC, along with improved cultivars, have markedly improved yields under field conditions. The ARC revolution is bringing a great deal of excitement and the promise of prosperity to remote and resource-poor communities. The aim of the climate-resilient agricultural programme on potato isto disseminate the ARC technology among the farmers in Bihar for self-sufficiency and upscaling potato seed production.

Keywords: Apically Rooted Cuttings, Tissue Culture, Juvenile Mother Plants, Potato Seed Production, Food Security

A Study on Herbal Preparations as Fly Control Measures on Jersey Crossbred Cattle

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ABSTRACT

The study was done on 20 Jersey crossbred dry cows (10 animals in two groups, viz. first control and second fly control measures group) at cattle yard, Eastern Regional Station, National Dairy Research Institute, Kalyani, West Bengal, India, during the year 2017-2018. In second group, some herbal mixture was tied on the neck of animals that act as fly repellent. Animals have tendency to exhibit some fly repelling behaviors (i.e., head throws, leg stamps, kicks, skin twitches, ear flicks and tail flicks). The animals were observed at 10 minutes interval till 2 hours (2 min. per animal) morning and afternoon during the dry period. It was found that frequencies of fly-repelling behaviors were highly dependent on fly population. The animals in first group showed more responses as compare to second group. Head throws and leg stamps were less frequent than skin twitches and tail flicks. Cows that stamped more tended to have lower fly population as compare to other fly-repelling behaviours. Therefore, in conclusion, cattle differed in fly population differed in these behaviours. Hence, fly control measures by herbal preparations could be an environmentally friendly management practices for maintaining the dairy cattle and a step towards environmental stewardship for sustainable livestock production.

Keywords: Herbal Mixture, Fly Repelling Behaviour, Herbal Preparations, Environmentally Friendly

Biophysical Determinants and Spatial Modelling of Makhana Cultivation Suitability in the Kosi Region Using Machine Learning-Assisted RS–GIS Analysis

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ABSTRACT

Makhana (*Euryale ferox*), a significant aquatic crop predominantly cultivated in Bihar, India, contributes to regional agriculture but remains underexploited in terms of its economic potential. The productivity of Makhana is influenced by various climatic and biophysical factors, necessitating the precise identification of suitable cultivation zones to optimize yield and resource use. This study aims to delineate the potential Makhana growing areas in the subtropical ecosystem of the Kosi region, specifically Purnia East in Northeastern Bihar, using Multi-Criteria Evaluation (MCE) integrated with Remote Sensing (RS), Geographic Information System (GIS), and machine learning techniques.The cultivation season was determined by analyzing Moderate Resolution Imaging Spectro-radiometer (MODIS) time-series data from February to August 2023. The Analytical Hierarchy Process (AHP), a multi-criteria decision-making (MCDM) tool, was employed within the RS-GIS framework to assess and weight nine critical factors influencing Makhana cultivation suitability: slope, soil texture, drainage, land use, pH, electrical conductivity (EC), soil organic carbon, sodium adsorption ratio (SAR), residual sodium carbonate (RSC), and total iron (Fe) content.Each spatial layer was assigned priority weights using the AHP method, and the layers were linearly combined to generate a comprehensive suitability map. The biophysical characteristics of these zones featured moderate drainage, gentle slopes (0-1%), and normalized difference vegetation index (NDVI) values ranging from 0 to 1, indicating healthy vegetation cover.This approach facilitates informed decision-making by enabling site-specific crop planning and management strategies for farmers, agricultural planners, and policymakers. The adoption of these findings can promote sustainable Makhana production, enhance regional agricultural productivity, and contribute to the local economy. The generated suitability map offers a valuable tool for optimizing land use and improving crop yield by identifying areas with favorable climatic and bio-physical conditions in the study area. Future work should focus on integrating socio-economic factors and validating the suitability map with ground-truth data to strengthen the applicability of this methodology for broader regional planning and crop diversification.

Keywords: Makhana cultivation, Kosi region, RS& GIS, Machine Learning, MCE and AHP

Carbon Bio fixation by *Tetraselmis striata*

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ABSTRACT

Tetraselmis striata is a promising marine microalga with significant potential for carbon capture and sustainable bioproduct development. It exhibits a CO_2 bio fixation rate of approximately 293 mg/L/day, efficiently converting atmospheric and industrial carbon dioxide into biomass via photosynthesis. The species is rich in proteins, lipids, and omega-3 fatty acids such as eicosapentaenoic acid (EPA), making it suitable for applications in aquaculture feed, nutraceuticals, and biofuel production.Additionally, T. striata produces natural phytohormones that function as bio-stimulants, enhancing plant growth and stress tolerance. The residual culture medium remains nutrient-rich and can be reused as an organic liquid fertilizer, supporting a circular bioeconomy. Its ability to grow in wastewater enables simultaneous carbon sequestration and nutrient removal, contributing to environmental remediation.Recent advancements in biotechnology, including genetic engineering, CRISPR-Cas systems, metabolic engineering, and synthetic biology, offer opportunities to enhance growth rate, lipid productivity, CO_2 fixation efficiency, and stress tolerance. Integration with advanced photobioreactors and wastewater-based cultivation systems further improves scalability and reduces operational costs.Despite challenges such as high cultivation and harvesting expenses, these innovative strategies can significantly enhance commercial feasibility.*Tetraselmis striata* holds strong potential as a sustainable platform for integrating carbon capture with the production of high-value bioproducts, contributing to climate change mitigation and the advancement of a green bioeconomy.

Keywords: *Tetraselmis Striata*, Carbon Capture, Bio Fixation, Wastewater Treatment, Biotechnology, Bio Economy

Theme 1: Climate Resilient Agriculture, Aquaculture and Livestock Farming

Effect of Jeevamrit application on water quality parameter, growth and immunity of *Labeo rohita* (Hamilton, 1822) fingerling

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Abstract

Aquaculture faces growing challenges in sustaining productivity while minimizing environmental impacts associated with excessive use of chemical fertilizers. Jeevamrit, a fermented liquid organic formulation prepared from cow dung, cow urine, jaggery, pulse flour, and soil, has gained prominence in natural farming systems due to its eco-friendly nature and ability to enhance microbial activity and nutrient recycling. A 90-days experimental trial was conducted to assess the effect of jeevamrit on the growth indices and water quality parameter for *Labeo rohita*. Fingerlings (7.75±0.10 g) were stocked in 21 tanks (500 L) across seven treatments, consisting of a control group (without Jeevamrit application) and six Jeevamrit treatment applied at concentrations of 0.05, 0.25 and 0.5ml L^{-1}, with application intervals of 7 days and 14 days. The data were analysed using two-way ANOVA and the results were expressed as mean ± standard error. Water quality parameters remained within optimal ranges for carp culture, with dissolved oxygen levels maintained between 7.314±0.06 to 7.57±0.047 mg L^{-1}, pH ranging from 8.951±0.041 to 8.1±0.54, and alkalinity fluctuating between 199.32±0.54 to 326±0.743 mg L^{-1}. Weight gain (%) and specific growth rate, were significantly higher ($p < 0.05$) in Jeevamrit-treated groups, with the highest growth observed at 0.5 mL L^{-1} applied at 7-day intervals, with values of 111.20 ± 1.65 and 0.83 ± 0.01 % day^{-1}, respectively. These findings suggest that Jeevamrit application effectively stimulates growth without compromising the aquatic environment, presenting a potent method for the sustainable development of low-input aquaculture systems.

Keywords: Jeevamrit, microbial activity, eco-friendly, sustainable development.

Pseudomonas putida- As a potential microbe in Bioremediation

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ABSTRACT

Environmental contamination from industrialization, agricultural runoff, and urban waste disposal has resulted in the accumulation of harmful substances including hydrocarbons, heavy metals, pesticides, and synthetic dyes in soil and water. These pollutants do not disappear on their own and can seriously harm entire ecosystems. Conventional chemical and physical cleanup methods are expensive and often produce harmful side effects, pushing scientists toward cheaper, safer alternatives - bioremediation and phytoremediation - which use microbes or plants to remove harmful pollutants. *Pseudomonas putida*, a Gram-negative aerobic bacterium found in soil, water, plant roots, and oil spill sites, has emerged as one of the most exciting organisms for microbial bioremediation. It survives extreme conditions including high temperatures, nutrient scarcity, and heavy metal stress, and can utilize many diverse toxic compounds as food including naphthalene, hydrocarbons, pesticides, and aromatic compounds. Its degradation ability is driven by enzymes - monooxygenases and dioxygenases - encoded on specialized circular DNA called catabolic plasmids. These enzymes break down BTEX compounds -benzene, toluene, ethylbenzene, and xylene - into harmless carbon dioxide and water. Remarkably, these catabolic plasmids undergo horizontal gene transfer to neighbouring bacteria, spreading degradation capability across microbial communities. *P. putida* also secretes siderophores that bind and immobilize heavy metals like lead, cadmium, and hexavalent chromium, preventing groundwater contamination, and forms biofilms on contaminated surfaces, massively increasing degradation efficiency. Despite exceptional laboratory performance, real-world application is challenging due to competition from native microflora, pollutant inaccessibility in soil, unpredictable environmental changes, and strict regulations around genetically modified organisms. These problems can be solved through smart biotechnological solutions - adaptive laboratory evolution produces tougher strains without genetic engineering; biochar encapsulation using rice husk protects bacteria from competition; rhizosphere-assisted bioaugmentation merges plant and microbial remediation into one low-cost strategy; and biosensor-integrated strains provide real-time monitoring without expensive laboratory equipment.

Keywords: *Pseudomonas putida*, Monooxygenases, Dioxygenases, Catabolic Plasmid, BTEX Compounds, Horizontal Gene Transfer, Rhizosphere-Assisted Bioaugmentation, Biosensor

Enhancing Climate Resilient Agriculture through Nutrient-Enriched Vermicompost: Comparative Analysis of Substrates and Enrichment Techniques in Kosi Region, Bihar

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ABSTRACT

Declining or stagnating crop yields in India, compounded by climate variability and the mounting challenge of municipal and agricultural wastes, underscore the urgent need for sustainable nutrient recycling strategies that not only improve soil health but also enhance climate resilience. Climate-resilient agriculture is critical for ensuring food security amid changing environmental conditions, as it promotes adaptive management practices that maintain productivity while reducing vulnerability to stresses such as drought, erratic rainfall, and soil degradation. Vermicomposting (VC) emerges as a viable approach to convert organic residues into stabilized, nutrient-rich soil amendments that support resilient agricultural systems by improving soil structure, nutrient availability, and microbial activity. This study aimed to develop standardized maturity and stability indices for agricultural waste-based VC enriched with rock phosphate (RP) and phosphate-solubilizing bacteria (PSB), and to evaluate nutrient composition and enzymatic activities under Agro-climatic Zone II of the Kosi region, Bihar, India. Windrow vermicomposting was conducted using *Eisenia fetida* (2 kg t^{-1}) with substrates of cow dung alone or a 40:60 agricultural waste: cow dung mix, with or without RP (5% P_2O_5, w/w) and PSB (100 mL t^{-1}). The study highlights the importance of developing standardized enzyme-based maturity and stability indices to better assess compost quality and functionality. Future research should focus on large-scale agronomic trials and economic analyses to validate the efficacy and cost-effectiveness of these enriched vermicompost's in diverse cropping systems. Integrating vermicomposting into broader climate-resilient agricultural frameworks can promote sustainable nutrient management, reduce reliance on chemical fertilizers, and strengthen the resilience of farming communities to climate change impacts.

Keywords: Vermicompost, Stability, Nutrient content, Substrates, Enrichment techniques and Kosi Region

Development and Evaluation of a Microbial Consortium for Enhancing Growth and Productivity of Finger millet under Calcareous Soil Conditions

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ABSTRACT

Finger millet (*Eleusine coracana* L.) is an important millet crop cultivated in marginal and calcareous soils of Bihar, where productivity is often limited by poor nutrient availability, imbalanced fertilizer use, and declining soil biological activity. Conventional fertilizer-centric approaches have shown limited success in sustaining crop performance under such soil conditions, highlighting the need for biologically driven nutrient management strategies. In this context, calcium solubilizing bacteria (CSB) in association with cyanobacteria offer potential for improving nutrient mobilization, rhizospheric activity, and plant growth through microbial-mediated processes.A field experiment was conducted during Kharif 2025 at the research farm of Dr. Rajendra Prasad Central Agricultural University using ragi variety RAU-8 on calcareous soil. Seven treatments comprising graded levels of NPK with $ZnSO_4$ and $FeSO_4$, alone and in combination with CSB and cyanobacteria, were evaluated to understand the role of microbial inoculation in improving crop growth, physiological traits, yield attributes, and soil enzyme activity. The integration of CSB with cyanobacteria, either alone or in combination with reduced fertilizer doses, consistently enhanced plant growth at both 30 and 60 DAS, improved tillering, and positively influenced root and shoot development compared to control and fertilizer-only treatments. Treatments involving CSB showed better performance in yield-contributing traits such as ear heads per plant and overall plant Vigor. Enhanced chlorophyll content and improved alkaline phosphatase activity of soil under CSB-based treatments indicated improved physiological efficiency and rhizospheric biological activity.The study demonstrates that CSB-centered microbial consortia can play a significant role in mobilizing nutrients, improving plant growth dynamics, and supporting productivity of ragi in calcareous soils. Such biologically integrated nutrient management practices provide a sustainable alternative to sole dependence on chemical fertilizers for millet cultivation in Bihar.

Keywords: Fingermillet, Microbial consortium, biofertilizers, Calcareous soil, Cyanobacteria

Long-Term Effect of Conservation Agriculture on Soil Physical Properties in Rice–Maize Cropping System

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ABSTRACT

Soil physical degradation caused by intensive tillage and residue burning is a major challenge to sustainable crop production in the rice–maize cropping systems of the eastern Indo-Gangetic Plains (IGP), particularly under calcareous soils. Conservation agriculture (CA)-based practices are considered an effective approach to restore soil health and improve sustainability; however, long-term information on their effects on soil physical properties in calcareous soils remains limited. Therefore, a 17-year field experiment was conducted to evaluate the impact of CA-based tillage, crop establishment, and residue management practices on soil physical properties under a rice–maize cropping system. The experiment consisted of four treatments in a randomized block design: (T_1) zero tillage direct-seeded rice followed by zero tillage maize with residue retention, (T_2) permanent bed direct-seeded rice followed by permanent bed maize with residue retention, (T_3) permanent bed direct-seeded rice followed by permanent bed maize without residue retention, and (T_4) puddled transplanted rice followed by conventionally tilled maize.The results revealed that conservation agriculture treatments significantly ($P< 0.05$) improved soil physical properties compared to conventional tillage (T_4), with the maximum improvement observed under permanent bed planting with residue retention (T_2). Compared to T_4, T_2 reduced bulk density by 12.75% and 12.16% after rice and maize harvest, respectively. Similarly, water-stable aggregates increased by 51.90% and 49.73%, porosity by 17.02% and 15.69%, gravimetric moisture content by 49.97% and 54.33%, and volumetric water content by 29.89% and 36.19% after rice and maize harvests, respectively.Overall, the study demonstrated that long-term conservation agriculture, particularly permanent bed planting with residue retention, significantly improves soil physical propertiesin calcareous rice–maize systems of the eastern Indo-Gangetic Plains, thereby supporting sustainable crop production and resource conservation.

Keywords: Conservation agriculture, Soil physical properties, Calcareous soils, Rice–maize system, Residue retention

Harnessing Plant–Microbe Interactions for Climate-Resilient and Sustainable Agriculture

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ABSTRACT

Agriculture is increasingly challenged by climate change, soil degradation, and the rising demand for food production, necessitating sustainable and resilient approaches. Plant–microbe interactions offer a promising eco-friendly strategy to enhance crop productivity while maintaining soil health. Beneficial microorganisms such as plant growth-promoting bacteria (PGPB) and mycorrhizal fungi play a crucial role in improving nutrient uptake, modulating phytohormone levels, and protecting plants against pathogens through mechanisms including antibiotic production, siderophore synthesis, quorum quenching, and induced systemic resistance.Symbiotic associations, particularly nitrogen-fixing rhizobia and phosphate-solubilizing microbes, significantly contribute to nutrient cycling and enhance plant tolerance to abiotic stresses such as drought and salinity. Advances in metagenomics and other omics technologies have enabled a deeper understanding of microbial diversity and functional potential, facilitating the identification of efficient bioinoculants suitable for diverse agro-ecosystems.The application of microbial biofertilizers and biopesticides can reduce dependency on chemical inputs, thereby restoring soil fertility, conserving biodiversity, and supporting climate-resilient agriculture. However, challenges such as inconsistent field performance, limited shelf life of inoculants, and low farmer awareness hinder their large-scale adoption.Integrating microbial biotechnology with traditional sustainable agricultural practices can bridge this gap and promote long-term agricultural sustainability. Therefore, harnessing plant–microbe interactions represent a vital approach toward achieving ecological balance, economic viability, and global food security under changing climatic conditions.

Keywords: Plant–microbe interactions, climate-resilient agriculture, PGPB, biofertilizers, metagenomics

Role of Teat Sealant in Improving Udder Health and Reducing Mastitis in Dairy Cattle

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ABSTRACT

India has one of the largest cattle populations globally, with approximately 192.49 million cattle as per the 20th Livestock Census (2019). Mastitis leads to substantial economic losses due to reduced milk yield, deterioration of milk quality, increased treatment costs, and premature culling of affected animals. In India, the annual economic loss due to mastitis is estimated to approx □7,500 crores,also there is antimicrobial resistance (AMR)has become a critical concerned in management of mastitis.A total of 12 pregnant cows which were about to dry during third trimester randomly selected and were divided into two groups, each group consisting of 6 animals, The control group were not given any treatment during the dry period while the treatment group treated with teat sealant (Novadip)during the dry period.The results revealed that the incidence of mastitis was highest in the control group (45.83%), whereas it was significantly reduced in the treatment group (20.83%). Significant difference was observed in SCC (324.46 ± 63.48) $\times 10^3$ Cells/ml, EC (5.027 ± 0.512 mS/cm), pH (6.78 ± 0.15),and CMT scores in the Novadip treated group compared to the control group. However, no significant differences were observed in physiological and haematological parameters. It may be concluded that the use of teat sealant is effective in reducing the incidence and severity of mastitis.

Keywords: AMR, Dairy cattle, Mastitis, Novadip, Teat Sealant, Somatic cell count

Effect of Stubble Bio Decomposer and Irrigation Levels on Growth Parameters of Indian Mustard (*Brassica juncea*)

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ABSTRACT

A field experiment was conducted during the *rabi* season of 2024-25 at Pusa farm, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, to study the Effectof stubble bio-decomposer and irrigation scheduling on growth parameters of Indian mustard (*Brassica juncea* L.) variety Rajendra Suflam. The experiment was laid out in a strip-plot design with three replications. The vertical plots consisted of three irrigation levels: **I_1**- no irrigation, **I_2**- irrigation at pre-flowering stage, and **I_3**- irrigation at pre-flowering + siliqua formation stage. The horizontal plots comprised four stubble management treatments with bio-decomposer: **S_1**- retention of 30 cm rice stubble without spray, **S_2**- one spray of bio-decomposer at 7 days before sowing (DBS), **S_3**- two sprays of bio-decomposer (7 DBS + at sowing), and **S_4**- spray of 0.5% urea at 7 DBS + one spray of bio-decomposer at sowing on 30 cm rice stubble.Results revealed that irrigation scheduling significantly influenced all growth parameters. The treatment **I_3** recorded significantly highest plant height, leaf area per plant, dry matter production, and number of branches per plant at all growth stages (30, 60, 90 DAS and at harvest) compared to I_2 and I_1. Among bio-decomposer treatments, **S_4** (0.5% urea spray at 7 DBS + bio-decomposer spray at sowing) produced significantly superior growth attributes over S_3, **S_2**and S_1. The interaction effect of $I_3 \times S_4$ exhibited the maximum values for plant height, leaf area, dry matter accumulation and branching pattern throughout the crop growth period.The study concluded that integrated application of irrigation at critical growth stages (pre-flowering and siliqua formation) along with combined use of 0.5% urea and Pusa bio-decomposer on rice stubble significantly enhanced the vegetative growth of Indian mustard by improving soil moisture availability, nutrient release and microbial activity. This combination holds promise for sustainable mustard production in rice-mustard cropping systems of Bihar.

Keywords: Indian mustard, Bio-decomposer, Irrigation scheduling, Rice stubble management, Growth parameters

Effect of Foliar Application of Iron and Zinc at Different Growth Stages on Growth, Yield, Quality, and Economics of Lentil (*Lens culinaris*Medik.)

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ABSTRACT

A field experiment was conducted during the Rabi season at the IFS Unit, Dr. Rajendra Prasad Central Agricultural University, to evaluate the effect of foliar application of iron and zinc at different growth stages on growth, yield, nutrient content, and economics of lentil (*Lens culinaris*Medik.) cv. 'IPL-316'. The experiment comprised seven treatments with three replications laid out in a randomized block design. The results revealed that foliar application of micronutrients significantly influenced growth, yield attributes, quality parameters, and economic returns of lentil. Among the treatments, application of RDF along with foliar spray of $ZnSO_4 \cdot 7H_2O$ (0.5%) + $FeSO_4 \cdot 7H_2O$ (1%) at both pre-flowering and pod-development stages (T_7) recorded significantly higher plant height, number of branches plant^{-1}, dry matter accumulation, crop growth rate, and number of nodules plant^{-1} at 90 DAS and at harvest.The same treatment also resulted in superior quality parameters, recording the highest protein content in grain (22.4%) and straw (11.4%). Economically, T_7 registered the maximum gross return (□99,917 ha^{-1}) and net return (□61,277 ha^{-1}). However, the highest benefit: cost ratio was observed under T_4 [RDF + $ZnSO_4 \cdot 7H_2O$ (0.5%) + $FeSO_4 \cdot 7H_2O$ (1%) at pre-flowering stage] with a B:C ratio of 1.82, which remained statistically at par with T_7 (1.80) and T_5 (1.68).The findings indicate that combined foliar application of iron and zinc at critical growth stages enhances nutrient utilization efficiency, crop productivity, and profitability in lentil. Such micronutrient-based foliar management practices can also serve as a climate-resilient strategy by improving crop vigour, physiological efficiency, and tolerance against abiotic stresses under changing climatic conditions.

Keywords: Lentil, Foliar Application, Iron and Zinc Nutrition, Yield and Quality, Economic Returns, Climate-Resilient Agriculture

Impact of Soil Carbon Sequestration on Sustainable Agriculture

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ABSTRACT

Millions of rural households in India are guaranteed food and a stable income by the country's agriculture sector. In Indian farming systems, soil carbon sequestration has emerged as a crucial strategy to improve soil health, agricultural output, and climate resilience. Climate, soil type, and the amount and quality of organic inputs all affect how much carbon may be stored in a particular soil. The soil organic content (SOC) is determined by the interplay of several elements. A key tactic for sustainable agriculture is soil carbon sequestration (SCS), which stores atmospheric CO_2 as soil organic carbon to improve soil health, productivity, and resilience while reducing climate change. Conservation tillage, organic amendment application, cover crops, crop rotation, crop residue management, and integrated nutrient management are examples of sustainable practices that enhance soil structure and water retention, ultimately boosting production. Soil carbon sequestration is significantly impacted by sustainable agricultural management methods. The impact on carbon sequestration of integrated nutrient management, organic amendment, no-tillage, crop rotation, residue retention, intercropping, and biochar, as well as the contributing elements and related economic advantages. In order to create resilient agricultural systems that will support livelihoods and productivity in the face of environmental and climatic change, carbon management in soils will be a crucial part of climate, soil health, and food security strategies.This strategy is a fundamental component of sustainable soil management, which aims to preserve and improve general soil health for agricultural productivity and serve as a CO_2 storage. Nonetheless, soil carbon sequestration is an essential, mutually beneficial tactic for sustainable agriculture that both lowers atmospheric CO_2 and boosts agricultural output, so mitigating climate change. It improves soil structure, nutrient cycling, and water retention by raising soil organic matter (SOM), which in turn increases agricultural yields and resilience to climate extremes.

Keywords*:* Carbon sequestration, Soil carbon, Soil health, Climate change, Sustainable agriculture

Economic impact of Climate Resilient Agriculture in Bihar

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ABSTRACT

Bihar's vulnerability to climate change is driven by limited forest cover, dependence on rainfed agriculture, high crop yield variability, lack of crop insurance, and weak healthcare systems. Other major factors include widespread poverty, small landholdings, low women's workforce participation, poor road connectivity, and ineffective implementation of MGNREGA, which together reduce the state's adaptive capacity. The most vulnerable districts to climate change in Bihar includes majorly Araria, Kishanganj, Purnia, Jamui, Sheohar, Madhepura, Purbi Champaran, Lakhisarai, Siwan, Sitamarhi, Khagaria, Gopalganj, Madhubani and Buxar as these districts are having lack of area under horticulture crops, low coverage of central crop insurance schemes, low adaptive capacity amount to major drivers of vulnerability in these districts. The Implementation of climate-resilient technologies—including direct seeded rice, zero tillage, laser land levelling, alternate wetting and drying irrigation systems, and precision nutrient management tools—generated substantial environmental and economic benefits. Irrigation water consumption decreased markedly in rice and wheat production, while crop yields improved significantly across major commodities including rice, wheat, maize, lentil, and mustard. Economic returns strengthened considerably, with net profits rising for rice, wheat, and mustard cultivation, along with improved benefit-cost ratios across crops. Some of the studies highlights that, transitioning from traditional burning to sustainable residue management—specifically through bale making, mushroom cultivation, and biochar generation—fundamentally enhances resource recycling. Across Bihar's diverse agroecological zones, prove that climate-resilient practices build vital adaptive capacity among farming communities.Observations from farming communities, extension networks collectively demonstrate a clear synergy where environmental sustainability and agricultural productivity coexist, ultimately driving higher economic returns while safeguarding the ecosystem for future cultivation cycles. Moreover, converting stubble into biochar or mushrooms transforms waste into a strategic asset. These results prove that adaptive farming fundamentally improves economic resilience.

Keywords: Climate resilient agriculture, Bihar, Crops, Vulnerability, Sustainability

The Impact of Climate Change on Farm Income in Bihar

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ABSTRACT

The current study examines how climate change affects agricultural revenue in four representative districts of Bihar's fouragro-climatic zones: Muzaffarpur (Zone I), Purnea (Zone II), Bhagalpur (Zone III a), and Gaya. Bihar's agricultural sector makes it vulnerable to rising temperatures, irregular rainfall, regular floods, and extended dry spells, which reduce agriculture productivity and earnings.The study examines crop output and farm income under changing climates using district-level meteorological and agricultural measurements. In flood-prone areas like Purnea and Muzaffarpur, excessive monsoon rains and frequent floods have reduced paddy and maize yield, costing smallholder farmers 18–25% of their revenue. However, drought-prone regions like Gaya saw dramatic losses in wheat and pulse yields due to higher temperature stress and moisture deprivation, reducing net agricultural revenue by 20% during severe droughts. The kharif season brought unpredictable rains and heat stress to Bhagalpur.This hurt agricultural diversification and farm profitability.A 1°C increase in maximum temperature during kharif season was associated with a loss in net farm revenue, while mild increases in seasonal rainfall had limited positive effects when supported by irrigation infrastructure. Paddy, wheat, maize, and pulses have suffered from climate variability, lowering gross farm returns in all agroclimatic zones. Due to fragmented landholdings, severe monsoon dependency, inadequate irrigation, and limited institutional financing, small and marginal farmers remain the most vulnerable.The study found that Bihar's different agro-climatic zones need region-specific climate adaptation policies, improved agricultural extension services, irrigation infrastructure, and institutional support mechanisms to protect farm income and promote sustainable agricultural development.

Keywords: Climate Change, Agricultural Revenue, Agro-Climatic Zones, Farm Income, Crop Productivity, Abiotic Stress

Effect of *Terminalia arjuna* bark extract based supplemented diets onthe non-specific immune system of *Cyprinus carpio haematopterus* (Temminck & Schlegel, 1846) against *Aeromonas salmonicida*

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ABSTRACT

The current study was carried out to evaluate the dietary effect of *Terminalia arjuna* bark extract based supplemented diets on growth performance, waterquality,haematologyduring 90 days of experimental period andpost-challenge with *Aeromonas salmonicida,* histopathological alterations inAmur carp were observed. The *T. arjuna*bark extract was incorporated in basal diet at four concentrations in treatments T1(0.1%), T2 (0.2%),T3 (0.3%), T4(0.4%)and Control (0.0%). The result of experiment showed that Net length gain, Net weight gain, Specific growth rate, Protein efficiency ratio and Feed conversion ratio were significantly higher ($p<0.05$) in T3 (0.3%) followed by T4 (0.4%) incorporated diet as compared to the control diet. Feeding the fish with T3 (0.3 %) of dietary *T. arjuna* bark extract resulted in better haematological indices (red and white blood cell counts, packed cell volume, and haemoglobin), in comparison with the other treatments and control. After the challenge study with *A. salmonicida*for 10 days, the lowest mortality was recorded in T3 (0.3%) followed by T4 (0.4%) of *T. arjuna* bark extract compared to the control and other two treatments. Histopathological analysis of the gill, liverand kidney tissues revealed severe damage in the positive control (infected) compared to other treatments. The gills of infected fish showed secondary lamellar fusion, with the most pronounced fusion occurring at the basal regions of the primary lamellae. Liver sections exhibited sinusoidal and large blood vessel congestion, hemorrhage and hepatocyte necrosis. Additionally, infiltration of red blood cells and hemorrhagic necrosis with karyolysis were noted. Kidney tissues demonstrated a loss of cytoplasmic delimitation in renal tubular cells, along with infiltration of leukocytes and erythrocytes. Among the groups - Control, T1, T2, T3 and T4 - the histological alterations were least pronounced in T3, followed by T4, T2 and T1.These findings suggest that *T. arjuna* bark extract exerted a protective effect, particularly at higher inclusion levels.

Keywords: Amur Carp, Growth Performance, Haematology, Histopathology, Disease Resistance, *Aeromonas Salmonicida* Infection

Empowering Farmers through Climate Resilient Agriculture and Livestock Farming

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ABSTRACT

Climate change has emerged as a major concern in all aspects. These changes are expected to increase risks towards food security. Global temperature has increased by about 1.1^0C since pre-industrial times, crop yields may decline about 10-25% by 2050 due to rising temperature and irregular rainfall and about 80% of Indian farmers depend on the rainfall, making agriculture high vulnerable to climate change. These changes affect all areas: agriculture, aquaculture and animal husbandry. These changes can be mitigated through adopting some climate resilient practices like integrated nutrient management, crop diversification, conservation tillage practices, sustainable agriculture, organic farming and supplemental irrigation systems.Aquaculture is extremely vulnerable to climate changes due to polluted water bodies and increased water temperature. Climate-resilient aquaculture practices involves the integrated fish farming systems, tolerant fish species, water conservation techniques and disease monitoring for sustainable fish production. Likewise, climate-resilient animal husbandry mainly promotes improved livestock breed, healthcare management, scientific housing management and stress reduction practices.The development of resilient breeds, utilization of vaccination programs and other measures also help to farmers on a broad scale. The integration of government's policies, modern technology and greater collaboration of ITK(Indigenous Technical Knowledgewill play a crucial role in climate resilience. There is need to encourage farmers to adopt new techniques. Climate-resilient practices are very important for securing food production,protecting ecosystems and improving rural livelihoods.

Keywords: Crop diversification, Conservation tillage, Climate change, Climate resilience, Food security, integrated nutrient management

Rice Bean: An Underutilized Climate-Resilient Pulse for Sustainable Agriculture and Nutritional Security

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ABSTRACT

Climate change has emerged as a major threat to agricultural productivity, particularly in rainfed and resource-poor regions. In this scenario, rice bean (*Vigna umbellata*), an underutilized pulse crop, has gained importance as a climate-resilient and sustainable agricultural option. Rice bean is well adapted to adverse environmental conditions such as drought, erratic rainfall, poor soil fertility, and marginal lands. Its hardy nature, deep root system, and low input requirement make it highly suitable for climate-stressed agro-ecosystems. The crop possesses remarkable tolerance to abiotic stresses and can thrive under diverse climatic conditions where many conventional pulse crops fail to perform efficiently. Rice bean also contributes significantly to soil health through biological nitrogen fixation, thereby reducing dependence on chemical fertilizers and enhancing sustainability in cropping systems. Nutritionally, it is a rich source of protein, dietary fiber, essential amino acids, vitamins, and minerals, which makes it valuable for combating malnutrition and ensuring food security among rural populations. The crop can be utilized for multiple purposes including grain, fodder, green manure, and cover cropping, thereby increasing farm resilience and livelihood opportunities for small and marginal farmers. Despite its immense potential, rice bean remains neglected due to limited research attention, lack of improved varieties, weak market linkage, and low consumer awareness. Therefore, systematic research, policy support, value addition, and promotion through extension services are essential for mainstreaming rice bean cultivation. Wider adoption of rice bean can play a crucial role in strengthening climate-resilient agriculture, nutritional security, and sustainable rural development.

Keywords: Rice Bean, Climate Resilience, Sustainable Agriculture, Nutritional Security and Underutilized Pulse Crop

Climate-Resilient Soil Management for Sustainable Agriculture

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ABSTRACT

Climate change poses serious challenges to agricultural sustainability through increasing temperatures, irregular rainfall, drought, floods and declining soil fertility. In the eastern Indo-Gangetic plains, particularly Bihar, maintaining soil health is essential for ensuring climate-resilient agriculture and long-term food security. Soil acts as a major reservoir of nutrients, water and organic carbon, thereby playing a crucial role in enhancing crop resilience under changing climatic conditions. Climate-resilient soil management practices such as conservation agriculture, integrated nutrient management, residue recycling and organic amendments can significantly improve soil quality as well as crop productivity. Practices including minimum tillage, crop diversification, green manuring, brown mannuring and use of FYM/ compost/ vermi-compost or biochar enhance soil organic carbon, water-holding capacity, microbial activity and nutrient-use efficiency. These approaches also help reduce greenhouse gas emissions and improve resilience against climatic stresses. Integrated farming systems and agroforestry further contribute to sustainable soil management by minimizing soil erosion, improving biodiversity and stabilizing farm income. In addition, soil test-based nutrient management and precision farming techniques can optimize fertilizer use efficiency as well as maintaining environmental sustainability. Adoption of climate-smart soil management practices is therefore essential for sustaining agricultural productivity under changing climatic scenarios. Strengthening soil health not only improves crop performance and resource-use efficiency but also supports climate change mitigation through enhanced carbon sequestration. In this context, the importance of location-specific technologies, farmer awareness and policy support for the wider adoption of sustainable soil management practices is crucial to ensure resilient agriculture in Bihar under vulnerable climatic conditions.

Keywords: Climate-resilient agriculture, Soil health, Integrated nutrient management, Carbon sequestration, Sustainable agriculture, Precision farming

Next-Generation Climate-Resilient Technologies for Sustainable Vegetable Production under Biotic and Abiotic Stresses in Bihar

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ABSTRACT

Climate-induced variability, particularly elevated temperature, erratic precipitation, recurrent flooding, prolonged drought and emerging pest–disease complexes, has become a critical constraint to sustainable vegetable production in Bihar. Major vegetables such as tomato, okra, brinjal, chilli, cucurbits and legumes are highly vulnerable to combined biotic and abiotic stresses, often resulting in 25–40% yield reduction, impaired reproductive efficiency, poor fruit quality and severe economic losses. In the eastern Indo-Gangetic plains, where vegetable cultivation is closely linked with nutritional and livelihood security, development of climate-resilient production systems is essential for sustaining productivity under rapidly changing climatic scenarios.Adoption of climate-smart horticultural technologies such as drip irrigation, plastic mulching, raised-bed cultivation, protected cultivation and integrated nutrient management has demonstrated substantial potential in improving water productivity, nutrient-use efficiency and stress tolerance. Drip irrigation integrated with mulching can reduce irrigation water requirement by 35–45% while enhancing marketable yield by 20–30% under stress environments. Deployment of heat, flood, drought and disease-tolerant cultivars, including YVMV-resistant okra and bacterial wilt-tolerant brinjal genotypes, provides greater yield stability and adaptive resilience under climatic extremes. Application of biochar, microbial consortia, organic amendments, and residue recycling further strengthens rhizospheric activity, soil carbon dynamics and ecosystem sustainability.Recent advances in Artificial Intelligence (AI), remote sensing, GIS-based crop modelling, IoT-enabled sensors, and drone-assisted phenomics are transforming precision vegetable production systems. AI-driven predictive analytics and weather-based decision-support tools enable real-time crop monitoring, precision irrigation scheduling, nutrient optimization and early pest–disease forecasting. Integration of digital agriculture, precision horticulture and climate-informed agro-advisories can substantially minimize production risks, enhance resource-use efficiency and mitigate greenhouse gas emissions. Therefore, promotion of location-specific

resilient technologies, climate-ready cultivars and data-driven extension frameworks will be pivotal for ensuring sustainable and climate-resilient vegetable production in Bihar.

Keywords: Biotic and abiotic stress, Precision horticulture, Climate-smart technologies, Stress-tolerant cultivars, AI, Remote sensing

Harnessing Rhizospheric and Nodule Associated Microbial consortia for Climate-Resilient Lentil Farming

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ABSTRACT

Climate-resilient agriculture requires sustainable approaches to enhance crop productivity, nutritional security, and soil health under changing climatic conditions. The present study aimed to isolate and evaluate rhizospheric and nodule-associated zinc-solubilizing bacteria (ZnSB) from lentil (*Lens culinaris* L.) for developing effective microbial consortia to improve productivity and biofortification. A total of 157 bacterial isolates were obtained from rhizospheric soil and root nodules collected from RPCAU research farms at Pusa and Dholi. Among them, 127 rhizospheric and 30 nodule isolates were screened for zinc solubilization using ZnO and $ZnCO_3$ as zinc sources. ZnO proved to be the most efficient substrate, with zinc-solubilizing efficiency ranging from 25.00–416.70 in rhizospheric isolates and 57.10–357.10 in nodule isolates.The most efficient isolates, Rh-ZnSB 38, Rh-ZnSB 60, Rh-ZnSB 90, and Nd-ZnSB 1, exhibited multiple plant growth-promoting traits, including phosphate and potassium solubilization, siderophore production, IAA and GA synthesis, and ammonia production. These compatible isolates were used to develop a microbial consortium. Seed germination studies showed that combined inoculation of Nd-ZnSB 1 with the rhizospheric consortium resulted in 100% germination and maximum seed vigor index. Pot experiments demonstrated significant improvements in plant growth, nodulation, yield attributes, and grain micronutrient content under consortium treatment (T_7). Grain zinc and iron contents increased up to 46.80 and 102.30 mg kg^{-1}, respectively. Soil fertility parameters, including available N, P, K, organic carbon, and DTPA-extractable Zn and Fe, were also enhanced. The findings suggest that ZnSB consortia can serve as climate-resilient bioinoculants for sustainable lentil production and nutritional security.

Keywords: Climate-Resilient Agriculture, Zinc-solubilizing bacteria (ZnSB), Microbial consortium, Biofortification, Lentil

Soil Carbon Sequestration Through Integrated Land Use and Management Strategies: A Pathway Towards Climate Resilient Agriculture in India

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ABSTRACT

Soil organic carbon (SOC) management is vital for building agricultural systems that can withstand climate-resilient. This review article brings together current knowledge and evidence on land use and management strategies for carbon sequestration in the soil within Indian agriculture. The paper discusses five main topics: (i) Soil Carbon Management Strategies, including Best Management Practices (BMPs); (ii) Crop Residue Management and its effect on SOC dynamics; (iii) Conservation Agriculture as a method to reduce soil disturbance and increase carbon stocks; (iv) Bio-char application as a strategy that captures carbon; and (v) Agroforestry systems, including Agrisilviculture and Silvopasture, for creating long-term carbon sinks. The paper also examines how carbon modeling tools like RothC and CENTURY estimate SOC dynamics. Data from long-term field experiments across India's various agro-ecological zones show that carbon sequestration rates in rainfed systems range from 0.32 to 1.18 Mg C ha^{-1} yr^{-1}, depending on the crop system and management practices. The review concludes that an integrated approach that combines these strategies is the most effective and scalable way to achieve climate-resilient agriculture in India. Seven figures and three tables illustrate carbon dynamics, geographic distribution, and strategic frameworks.

Keywords: Soil Organic Carbon, Carbon Sequestration, Conservation Agriculture, Bio-char, Agroforestry, Climate Change Mitigation, Rainfed Agriculture, India

Underutilized *Momordica* Species as Climate-Resilient Crops for Food and Health Security in Bihar

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ABSTRACT

Underutilized *Momordica* species possess immense potential for improving food and health security under the diverse agroclimatic conditions of Bihar. Species such as *Momordica dioica* (spine gourd/teasle gourd), *Momordica cochinchinensis*, *Momordica cymbalaria*, and wild bitter gourd types are rich sources of proteins, dietary fibre, vitamins, minerals, antioxidants, and bioactive compounds with significant nutraceutical and medicinal value. These crops are traditionally consumed in rural and tribal communities due to their antidiabetic, antioxidant, anti-inflammatory, antimicrobial, hepatoprotective and immune-boosting properties. The agroclimatic conditions of Bihar, characterized by humid subtropical climate, fertile alluvial soils and are highly suitable for the cultivation of perennial and annual *Momordica* species. These crops exhibit adaptability to marginal lands, tolerance to biotic and abiotic stresses and low input requirements, making them ideal for climate-resilient and sustainable vegetable production systems. In addition, it can enhance crop diversification, nutritional security, livelihood opportunities and income generation for small and marginal farmers. Despite their nutritional and medicinal importance, these species remain neglected due to lack of improved varieties, poor awareness, limited research attention, inadequate planting material, and absence of organized value chains. Conservation, characterization, genetic improvement, and promotion of these underutilized *Momordica* species are therefore essential for broadening the future food basket and addressing malnutrition and hidden hunger. Interventions like germplasm collection, molecular characterization, development of production technologies and value addition can significantly enhance their utilization and commercialization in Bihar. Underutilized *Momordica* species offer promising opportunities for achieving sustainable food, nutritional, and health security while supporting biodiversity conservation and climate-resilient horticulture in Bihar and agroecological regions of India.

Keywords: Underutilized, Momordica Species, Conservation, Commercialization

Growth performance of three estuarinepolychaete worms adopting different feeding diets

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ABSTRACT

This study investigated the growth performance of three estuarine polychaete worm species*Perinereisculturifera, Dendronereideshetropoda*, and *Lumbrinerisjaponica*under different feeding regimes, aiming to optimize their potential as sustainable feed sources in aquaculture. Three distinct diet treatments were employed: groundnut oil cake, microalgae, and shrimp minced meat, against an untreated control group. Growth parameters, including total biomass and total abundance, were systematically monitored and compared across the dietary treatments over the study period. *Perinereiscultifera* exhibited superior total abundance and biomass (96% increase/higher biomass compared to control/other diets - *please clarify what 96% refers to, e.g., percentage increase or specific measure*) when fed groundnut oil cake. *Dendronereidesheteropoda* showed optimal growth (90%) with microalgae, while *Lumbrineris japonica* also demonstrated best performance (96%) on microalgae. These findings underscore that dietary requirements for estuarine polychaetes are species-specific, with different species responding uniquely to variations in diet. The study highlights the critical importance of selecting appropriate feeding diets for estuarine polychaetes in aquaculture and their considerable potential as sustainable live feed sources.

Keywords: Aquaculture, Polychaetes, *Perinereisculturifera*, *Dendronereideshetropoda*, *Lumbrineris japonica*, Microalgae

Empowering Farmers through Climate Resilient Agriculture and Livestock Farming

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ABSTRACT

Climate change has emerged as a major concern in all aspects. These changes are expected to increase risks towards food security. Global temperature has increased by about 1.1^0C since pre-industrial times, crop yields may decline about 10-25% by 2050 due to rising temperature and irregular rainfall and about 80% of Indian farmers depend on the rainfall, making agriculture high vulnerable to climate change. These changes affect all areas: agriculture, aquaculture and animal husbandry. These changes can be mitigated through adopting some climate resilient practices like integrated nutrient management, crop diversification, conservation tillage practices, sustainable agriculture, organic farming and supplemental irrigation systems. Aquaculture is extremely vulnerable to climate changes due to polluted water bodies and increased water temperature. Climate-resilient aquaculture practices involves the integrated fish farming systems, tolerant fish species, water conservation techniques and disease monitoring for sustainable fish production. Likewise, climate-resilient animal husbandry mainly promotes improved livestock breed, healthcare management, scientific housing management and stress reduction practices.The development of resilient breeds, utilization of vaccination programs and other measures also help to farmers on a broad scale. The integration of government's policies, modern technology and greater collaboration of ITK(Indigenous Technical Knowledgewill play a crucial role in climate resilience. There is need to encourage farmers to adopt new techniques. Climate-resilient practices are very important for securing food production,protecting ecosystems and improving rural livelihoods.

Keywords: Crop diversification, Conservation tillage, Climate change, Climate resilience, Food security, Integrated nutrient management

The Climate-Resilience Stack: Integrating Digital Agronomy and Precision Systems in High-Value Horticultural Production

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ABSTRACT

The global agricultural landscape is currently undergoing a structural shift from traditional staple grain production toward high-value horticultural crops (HVHCs), driven by rising urbanization, changing dietary preferences and the pursuit of superior economic returns per unit of land. This study examines the multi-faceted approach required to optimize the production of fruits, vegetables and plantation crops such as cocoa, cashew and medicinal plants which now contribute significantly to agricultural Gross Value Output (GVO), yet remain highly susceptible to climate volatility and post-harvest losses due to their perishable nature. Central to modern production is the integration of Precision Agriculture (PA) and Protected Cultivation, with 2026 trends highlighting a shift toward real-world scaling of AI-driven advisory tools, autonomous field robotics and IoT-based sensor networks that allow for "data-as-fertilizer" strategies. These systems utilize variable-rate application (VRA) to reduce chemical inputs by up to 60% while maintaining yields, while controlled-environment technologies like hydroponics and spectral-managed LED greenhouses prove essential in mitigating climate-driven risks and enhancing resource efficiency. Although technological interventions such as drone-enabled scouting and precision irrigation significantly bolster resilience, significant barriers to adoption remain, including high initial capital costs and a lack of specialized technical skills among smallholders. Consequently, a regionally differentiated strategycombining targeted policy support, such as the 2026 Coconut Promotion Scheme, with digitized value chains and cold-chain infrastructureis vital for realizing the full economic potential of horticulture, as the transition toward a "climate-resilience stack" of integrated biologicals and digital agronomy defines the future trajectory of sustainable high-value crop production.

Keywords: High-value Horticultural Crops, Precision Agriculture, Protected Cultivation, Hydroponics, Digital Agronomy

Climate Resilient Agriculture, Aquaculture and Livestock Farming

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ABSTRACT

According to the Food and Agriculture Organization (FAO), climate resilient agriculture is defined as "the ability of an agricultural system to anticipate and prepare for, as well as adapt to, absorb and recover from the impacts of changes in climate and extreme weather".In India 65% of the population is engaged in agriculture and allied activities. An extreme rainfall shock (defined as rainfall in the bottom two deciles) reduces farm revenues during the Kharifby 7% in Irrigated areas and by 14.3% in unirrigated Areas. Similarly, an extreme temperature shock (defined as temperature in the top Two deciles) reduces Rabi yields by 3.2% in Irrigated areas and by 5.9% in unirrigated areas.Climate Resilient Agriculture is a comprehensive approach designed to ensure the sustainable use of a given ecosystem's natural resources, incorporating both crop and livestock production systems. The ultimate goal is to maintain and enhance productivity and farm incomes in the face of climate variabilities. To enhance the resilience of agriculture to climate change, it is essential to implement targeted nutrient management, organic farming, conservation agriculture, crop diversification and water efficient farming practices. However, there are challenges in implementing these methods, even with governmental support. Climate-resilient aquaculture includes proper water management and sustainable fish farming methods. Livestock farming uses improved animal breeds, better nutrition, and disease control techniques to maintain productivity during extreme weather conditions. These approaches help ensure food security, protect farmer livelihoods, reduce environmental damage, and support long-term agricultural sustainability in the face of changing climate conditions.

Keywords: Agricultural Sustainability, Climate Resilient Agriculture, Climate Change, Farmer Livelihoods

Climate Resilient Integrated Farming System: Role of Skill Development, Innovation and Entrepreneurship in Agriculture, Aquaculture and Livestock Farming

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ABSTRACT

Climate change has emerged as a major challenge affecting agricultural productivity, food security, and rural livelihoods. Climate Resilient Integrated Farming System (CRIFS) is considered a sustainable approach for improving farm productivity, resource-use efficiency, and income stability under changing climatic conditions. The integration of agriculture, aquaculture, and livestock farming promotes diversification, nutrient recycling, and reduction of production risks (FAO, 2021). Skill development and innovation play a significant role in promoting climate-smart agricultural practices. Modern technologies such as precision farming, efficient irrigation systems, organic nutrient management, improved livestock management, and sustainable aquaculture practices help farmers adapt to climatic stresses including drought and floods (IPCC, 2022). Training and extension services further strengthen farmers' technical knowledge and adaptive capacity. Entrepreneurship development in agriculture and allied sectors provides opportunities for employment generation and rural economic growth. Enterprises related to dairy farming, fish production, vermicomposting, and value-added agricultural products contribute to income diversification and self-reliance among rural communities (Sharma et al., 2020). Furthermore, integrated farming systems improve soil health, conserve water resources, and support environmental sustainability.Therefore, Climate Resilient Integrated Farming Systems can serve as an effective strategy for sustainable agriculture and socio-economic development.

Keywords: Climate Resilient Agriculture, Integrated Farming System, Innovation, Entrepreneurship, Aquaculture, Livestock Farming

Soil Carbon Sequestration Through Integrated Land Use and Management Strategies:A Pathway Towards Climate Resilient Agriculture in India

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ABSTRACT

Soil organic carbon (SOC) management is vital for building agricultural systems that can withstand climate-resilient. This review article brings together current knowledge and evidence on land use and management strategies for carbon sequestration in the soil within Indian agriculture. The paper discusses five main topics: (i) Soil Carbon Management Strategies, including Best Management Practices (BMPs); (ii) Crop Residue Management and its effect on SOC dynamics; (iii) Conservation Agriculture as a method to reduce soil disturbance and increase carbon stocks; (iv) Bio-char application as a strategy that captures carbon; and (v) Agroforestry systems, including Agrisilviculture and Silvopasture, for creating long-term carbon sinks. The paper also examines how carbon modeling tools like RothC and CENTURY estimate SOC dynamics. Data from long-term field experiments across India's various agro-ecological zones show that carbon sequestration rates in rainfed systems range from 0.32 to 1.18 Mg C ha^{-1} yr^{-1}, depending on the crop system and management practices. The review concludes that an integrated approach that combines these strategies is the most effective and scalable way to achieve climate-resilient agriculture in India. Seven figures and three tables illustrate carbon dynamics, geographic distribution, and strategic frameworks.

Keywords: Soil Organic Carbon, Carbon Sequestration, Conservation Agriculture, Bio-char, Agroforestry, Climate Change Mitigation, Rainfed Agriculture, India

Carbon-Negative Aquaponics: Integrating Algae Biofilters with Fish Farming

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ABSTRACT

Climate-resilient food production demands innovative systems that not only sustain yields but also mitigate carbon emission. This model introduces a novel Carbon-Negative Aquaponics that integrates algae biofilters into conventional fish-vegetable aquaponic systems to achieve carbon sequestration and circular nutrient recycling. In this model, fish waste containing ammonia and carbon dioxide is channeled into algae chambers, where microalgae utilize these compounds for rapid growth and water purification. The treated water then nourishes hydroponic crops, completing a closed-loop, zero-waste cycle. Advanced AI-based sensors continuously track water parameters such as temperature, pH, and nutrient concentration, allowing automated adjustments for optimal algae performance and system stability. This intelligent integration transforms aquaponics from a carbon-neutral approach into a carbon-negative production system, generating three valuable outputs—fish, vegetables, and algal biomass. The harvested algae serve as raw material for biofuel, livestock feed, and nutraceuticals, promoting a sustainable bio-economy. The proposed model offers a pathway toward climate-positive aquaculture, significantly lowering greenhouse gas emissions while improving food security and supporting rural livelihoods. Its scalability across rural, urban, and industrial contexts positions it as a futuristic solution for eco-efficient and carbon-smart farming, aligning with India's vision for sustainable agricultural transformation.

Keywords: Carbon-Negative Aquaponics, Algae Biofilters, AI Optimization, Circular Bioeconomy, Climate-Resilient Farming

Climate Smart Nitrogen Management in Indian Mustard through Leaf Colour Chart Approach

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ABSTRACT

Indian mustard [*Brassica juncea* (L.) Czern & Coss.] is an important oilseed crop requiring efficient nitrogen management for sustainable productivity under changing climatic conditions. Excessive and untimely nitrogen application often leads to poor nitrogen use efficiency and increased environmental losses. Therefore, the present research was carried out to evaluate the effect of Leaf Colour Chart (LCC)-based nitrogen management on growth, yield and economics of Indian mustard. The field experiment was conducted during the Rabi season using different nitrogen management treatments comprising varying basal nitrogen levels, LCC threshold values and neem coated urea (NCU)-based nitrogen application. Among the treatments, T_2 [50% recommended dose of nitrogen (RDN) as basal + LCC ≤3.5 based nitrogen application at 28 kg N ha^{-1} through NCU] recorded performance statistically at par with T_1 (100% RDF; N:P:K at 80:40:40) in terms of crop growth, yield attributes and productivity. LCC-based nitrogen scheduling significantly improved nitrogen use efficiency, chlorophyll retention and economic returns over conventional fertilizer practices, which corroborates the findings of Singh et al. (2020) and Kumar and Singh (2021). Higher seed yield, nutrient uptake and benefit-cost ratio were observed under T_2 treatment. The real-time nitrogen management approach synchronized crop nitrogen demand with fertilizer application, thereby reducing excessive nitrogen losses and improving resource use efficiency. Application of neem coated urea further enhanced nitrogen availability and minimized nutrient losses to the environment, supporting the observations reported by Prasad et al. (2017). The study concluded that LCC-based nitrogen management through neem coated urea can be an effective climate smart strategy for sustainable Indian mustard production with improved productivity, nitrogen use efficiency and environmental sustainability.

Keywords: Indian Mustard, Leaf Colour Chart, Climate Smart Agriculture, Nitrogen Management, Neem Coated Urea, Nitrogen Use Efficiency

Effect of Potassium and Zinc on yield and economics of Pearl millet (*Pennisetum glaucum* L.)

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ABSTRACT

The field experiment was conducted in Crop Research Farm (CRF) in Department of Agronomy during *Zaid* season 2023-24 on Pearl millet crop**.** The treatment consisted of Potassium (30, 40 and 50 Kg/ha) and Zinc (15,20 and 25 kg/ha) and a control. The experiment was laid outwith a Randomized Block Design (RBD) with ten treatments which were replicated thrice as T_1 Potassium 30kg/ha+Zinc 15 kg/ha, T_2 Potassium 30kg/ha+Zinc 20 kg/ha, T_3 Potassium 30kg/ha+Zinc 25 kg/ha T_4 Potassium 40kg/ha+Zinc 15 kg/ha, T_5 Potassium 40kg/ha+Zinc 20 kg/ha, T_6 Potassium 40kg/ha+Zinc 25 kg/ha,T_7 Potassium 50kg/ha+Zinc 15 kg/ha, T_8 Potassium 50kg/ha+Zinc 20 kg/ha, T_9 Potassium 50kg/ha+Zinc 25 kg/ha and a T_{10} Control. The soil of experiment plot was sandy loamy in texture, nearly neutral in soil reaction (pH 6.8), low inorganic carbon (0.46 %), available N (225.42 kg/ha), available P (38.2 kg/ha) and available K (240.7 kg/ha). Application of Potassium 50kg/ha+Zinc 25 kg/ha was recorded with the results which revealed that significantly yield attributes such as Grain yield (4530.43 kg/ha), Stover yield (7246.59 kg/ha) and Harvest index (38.46 %) were recorded highest in treatment 9 (Potassium 50 kg/ha + Zinc 25kg/ha) as compared to other treatments. Maximum gross return (INR 1,09,857.7/ha), net return (INR 71,773.74/ha) and B:C ratio (1.88) was also recorded in the same treatment.

Keywords: Economics, Nitrogen, Pearl Millet, Phosphorus, Potassium, Zinc

Recent Advances in Sustainable Crop Protection Technologies for Climate-Resilient Agriculture

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ABSTRACT

The challenges of climate change, this addresses the critical aspects of adapting to and mitigating the challenges of crop protection in modern agriculture. It focuses on the use of advanced technologies and innovative methods to detect and control pests to ultimately increase crop yields. Climate change is intensifying the occurrence of pests, diseases, and weeds, posing serious threats to global food security and agricultural sustainability. Conventional crop protection methods, heavily dependent on synthetic pesticides often lead to environmental degradation, pest resistance, and negative impacts on human and ecosystem health. In recent years, sustainable crop protection technologies have emerged as effective alternatives for developing climate-resilient agriculture. These innovations integrate ecological principles, biological solutions and digital technologies to reduce crop losses while minimizing environmental impacts. Recent advances include the use of biopesticides, microbial formulations, RNA-based pesticides, nanotechnologyand precision agriculture tools such as drones, remote sensing, and artificial intelligence for real-time pest monitoring and management. Integrated Pest Management (IPM) strategies combining biological control agents, resistant crop varieties and climate-smart agronomic practices are also gaining importance.These approaches not only enhance agricultural productivity and resilience but also support biodiversity conservation, soil health, and reduced chemical dependency. Despite significant progress, challenges related to high implementation costs, limited farmer awareness, regulatory constraints, and scalability remain barriers to widespread adoption. Strengthening research, policy support, and farmer-centered extension services is essential for promoting sustainable crop protection technologies globally. Overall, recent innovations in sustainable crop protection provide promising pathways toward achieving resilient, productive, and environmentally sustainable agricultural systems under changing climate scenarios.

Keywords: Climate-Resilient Agriculture, Sustainable Crop Protection, Biopesticides, Integrated Pest Management, Precision Agriculture

Development and Evaluation of Endophytes and Rhizospheric Bacteria Based Consortia for Growth, Yield and Quality of Finger Millet Crop

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ABSTRACT

In the calcareous soils of Bihar, finger millet (*Eleusine coracana* L.) productivity is frequently hampered by poor nutrient bioavailability and declining soil health. This study explores a biologically driven alternative to conventional chemical-intensive practices by evaluating the potential of specialized microbial inoculants. A total of 26 bacterial isolates - comprising 14 rhizospheric and 12 endophytic strains (derived from root and stem tissues) were systematically characterised for their plant growth-promoting (PGP) attributes. These isolates demonstrated significant multifunctional traits, including the solubilization of phosphorus, zinc, and potassium, as well as the biosynthesis of essential phytohormones such as Indole-3-Acetic Acid (IAA) and Gibberellic Acid (GA). The pot efficacy was validated through a comprehensive 16-treatment experimental matrix conducted during the 2025 Kharif season at RPCAU, Pusa. Using the Ragi variety RAU-8, the research investigated interactions between graded NPK levels and microbial consortia enriched in PGP bacteria. Results indicated that the integration of endophytes and rhizospheric consortia, particularly when paired with a 75% reduction in chemical NPK, significantly enhanced vegetative growth parameters, tillering capacity, and root-shoot architecture at both 30 and 60 days after sowing (DAS). Furthermore, treatments supplemented with these microbial agents showed superior yield-contributing traits, specifically increasing ear heads per plant and overall crop vigor. This multifactorial synergy is vital for the development of robust microbial consortia-based biofertilizers. The integration of such PGP-based strategies into farming systems holds promise for boosting crop productivity, promoting environmental health, and empowering smallholder farmers in resource-poor settings.

Keywords: Finger Millet, PGP Bacteria, Consortia, Rhizospheric Bacteria, IAA, Gibberellic Acid

THEME: -2

Advancement in Crop Production

Biocontrol Potential of Entomopathogenic Fungi Against Crop Insect Pests

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ABSTRACT

Entomopathogenic fungi (EPF) are important eco-friendly alternatives to chemical insecticides for sustainable management of insect pests in agriculture. Growing concerns over pesticide resistance, environmental pollution, and residue accumulation have promoted the use of microbial biocontrol agents in India. Fungal pathogens such as *Beauveria bassiana, Metarhizium anisopliae, Lecanicillium lecanii, Nomuraea rileyi*, and *Isaria fumosorosea* have shown significant effectiveness against insect pests of cereals, pulses, vegetables, oilseeds, and horticultural crops. These fungi infect insects through direct penetration of the cuticle, leading to mortality and suppression of pest populations. India's diverse agro-climatic conditions support the occurrence and utilization of indigenous entomopathogenic fungi. The Indian biopesticides market reached nearly USD 286.8 million in 2025, reflecting increasing adoption of sustainable and residue-free crop protection practices. More than 970 biopesticide products are currently registered in India, with fungal biopesticides forming a major component of microbial formulations. Several agricultural universities and research institutions are actively involved in isolation, mass multiplication, formulation development, and field evaluation of EPF under integrated pest management (IPM) programs. Despite their promising potential, factors such as inconsistent field efficacy, environmental sensitivity, limited shelf life, and inadequate farmer awareness continue to restrict large-scale adoption. Recent advances in molecular biology and biotechnology have improved understanding of fungal virulence and host-pathogen interactions, providing opportunities for strain improvement and enhanced field performance. Therefore, entomopathogenic fungi hold significant promise for reducing dependence on chemical insecticides and promoting environmentally safe and sustainable agriculture in India.

Keywords: Fungal biopesticides, Integrated pest management, Sustainable agriculture, Microbial biocontrol, Insect pests

Biosynthesized Nanoparticles as Eco-friendly Nematicides and Diagnostic Agents for Sustainable Management of Plant-Parasitic Nematodes

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ABSTRACT

Plant-parasitic nematodes are one of the most destructive pests of agricultural crops, responsible for substantial yield losses worldwide. Species such as *Meloidogyne incognita*, *Meloidogyne javanica*, *Heterodera avenae*, *Globodera rostochiensis* and *Radopholussimilis* severely affect root systems, leading to impaired water and nutrient uptake, reduced plant vigor and significant economic damage. Although conventional nematicides are widely used for their control, their repeated application has raised serious concerns due to harmful environmental effects, soil health deterioration, groundwater contamination and toxicity to non-target organisms, including beneficial soil biota. These challenges have intensified the search for safer and more sustainable alternatives. Nanotechnology has emerged as a promising eco-friendly approach for plant protection and nematode management. In this context, biosynthesized nanoparticles, derived from plant extracts and beneficial microorganisms, offer a green and sustainable route for nanoparticle production. These biologically synthesized nanomaterials exhibit strong nematicidal activity by interfering with egg hatching, reducing juvenile mobility and inhibiting root penetration and establishment, thereby effectively suppressing nematode populations in the rhizosphere. Furthermore, advanced nanomaterials such as quantum dots add a novel diagnostic dimension to nematology. Owing to their unique quantum confinement properties, quantum dots at lower concentrations act as highly sensitive diagnostic probes for detecting nematode–host interactions and early infection stages. At optimized higher concentrations, they also demonstrate potential in nematode suppression, enabling a dual role in both detection and management.Overall, the integration of biosynthesized nanoparticles and quantum dot-based technologies presents a sustainable, innovative and precision-oriented strategy for nematode management. This approach reduces reliance on chemical nematicides while enhancing early diagnosis, promoting environmental safety and supporting sustainable agricultural productivity.

Keywords: Plant-parasitic nematodes, Green nanotechnology, Nematode diagnostics, Quantum dots, Sustainable agriculture

Trends in Management of Plant Viruses

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ABSTRACT

Plant viruses are highly significant agricultural pathogens causing devastating diseases globally and regionally, such as Cassava mosaic disease, Maize lethal necrosis, and Citrus tristeza. The emergence of novel viral variants, the introduction of exotic viruses, and the impacts of climate change have created unprecedented challenges in plant virus management. Because direct curative measures for infected plants are lacking, contemporary disease management heavily relies on preventative risk-reducing strategies and vector management. The current trends and advancements in crop protection against plant viruses encompass a range of strategies. Fundamental approaches include exclusion through strict quarantine and certified virus-free propagating materials, alongside avoidance tactics like eliminating green bridges, removing alternative weed hosts, and altering sowing dates. Beyond cultural practices and the insecticidal control of vectors, genetic resistance remains a cornerstone of defense. This includes the deployment of dominant R genes that typically elicit a hypersensitive response, as well as recessive resistance mechanisms involving mutations in host translation initiation factors (eIFs) to provide broad-spectrum protection. Furthermore, the landscape of viral management is being transformed by novel molecular technologies. RNA-interference (RNAi) approaches, particularly Spray-Induced Gene Silencing (SIGS) through the topical application of double-stranded RNAs (dsRNA), offer a promising non-transgenic method to trigger targeted viral resistance. Techniques utilizing nanoparticles like BioClay significantly enhance the stability and efficacy of these exogenously applied molecules. Additionally, site-directed genome editing via CRISPR/Cas systems allows for precise targeting of viral genomes or host susceptibility genes. Finally, cross-protection strategies functioning as "plant vaccines," such as those utilizing attenuated Pepino mosaic virus strains, represent a highly effective biological management tool. Future advancements depend on optimizing large-scale dsRNA application, developing high-throughput diagnostics, and discovering novel crop resistance genes.

Keywords: Plant Viruses, Genetic Resistance, RNA Interference (RNAi), Spray-Induced Gene Silencing (SIGS), CRISPR/Cas, Cross Protection.

In Vitro Efficacy of Fungicides and Botanicals Against *Sclerotiniasclerotiorum*: A Comparative Evaluation

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ABSTRACT

Sclerotinia sclerotiorum is a devastating polyphagous fungal pathogen causing stem rot disease in rapeseed-mustard with annual crop losses reaching up to 70% under conducive conditions. Management of this disease requires integrated approaches combining chemical fungicides and botanical extracts. This study evaluated the in vitro efficacy of novel fungicides and plant-based botanicals against *S. sclerotiorum* isolates using the poisoned food technique. Twelve fungicide treatments and eight botanical extracts were tested against the pathogen to determine their inhibitory potential on mycelial growth. Colony diameter was recorded at 3, 5, and 7 days after inoculation (DAI), and percent inhibition of mycelial growth was calculated. Among fungicides tested, carbendazim, chlorothalonil, and thiophanate-methyl exhibited superior efficacy with mean inhibition rates exceeding 80% by 7 DAI, while newer fungicides demonstrated comparable or superior activity. Botanical extracts from *Allium sativum, Zingiber officinale*, and *Ocimum basilicum* demonstrated significant antifungal properties with inhibition rates ranging from 60-75% at 7 DAI. Statistical analysis revealed significant differences ($P \leq 0.05$) among treatments, with fungicides showing faster inhibition kinetics compared to botanicals. The combined approach of integrating both chemical fungicides for quick control and botanicals as eco-friendly alternatives offers promising prospects for sustainable management of Sclerotinia stem rot in rapeseed-mustard cultivation. These findings provide a foundation for developing integrated disease management strategies that balance efficacy with environmental sustainability.

Keywords: *Sclerotinia sclerotiorum,* Fungicides, Botanical extracts, In vitro efficacy, Mycelial growth inhibition, Rapeseed-mustard, Stem rot management, Integrated disease management

Advancements in Crop Protection: Bridging Science and Sustainable Agriculture

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ABSTRACT

Global food security faces an unprecedented crisis as approximately 40% of global crop yield is lost annually to pests, while the overuse of conventional chemical pesticides continues to generate resistant "super-pests" and long-term ecological damage. The urgency to develop safer, more targeted, and environmentally sustainable crop protection strategies has accelerated biotechnological innovation at a remarkable pace. Recent advancements have positioned CRISPR-based genome editing at the forefront of crop protection. Rapid advances in genome editing, especially CRISPR, have enabled precise, faster crop improvements compared to traditional breeding, unlocking new possibilities through AI-driven bioinformatics and economical genome sequencing. Simultaneously, RNA Interference (RNAi) technology has emerged as a powerful tool, silencing specific genes in pests or pathogens and boosting crop resistance without the use of harmful chemicals. In April 2025, GreenLight Biosciences announced a significant breakthrough in RNAi-based pesticides, which silence specific pest genes, reducing crop damage while minimizing harm to beneficial organisms. Biological solutions have gained significant momentum alongside genetic tools. Microbial biotechnology now leverages beneficial microbes including biopesticides and biofertilizers to improve soil health, nutrient uptake, and plant protection while reducing chemical input dependency. Companies like Corteva have introduced next-generation bioinsecticides derived from novel strains of *Beauveria bassiana*, offering broad, resistance-breaking pest control across major global crops. Complementing these biological and genetic innovations, precision agriculture integrates satellite imagery, AI, and sensor-based data to enable targeted decision-making, applying pesticides only where and when needed — reducing chemical inputs by as much as 40%. Nanotechnology, controlled-release formulations, and drone-compatible delivery systems further refine the precision and efficacy of crop protection interventions. In conclusion, the convergence of genomics, microbial biotechnology, RNAi, and digital precision agriculture marks a paradigm shift in crop protection moving from broad-spectrum chemical dependence toward intelligent, targeted, and sustainable solutions.

Keywords- CRISPR, RNAi, Biopesticides, Precision Agriculture, Bioinsecticides, Sustainable Crop Protection

Integrated Biocontrol Consortium and Reduced Chemical Compatibility for the Management of Rice Sheath Blight and Bacterial Leaf Blight

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ABSTRACT

Rice sheath blight caused by *(RhizoctoniasolaniKühn*)and bacterial leaf blight caused bypathogen (*Xanthomonasoryzaepv. Oryzae)* are important constraints in rice cultivation and are responsible for considerable yield loss under humid agroecosystemsThe present study evaluated the antagonistic activity and compatibility of *Pseudomonas spp, Bacillus spp*, and *Trichodermaspp*. individually and in consortium combinations against both pathogens under laboratory and pot conditions. Dual culture and antagonist assays revealed that the consortium of *Pseudomonas* + *Bacillus* + *Trichoderma* produced higher inhibition of pathogen growth compared with individual bioagents. In vitro inhibition of *Rhizoctoniasolani* ranged between 72–84% in consortium treatments, whereas individual isolates recorded 48–66% inhibition. Against *Xanthomonasoryzaepv. oryzae*, bacterial antagonism and metabolite-mediated suppression ranged from 61–79% in combined treatments. Compatibility studies conducted through cross-streak and paired culture methods indicated that selected isolates *of Pseudomonas, Bacillus, and Trichoderma* were mutually compatible without significant suppression of each other's growth. Chemical compatibility assays demonstrated that reduced concentrations of validamycin 3L (2 ml L^{-1}) used for sheath blight management and copper oxychloride + streptocycline (2.5 g L^{-1} + 0.1 g L^{-1}) used for bacterial leaf blight management caused minimal inhibitory effect on the growth of selected bioagents under in vitro conditions. However, higher chemical concentrations reduced microbial growth and therefore were not considered suitable for consortium integration. Nine treatments including untreated control, pathogen control, individual bioagents, and consortium combinations were evaluated under pot conditions following seed treatment, soil drenching, and foliar spray application methods. Disease severity recorded using IRRI standard evaluation scales showed that the consortium treatment integrated with reduced chemical dose significantly reduced sheath blight and bacterial leaf blight severity by 64–78% over pathogen control. Individual bioagent treatments reduced disease severity by 32–54%, while untreated pathogen control recorded maximum disease incidence and lesion development. Consortium-treated plants also showed improved seed germination, seedling vigour, plant height, tiller production, and overall plant health compared with control treatments. The integrated use of compatible microbial consortia with reduced chemical dosage demonstrated effective and sustainable management of both rice diseases while reducing dependency on chemical pesticides.

Keywords: Microbial consortium, dual culture assay and compatibility test.

Advancements in Crops Production: Revolutionizing Crop Protection for a Smarter and Sustainable Future

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ABSTRACT

Advancements in crop protection are revolutionizing modern agriculture by introducing smarter, safer, and more sustainable methods of protecting crops from pests, diseases, and environmental stress. With the rapid increase in population, climate change, and the growing demand for food, traditional crop protection practices are no longer sufficient. Excessive dependence on chemical pesticides has led to serious problems such as soil and water pollution, pest resistance, loss of beneficial organisms, and risks to human health. Therefore, the need for advanced and eco-friendly crop protection technologies has become more important than ever. Modern innovations such as RNA Interference (RNAi) technology provide highly targeted pest control by deactivating specific genes in harmful insects without affecting useful organisms. Artificial Intelligence (AI) and Drone Technologies (UAVs) are transforming farming through real-time field monitoring, early disease detection, and precision spraying, which significantly reduce chemical usage, labor requirements, and production costs. The growing use of bio-based and microbial pesticides prepared from bacteria, fungi, viruses, and plant-derived materials is promoting environmentally safe pest management. At the same time, genetic engineering and gene-editing technologies are helping scientists develop crop varieties with stronger resistance to pests, diseases, drought, and climatic stress, thereby improving crop productivity and reducing chemical dependency. In addition, Smart Formulation Technologies and advanced pesticide mixtures are enhancing the effectiveness and durability of crop protection products while supporting better resistance management. Newly approved modern chemicals such as Fluxapyroxad, Fluxametamide, and Chlorantraniliprole are also contributing to more efficient and sustainable pest control in major crops. Overall, these advancements are improving agricultural productivity, ensuring food safety, conserving natural resources, and protecting the environment. Modern crop protection technologies are paving the way for a future where agriculture becomes more precise, productive, and sustainable, helping to achieve global food security and long-term agricultural development.

Keywords: Precision Agriculture, RNA interference (RNAi), Eco-friendly Pest Management, Genetic Engineering, Sustainable Agriculture Development

Laboratory Evaluation of Host Range in *Spodopterafrugiperda*: Insights for Crop Protection

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ABSTRACT

The Fall Armyworm (*Spodopterafrugiperda(*Smith, 1797*)*) is a highly destructive, polyphagous pest that has become a major threat to maize production in India. However, its ability to utilize alternative host plants could further expand its impact across cropping systems. The present study evaluated the developmental biology, feeding efficiency, and morphometric traits of *S. frugiperda* on five host plants*viz*., maize (*Zea mays*), pearl millet (*Pennisetum glaucum*), sorghum (*Sorghum bicolor*), sugarcane (*Saccharum officinarum*), and banana (*Musa spp.*) under laboratory conditions. The results revealed that, maize was most suitable host, supporting the faster development and higher reproductive potential, the pest was also able to complete its life cycle as compared to other crops. Nevertheless, the insect successfully completed its life cycle on all tested hosts, demonstrating its broad host adaptability but larvae reared on sorghum, pearl millet, and sugarcane showed moderate survival and development, indicating that these crops can sustain field populations of the pest. In contrast, larvae fed on banana exhibited prolonged developmental duration and additional larval instars, suggesting nutritional stress and reduced feeding efficiency. However, the pest was still capable of surviving and reproducing on banana, highlighting its ecological plasticity. Despite reduced efficiency on non-maize hosts, the ability of *S. frugiperda* to survive and reproduce on a broad range of crops raises serious concerns for pest persistence, pest spillover and seasonal carryover into non-maize cropping systems. These findings emphasize the importance of continuous surveillance and integrated host-based management strategies, particularly in regions cultivating sorghum, millet, sugarcane, and banana. Early monitoring and preventive management in non-maize crops will be essential to minimize the establishment and economic impact of this invasive pest across tropical agroecosystems.

Keywords: Developmental biology, Feeding efficiency,Invasive pest, Alternative hosts, Pest spillover, Polyphagous pest

RNA Interference (RNAi): A Precision and Eco-Friendly Strategy for Sustainable Management of Fall Armyworm (*Spodopterafrugiperda*)

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ABSTRACT

Fall armyworm (*Spodopterafrugiperda*) is a highly destructive invasive pest responsible for substantial yield losses in maize and other crops. The excessive dependence on chemical insecticides has resulted in resistance development, environmental contamination, and adverse effects on beneficial organisms, highlighting the urgent need for sustainable and innovative pest management strategies. In this context, RNA interference (RNAi) has emerged as a precise and environmentally safe approach due to its gene-specific mode of action. RNAi operates through the introduction of double-stranded RNA (dsRNA), which silences target genes by degrading complementary messenger RNA (mRNA). In fall armyworm, targeting essential genes such as v-ATPase (metabolism), chitin synthase (molting) and cytochrome P450 (detoxification)—has shown promising results. Silencing these genes leads to significant larval mortality, impaired growth, and reduced feeding capacity. Two primary delivery approaches have been developed: Host-Induced Gene Silencing (HIGS), involving transgenic plants expressing dsRNA and Spray-Induced Gene Silencing (SIGS), a non-transgenic method based on external application. However, the rapid degradation of dsRNA under field conditions remains a key limitation. Recent advancements in nanotechnology, including the use of nanocarriers such as chitosan and layered double hydroxides, have enhanced dsRNA stability and cellular uptake, improving its field applicability. Experimental evidence demonstrates that RNAi-based strategies effectively suppress fall armyworm populations while minimizing non-target effects and environmental risks. Its high specificity provides a significant advantage over conventional insecticides. Although challenges related to large-scale production and regulatory frameworks persist, RNAi represents a resilient and eco-friendly paradigm shift in integrated pest management, ensuring sustainable crop protection and reduced ecological impact.

Keywords- Gene Silencing, Nanocarriers, RNA interference (RNAi), Spodopterafrugiperda, v-ATPase

Decoding Host Plant Resistance in Pigeonpea (*Cajanuscajan*) against Pod Fly: Morpho-Biochemical Determinants and Biopesticide-Based Management

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ABSTRACT

The pigeonpea [*Cajanuscajan* (L.) Millsp.]is the second most significant source of pulses in India and contributes 80% of global cultivation and production and suffers tremendous yield losses due to the pod fly (*Melanagromyzaobtusa)*. The damage by pod fly ranges from 2% to over 90% depending upon the genotype. This internal feeding behaviour of this pest makes most insecticides ineffective for its control;use of indiscriminate chemical insecticides leads to the insecticide resistance problem. Host Plant Resistance (HPR), acting on antixenosis, antibiosis, and tolerance principles, can prove to be the most sustainable and environmental friendly option within an IPM context. Studies have shown that the biophysical defences, such as the density and length of trichomes, pod wall thickness, and pod length, act as antixenotic barriers, which prevent the oviposition and entry of larvae into pods. In addition, biochemical defense components, namely phenolics, flavonoids, tannins, and protease inhibitors, work as the principle for antibiosis via inhibition of digestive enzymes in the larvae gut, such as proteinases and alpha-amylase enzymes.This research project will screen some genotypes of pigeonpea for their resistance to pod flythrough systematic assessment of morphological traits, i.e., trichome density, pod wall thickness, and pod length, along with biochemical properties, and field parameters like percentage of pod damage and maggots per pod. At the same time, efficacy of promising biopesticides will be investigated in terms of their field performance on randomised block design basis in order to look for some residue-free Bio-pesticides. Those genotypes which show promising morphological as well as biochemical resistance traits can be used as valuable pre-breeding material for breeding resistant lines using MAS technology and gene mapping using multi-omics approach to understand the genetics of pod fly resistance trait.

Keywords: Pigeonpea, Podfly, Host Plant Resistance, Antixenosis, Antibiosis, Biochemical properties, Biopesticides, IPM

Eco-compatible Crop Protection Strategies through Microbial Bio-pesticides and Botanically Active Secondary Metabolites

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ABSTRACT

The escalating global demand for food security, coupled with the detrimental environmental and toxicological impacts of synthetic agrochemicals, has necessitated a paradigm shift toward eco-compatible crop protection. As the global population continues to rise and the demand for food reaches unprecedented levels, the agricultural sector is confronted with the challenge of enhancing yield production. Modern agriculture is experiencing unparalleled difficulties due to climate change, which has significantly affected crop productivity through changes in weather patterns, rising temperatures, and severe pest infestations. With traditional chemical pest control methods becoming increasingly untenable due to environmental concerns, there has been a marked rise in pest populations, including insects, nematodes, and pathogens. Bio-pesticides and botanical extracts present environmentally friendly alternatives that contribute to Integrated Pest Management (IPM) while safeguarding biodiversity and soil health. Bio-pesticides, which are derived from microorganisms such as bacteria, fungi, and viruses, as well as naturally occurring substances, effectively manage a broad spectrum of insect pests, plant pathogens, and weeds with minimal residual toxicity. Additionally, botanical extracts sourced from plants like neem, tobacco, eucalyptus, and pyrethrum exhibit insecticidal, antifungal, antibacterial, and repellent properties that bolster crop resilience against pests and diseases. These natural products are specifically targeted and less detrimental to the environment. The integration of bio-pesticides and botanical formulations promotes sustainable agricultural practices by decreasing chemical usage, reducing environmental pollution, and enhancing food safety. Nevertheless, challenges such as limited shelf life and insufficient farmer awareness continue to hinder their widespread adoption. Progress in formulation technologies and supportive policies is crucial to improve their commercial viability and effectiveness. This study underscores the significance of bio-pesticides and botanical extracts as valuable instruments for sustainable crop protection and highlights their role in fostering environmentally sound and economically viable agricultural systems. This transition necessitates a reassessment of existing pest management strategies and the creation of more sustainable solutions.

Keywords: Sustainable agriculture, Crop protection, Bio-pesticides, Botanical extracts, Environment sustainability.

Synthetic Microbial Communities for Sustainable Management of Soil-Borne Plant Diseases

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ABSTRACT

Soil-borne plant pathogens such as Fusarium, Rhizoctonia, Pythium, and Phytophthora are major threats to global crop production and food security. Excessive dependence on chemical fungicides has resulted in environmental pollution, development of resistant pathogen populations, and disruption of beneficial soil microbiota. Therefore, sustainable and eco-friendly disease management strategies are urgently needed. Synthetic microbial communities (SynComs), composed of functionally compatible beneficial microorganisms, have emerged as a promising next-generation approach for biological control of plant diseases. SynComs enhance disease suppression through synergistic interactions, improved rhizosphere colonization, nutrient competition, antibiosis, biofilm formation, and induction of systemic resistance in plants. Prigigallo et al., (2022) demonstrated the effectiveness of microbial consortia containing *Pseudomonas, Bacillus, Trichoderma*, and *Streptomyces* species against several soil-borne pathogens. In a notable study on Fusarium wilt of banana caused by *Fusariumoxysporum f. sp. cubense* tropical race 4 (Foc TR4), researchers developed different SynComs using rhizospheric isolates with antagonistic activity against the pathogen. Optimized SynComs significantly reduced disease incidence and severity and performed better than commercial biocontrol formulations. The study further revealed that understanding microbial compatibility and antagonistic interactions among beneficial microbes is essential for designing efficient microbial communities for disease management. Advances in metagenomics, microbiome engineering, and omics technologies are accelerating the development of precision SynComs for sustainable agriculture. Despite challenges associated with formulation stability, field performance, and commercialization, synthetic microbial communities represent a powerful tool for integrated disease management and future climate-resilient crop protection systems.

Keywords : Synthetic microbial communities, Plant disease management, Biological control, Sustainable agriculture, Fusariumoxysporum, SynComs

Next-Generation Crop Protection Strategies for Sustainable Management of Rice Weevil, *Sitophilusoryzae* (L.)

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ABSTRACT

Stored grain insect pests continue to threaten global food security, particularly in developing countries. Among them, the rice weevil, *Sitophilusoryzae*, is one of the most destructive pests of stored rice, wheat, maize, and other cereals, causing severe quantitative and qualitative losses through grain damage, weight reduction, decreased germination, and deterioration of nutritional quality. Excessive reliance on synthetic insecticides has led to the development of insecticide resistance, environmental contamination, and food safety concerns. Consequently, recent advancements in crop protection have focused on sustainable and eco-friendly approaches for effective management of *S. oryzae*.This review highlights the biology, distribution, and damage potential of the rice weevil along with recent advances in its management, including botanicals, inert materials, entomopathogenic fungi, biological control agents, and molecular approaches. Plant-derived products such as neem, *Ageratum conyzoides*, *Meliaazedarach*, and essential oils have demonstrated significant insecticidal and repellent activity against stored grain pests. In addition, biotechnology-driven interventions including RNA interference (RNAi), genome-based pest management, molecular markers, and gene expression studies are emerging as promising tools for long-term and targeted pest suppression.Integration of conventional and advanced crop protection strategies can substantially reduce storage losses, improve grain quality, and support sustainable agriculture. The review emphasizes the importance of innovative, safe, and environmentally compatible technologies for the effective management of *S. oryzae* under changing agricultural scenarios.

Keywords: *Sitophilusoryzae*, Crop protection, Stored grain pests, Botanicals, Molecular management

Green synthesis of Copper Oxide nanoparticles using *Trichoderma* and vermicompost extract: Implications for crop protection

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ABSTRACT

Copper oxide nanoparticles (CuO NPs) have emerged as promising nanomaterials for sustainable crop protection owing to their antimicrobial and plant growth–modulating properties. The present study investigated the green synthesis, physicochemical characterization, antifungal efficacy, and phytobiological effects of myco-synthesized CuO NPs produced using *Trichoderma* culture filtrate and vermicompost extract as eco-friendly bioreductants, with copper sulfate serving as the precursor. The synthesized nanoparticles were characterized using UV–Vis spectroscopy, FTIR, XRD, and SEM analyses. UV–Vis spectroscopy revealed a characteristic absorption peak around 380 nm, confirming nanoparticle formation, while XRD analysis demonstrated the crystalline nature of CuO with a monoclinic/hexagonal structure. The antifungal activity of CuO NPs was evaluated against six economically important phytopathogenic fungi, namely *Alternaria* sp., *Bipolaris* sp., *Botrytis* sp., *Curvularia* sp., *Fusarium* sp., and *Helminthosporium* sp. *In vitro* assays employing poisoned food technique, mycelial biomass estimation, and conidial germination tests demonstrated significant dose-dependent inhibition of fungal growth. Increasing nanoparticle concentrations markedly reduced radial mycelial growth, fresh and dry biomass accumulation, and conidial germination percentages, highlighting the strong antifungal potential of the synthesized nanomaterial. Seed bioassays conducted on brinjal, tomato, rice, and pigeon pea revealed that low to moderate concentrations of CuO NPs enhanced seed germination and seedling vigor through improved root and shoot elongation. Overall, the findings indicate that myco-synthesized CuO nanoparticles possess dual functionality as eco-friendly nanofungicides and potential nanofertilizers, offering promising applications in sustainable crop protection and plant growth enhancement.

Keywords: Nanoparticles, UV–Vis spectroscopy, Myco synthesized nanoCuO, XRD, SEM

Development of a Weed Detection and Targeted Herbicide Spraying System in Row Crops

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ABSTRACT

Weed infestation in row crops is a major constraint to agricultural productivity, and existing control methods have serious limitations for small and marginal farmers. Manual herbicide spraying exposes workers to toxic chemicals, while large boom sprayers demand high capital investment and operating costs. Mechanical weeding, though chemical-free, is labour-intensive, disturbs soil structure and may damage shallow root systems. These approaches lack site-specificity, leading to uniform herbicide application irrespective of weed distribution, which increases input cost and risks environmental contamination. To address these challenges, a three-wheeled autonomous vehicle has been designed for weed detection and targeted herbicide spraying in row crops. The system consists of a lightweight mild-steel chassis with adjustable wheel track to accommodate different row spacings. Front-wheel steering is actuated by a stepper motor, while rear-wheel differential drive is powered by DC wiper motors. Dual solenoid-controlled nozzles are positioned at the vehicle midpoint, and their actuation is time-compensated for the offset between the front-mounted camera and spray delivery point to enable spot-spraying at detected weed locations. The perception and control architecture is implemented on a Raspberry Pi 5 using ROS2 Humble. Crop row navigation is based on a lightweight U-Net semantic segmentation model trained on publicly available crop-row image datasets. Weed detection is performed using the Excess Green vegetation index, which offers robustness under variable field illumination. The integrated ROS2 framework coordinates vision, navigation and spray nodes for real-time operation. The developed system is expected to reduce herbicide consumption through selective application, eliminate direct operator exposure to chemicals, lower operational costs compared to boom sprayers and avoid soil disturbance associated with mechanical weeding, thereby providing an affordable precision weed management solution for small and marginal farmers.

Keywords: Weed detection; Autonomous spraying system; U-Net segmentation; Row crop navigation; Targeted herbicide spraying; Precision agriculture.

Innovations in Cold Plasma Technology for sustainable agricultural disease management

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ABSTRACT

In agriculture, crop protection chemicals such as fungicides, insecticides, and pesticides are widely used as major tools for crop protection. However, the increasing demand and excessive use of these chemicals have led to several adverse effects, including crop toxicity, environmental pollution, pest resistance, and pest resurgence. To overcome these limitations, alternative approaches such as RNA interference, cold plasma treatment, and nanobiotechnology are gaining importance. Cold plasma, also known as non-thermal plasma, is an ionized gas generated at room temperature in which electrons are highly energetic while ions and neutral particles remain relatively cool. It consists of reactive oxygen and nitrogen species, charged particles, and ultraviolet radiation produced under an electric field, and is therefore referred to as the "fourth state of matter." Cold plasma can sterilize surfaces, decontaminate pathogens, and induce regenerative biological effects without causing thermal damage. Its reactive components cause physical disruption of microbial cell walls and oxidative stress, leading to damage of pathogen DNA and proteins. Beyond surface sterilization, cold plasma acts as a seed priming agent by modifying seed coat topography and increasing its hydrophilic nature, thereby enhancing water uptake and metabolic activity. At the cellular level, plasma exposure induces a controlled oxidative burst that stimulates beneficial stress responses. It regulates the expression of defense-related genes, activates systemic acquired resistance (SAR), and enhances the production of antioxidants and secondary metabolites, thereby improving plant immunity against fungal and bacterial infections. Cold plasma treatment is a sustainable and chemical-free technology that can reduce dependence on conventional crop protection chemicals. These abstract highlights the mechanism of cold plasma, its interaction with plants, and its scalability for field-level applications as a low-cost, eco-friendly, and efficient tool for modern Integrated Pest Management (IPM).

Keywords: Cold plasma, ionized gas, crop protection, decontamination, stress tolerance, Integrated Pest Management.

Role of Bioinformatics in Crop Protection

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ABSTRACT

Bioinformatics has emerged as an important interdisciplinary tool in modern crop protection by integrating biology, computer science and information technology to analyse complex biological data. Which plays a significant role in understanding the molecular mechanisms of insect pests, plant pathogens and host–pest interactions, thereby supporting sustainable agricultural production. Advanced bioinformatics tools facilitate genome sequencing, gene annotation, phylogenetic analysis, protein modelling and identification of molecular markers associated with resistance traits. These approaches help in accurate identification and classification of economically important pests and pathogens. In crop protection, bioinformatics is widely used for studying genetic diversity, evolutionary relationships and population dynamics of insect pests through molecular markers such as COI, COII and 16S rRNA genes. It also contributes to the development of RNA interference (RNAi)-based pest management strategies by identifying target genes essential for pest survival. Furthermore, bioinformatics supports the discovery of novel biopesticides, resistance genes, and biomarkers for early disease detection. The integration of artificial intelligence, machine learning and big data analytics with bioinformatics has further improved pest forecasting, surveillance and decision-making systems in precision agriculture. Databases and computational platforms enable researchers to access genomic and proteomic information for developing eco-friendly and effective crop protection technologies. Overall, bioinformatics provides innovative solutions for sustainable pest and disease management while reducing excessive dependence on chemical pesticides. Its application in crop protection is expected to expand significantly with advancements in next-generation sequencing and computational biology.

Keywords: Bioinformatics, Molecular markers, RNA interference, Phylogenetic analysis, Genomics, Artificial intelligence and Sustainable agriculture

THEME: -3

Startups and Entrepreneurship for Circular Economy

Aloe Vera-Based Bio-Batteries as a Circular Economy Venture: Startup Opportunities, Biotechnological Interventions, and Entrepreneurial Challenges

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ABSTRACT

The transition toward a circular economy has renewed global interest in bio-based, biodegradable alternatives to conventional energy storage systems. This abstract examines the startup and entrepreneurial landscape surrounding aloe vera-based bio-batteries, a technology gaining momentum at the nexus of green chemistry, biotechnology, and sustainable innovation. In India, premier research institutions including the Indian Institutes of Technology (IITs), the Indian Institute of Science (IISc), the Council of Scientific and Industrial Research (CSIR) laboratories, and the National Institutes of Technology (NITs) are actively conducting research on aloe vera gel as a plant-based bio-electrolyte for applications in bio-batteries and supercapacitors. The Aloe E-Cell Research Group further exemplifies niche entrepreneurial focus on aloe-derived electrolyte concepts, though large-scale commercialization remains pending. From a biotechnological perspective, multiple pathways are being explored to address current performance limitations. Microbial biotechnology employs specific bacteria and enzymes like Laccase and Glucose oxidase to enhance electron transfer efficiency and improve biobattery performance. Nanobiotechnology approaches combine aloe vera bioactive compounds—including acemannan polysaccharides, anthraquinones (aloin, emodin), flavonoids, and saponins—with transition metal oxide nanostructures such as $NiCo_2O_4$ and $MnCo_2O_4$ to yield high-performance electrode materials. Biopolymer innovation contributes biodegradable structural components that improve device stability and minimize ecological impact. Waste-to-resource strategies converting aloe vera agricultural residues into functional electrode materials align closely with circular economy principles and promise meaningful reductions in production cost. Despite these advances, significant barriers to commercialization persist. Aloe vera batteries currently exhibit lower energy density compared to mature lithium-ion systems, uncertain charge-discharge cycle longevity, performance sensitivity to environmental conditions such as temperature and humidity, and limited scalability from laboratory to industrial production. Industry trust and consumer adoption further depend on rigorous, long-term safety and performance validation. Nevertheless, the eco-friendly profile—reduced toxic chemicals, biodegradable materials, and lower carbon footprint—presents a compelling value proposition for circular-economy-aligned startups targeting niche markets such as low-power biomedical devices, biodegradable sensors, and rural off-grid energy solutions.

Keywords: Bio-battery, Aloe vera electrolyte,Circular economy,green energy storage. Sustainable, entrepreneurship, Biotechnology Nanobiotechnology, Biodegradable materials, Startup Ecosystem, Biopolymers Abstract

Startups and Entrepreneurship for Circular Economy: A Sustainable Business Model

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ABSTRACT

The global agricultural sector generates billions of tons of lignocellulosic waste annually, often resulting in environmental degradation through open burning. This study explores the potential of mushroom farming as a cornerstone of the circular economy, specifically focusing on the bioconversion of agricultural residues into high-value protein sources. By utilising crop residues such as paddy straw, wheat straw, and cornstalks as substrates, mushroom cultivation provides a sustainable solution for waste management. The process operates on a zero-waste principle: agricultural "waste" is used as a primary resource to produce nutrient-dense mushrooms, generating significant rural income and entrepreneurship opportunities. The Indian mushroom market is valued at USD 1.33 billion in 2024 and is projected to reach USD 2.72 billion by 2030. 300sq.ft. unitcanproduce2400-3000kg/year, generating anannual revenue of 3.5 to5 lakh where net profit is 2-3 lakh. Oyster mushrooms mixed with water hyacinth produce biogas within 12 days. This model reduces dependency on chemical fertilisers, mitigates carbon emissions from waste burning, and fosters local entrepreneurship among youth and women. By integrating biotechnology with traditional farming, mushroom-based startups can drive the "Purvodaya" vision, ensuring food security and environmental sustainability through innovative resource recycling.

Keywords: Circular Economy, Mushroom Cultivation, Waste-to-Wealth, Agricultural Residue, Organic Compost.

Circular Economy Transformations in Indian Agriculture: Evaluating the Socio-Economic Impact of Startups on Farmer Prosperity and Rural Livelihoods

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ABSTRACT

Transitioning from traditional "take-make-dispose" linear systems to a circular economy (CE) is essential for sustainable agricultural growth in India. Generating approximately 350 million tonnes of agricultural waste annually, the sector possesses a projected market potential of $2 trillion and the capacity to create 10 million green jobs by 2050. This research evaluates the burgeoning ecosystem of over 6000 ag-tech startups as a primary catalyst for enhancing farmer prosperity and rural development.Utilizing recent data from NITI Aayog and the Agriculture Infrastructure Fund (AIF), this study examines how startups operationalize the "waste-to-wealth" paradigm through biomass valorization and precision technologies. Key findings indicate that circular interventions can increase average farm incomes by 10–25% by converting residues into compressed biogas, biochar and organic fertilizers. These innovations reduce chemical input dependency by up to 25% while mitigating environmental externalities, such as the □2,540 crore annual health cost associated with stubble burning. The analysis further highlights the socio-economic benefits for rural livelihoods, where decentralized micro-processing and community-led models provide stable employment for youth and women. Strategic government initiatives, including GOBARdhan and the Crop Residue Management (CRM) scheme, have provided the institutional backbone for this transition, supporting over 979 biogas plants and 42,000 Custom Hiring Centres as of 2026. This research concludes that integrating circular principles through startup-led innovation is vital for achieving agricultural resilience and fulfilling India's commitment to a resource-efficient, low-carbon future by 2047.

Keywords: Circular Economy, Ag-tech Startups, Farmers' Income, Waste-to-Wealth, Rural Livelihoods.

Economic Valuation and Carbon Credit Potential of Biochar from Crop Residue: A Proposed Circular Entrepreneurship Model in Bihar

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ABSTRACT

The shift to a circular economy in agriculture offers great chances for better waste management and rural entrepreneurship. Bihar's agriculture, which mainly focuses on paddy, wheat, and maize, produces millions of tonnes of crop residue each year. Mismanaging this biomass, including open field burning, leads to serious environmental and economic issues. However, this often-ignored agricultural waste offers a key opportunity for youth-led "waste-to-wealth" agribusiness startups in Eastern Bharat. Turning crop residue into engineered biochar creates a valuable soil amendment and forms a lasting carbon sink.This study outlines a method to evaluate the financial viability and carbon capture potential of setting up decentralized rural biochar production units in Bihar. It will look into the capital needed, operational costs, and possible revenue sources for these ventures. Based in agricultural economics, the method will use thorough cost-benefit analysis and include current voluntary carbon market accounting frameworks. The main goal is to measure the potential economic value of trading verifiable carbon credits created from biochar, along with the domestic market value of biochar as an organic fertilizer. Additionally, the analysis will look at the long-term economic effects of applying biochar to local agricultural soils to improve moisture retention, boost nutrient efficiency, and lessen the need for synthetic fertilizers. By outlining the financial pathways of this dual-revenue model, the research will offer a solid business plan for new agri-entrepreneurs. Ultimately, the study presents a blueprint showing how connecting carbon markets to secondary agriculture can promote climate resilience and sustainable economic growth in Bihar.

Keywords: Circular Economy, Biochar, Carbon Credits, Crop Residue, Agri-entrepreneurship.

Agri-Waste to Wealth: Mushroom Production and Bio-Briquette Unit as an Integrated Agripreneurship Model for Rural Youth

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ABSTRACT

India produces more than 500 million tonnes of agro-wastes every year, which is either burnt or left to decompose, resulting in environmental degradation and economic loss.In this paper, an integrated agripreneurship model is proposed to utilize all agricultural residues to produce two high-quality value-added products such as edible mushrooms and bio-briquettes to provide a viable livelihood opportunity to young people of the rural areas.Crop residues including paddy straw, wheat straw and sugarcane bagasse are used as substrates for growing oyster mushroom (*Pleurotus ostreatus*).The mushroom 'spent' material and other dry bio-mass waste materials are then converted to bio-briquettes, a clean and renewable energy fuel source that can be used instead of fire wood and coal.By using a dual output method, the generation of waste is close to zero and the use of the resources is as efficient as possible in a circular economy.This unit will need low capital investment, low level of technical skills and if implemented at village level, simple infrastructure.The mushroom culture is a highly profitable business with a return of investment between 30-45 days and the bio-briquette is another industry that could be tapped for domestic and industrial fuel use, making the mixed business very viable.This model gives the youth of rural areas an opportunity to empower themselves, especially the women and first generation entrepreneurs, by converting their locally available waste to marketable commodities.It is aligned with the national agendas like Atmanirbhar Bharat, Viksit Bharat 2047 and sustainable agriculture, green entrepreneurship, inclusive rural development etc.

Keywords: Agri-waste, Oyster mushroom, Bio-briquettes, Circular economy, Rural\ entrepreneurship

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ABSTRACT

The shift to a circular economy in agriculture offers great chances for better waste management and rural entrepreneurship. Bihar's agriculture, which mainly focuses on paddy, wheat, and maize, produces millions of tonnes of crop residue each year. Mismanaging this biomass, including open field burning, leads to serious environmental and economic issues. However, this often-ignored agricultural waste offers a key opportunity for youth-led "waste-to-wealth" agribusiness startups in Eastern Bharat. Turning crop residue into engineered biochar creates a valuable soil amendment and forms a lasting carbon sink.This study outlines a method to evaluate the financial viability and carbon capture potential of setting up decentralized rural biochar production units in Bihar. It will look into the capital needed, operational costs, and possible revenue sources for these ventures. Based in agricultural economics, the method will use thorough cost-benefit analysis and include current voluntary carbon market accounting frameworks. The main goal is to measure the potential economic value of trading verifiable carbon credits created from biochar, along with the domestic market value of biochar as an organic fertilizer.Additionally, the analysis will look at the long-term economic effects of applying biochar to local agricultural soils to improve moisture retention, boost nutrient efficiency, and lessen the need for synthetic fertilizers. By outlining the financial pathways of this dual-revenue model, the research will offer a solid business plan for new agri-entrepreneurs. Ultimately, the study presents a blueprint showing how connecting carbon markets to secondary agriculture can promote climate resilience and sustainable economic growth in Bihar.

Keywords: Circular Economy, Biochar, Carbon Credits, Crop Residue, Agri-entrepreneurship.

Agriculture Cropping Pattern in Bihar: A Markov Chain Analysis of Major Crops over the Last 20 Years

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ABSTRACT

Agriculture plays a vital role in the economy of Bihar, where changes in cropping pattern significantly influence farm income, resource utilization, and regional agricultural development. Over the past two decades, the state has experienced considerable shifts in the cultivation of major crops due to changing climatic conditions, market demand, irrigation facilities, technological advancement, and government policies. In this context, the present study aims to examine the dynamics of cropping pattern shifts in Bihar during the period 2001–02 to 2020–21 using Markov Chain Analysis.The study is based on secondary data collected from sources such as the Directorate of Economics and Statistics Bihar□, Department of Agriculture Bihar□, Agricultural Statistics at a Glance□ and Indiastat□. Major crops considered in the analysis include rice, wheat, maize, pulses, oilseeds, sugarcane, and other commercial crops. The study employs descriptive statistics, compound annual growth rate (CAGR), and Markov transition probability matrices to estimate the stability and movement of cropped area among different crops over time.The results are expected to reveal significant changes in crop allocation patterns across Bihar, with increasing area under maize, sugarcane, and commercial crops, while some traditional cereal and pulse crops may show declining trends. The Markov transition matrix will identify stable crops through higher retention probabilities and unstable crops through greater area shifts toward competing crops. The findings of the study will help policymakers understand long-term agricultural transformation and formulate suitable strategies for crop diversification, sustainable resource management, and agricultural planning in Bihar.The study contributes to the literature on agricultural diversification and regional crop dynamics by providing empirical evidence on the nature and direction of cropping pattern changes in Bihar over the last twenty years.

Keywords: Markov transition probability matrices, compound annual growth rate (CAGR), cropping pattern, retention probabilities.

Agri-Waste to Wealth: Mushroom Production and Bio-Briquette Unit as an Integrated Agripreneurship Model for Rural Youth

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ABSTRACT

India produces more than 500 million tonnes of agro-wastes every year, which is either burnt or left to decompose, resulting in environmental degradation and economic loss.In this paper, an integrated agripreneurship model is proposed to utilize all agricultural residues to produce two high-quality value-added products such as edible mushrooms and bio-briquettes to provide a viable livelihood opportunity to young people of the rural areas.Crop residues including paddy straw, wheat straw and sugarcane bagasse are used as substrates for growing oyster mushroom (*Pleurotus ostreatus*).The mushroom 'spent' material and other dry bio-mass waste materials are then converted to bio-briquettes, a clean and renewable energy fuel source that can be used instead of fire wood and coal.By using a dual output method, the generation of waste is close to zero and the use of the resources is as efficient as possible in a circular economy.This unit will need low capital investment, low level of technical skills and if implemented at village level, simple infrastructure.The mushroom culture is a highly profitable business with a return of investment between 30-45 days and the bio-briquette is another industry that could be tapped for domestic and industrial fuel use, making the mixed business very viable.This model gives the youth of rural areas an opportunity to empower themselves, especially the women and first generation entrepreneurs, by converting their locally available waste to marketable commodities.It is aligned with the national agendas like Atmanirbhar Bharat, Viksit Bharat 2047 and sustainable agriculture, green entrepreneurship, inclusive rural development etc.

Keywords: Agri-waste, Oyster mushroom, Bio-briquettes, Circular economy, Rural entrepreneurship

Infant Feeding Transition: From Exclusive Breastfeeding to Commercial Baby Foods

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ABSTRACT

The increasing consumption of commercial baby food products in place of breastfeeding has become a growing concern for infant health and development. Traditionally, breastfeeding for the first six months has been considered the most beneficial source of nutrition for infants, providing essential nutrients and immunity for healthy growth. However, rapid changes in food habits and the rising availability of ultra-processed infant foods and formula milk have influenced parental feeding practices. The present study focuses on parent's concerns regarding baby food safety and the health effects associated with the replacement of exclusive breastfeeding by commercial infant food products. The study is based on a review of literature published between 2014 and 2026 from various national and international journals. Findings revealed that early and frequent consumption of processed baby foods may negatively affect breastfeeding practices, infant growth, immunity and long-term health outcomes. Infant formulas mainly contain milk solids, vegetable oils, probiotics and additives, which may not provide the same nutritional and protective benefits as breast milk. The study concludes that promoting breastfeeding awareness and reducing dependence on processed baby foods are essential for ensuring better infant health and development.

Keywords: Breastfeeding Awareness, Exclusive Breastfeeding, Infant Growth, Parental Feeding Practices, Ultra-Processed Infant Foods.

Response of composts and chemical fertilizers on yield and economics of chickpea (*Cicer arietinum* L.)

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ABSTRACT

The continuous and excessive use of chemical fertilizers has resulted in deterioration of soil health and reduced sustainability of crop productivity. Integrating organic manures with chemical fertilizers is essential to improve soil fertility, enhance nutrient use efficiency, and maintain long-term productivity. Therefore, a field experiment entitled "Response of composts and chemical fertilizers on yield and economics of chickpea (*Cicer arietinum* L.)" was conducted to assess the use of integrated nutrient management for sustainability and soil health in vertisols. The experiment was conducted at Research Field No. 31, College of Agriculture, Indore (M.P.), India, during the *rabi* season of 2024-25. The experiment was arranged in a randomized block design with 10 treatments and 3 replications. The treatments included: T_1: Control; T_2: 75% RDF; T_3: 100% RDF; T_4: 125% RDF; T_5: 75% RDF + vermicompost @ 3 t/ha; T_6: 100% RDF + vermicompost @ 3 t/ha; T_7: 125% RDF + vermicompost @ 3 t/ha; T_8: 75% RDF + compost @ 5 t/ha; T_9: 100% RDF + compost @ 5 t/ha; and T_{10}: 125% RDF + compost @ 5 t/ha.The findings indicated that the application of 125% RDF + vermicompost @ 3 t/ha produced the highest yield attributes, including number of pods/plant (49.73), number of seeds/pod (1.83), and seed index (23.68 g). Moreover, the highest seed yield (1982 kg/ha) was also recorded under this treatment. In contrast, the maximum straw yield (4119 kg/ha) and biological yield (6097 kg/ha) were observed with 100% RDF + vermicompost @ 3 t/ha. The highest harvest index (32.56%) was achieved with 125% RDF + vermicompost @ 3 t/ha.Economic evaluation showed that the highest gross monetary return (□128,380/ha) was obtained with 125% RDF + vermicompost @ 3 t/ha, whereas the maximum net monetary return (□78,358/ha) was recorded under 100% RDF + vermicompost @ 3 t/ha. The benefit-cost ratio (2.80) was found to be highest under 100% RDF.

Keywords- Chickpea, vermicompost, vertisol, INM

Startups and Entrepreneurship for circular economy

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ABSTRACT

The Bio-Circular Frontier: Entrepreneurship at the Intersection of Agriculture and Biotechnology. The transition to a Circular Economy (CE) finds its most profound application at the intersection of Agriculture and Biotechnology. While industrial circularity often focuses on "technical cycles" (metals and plastics), the integration of agrifood systems and biotech innovations addresses the "biological cycle"—the restoration of natural capital. This abstract examines how startups are leveraging biotechnological advancements to transform linear agricultural waste into high-value regenerative inputs.Agricultural entrepreneurship is currently undergoing a paradigm shift, moving away from extractive "monoculture" logic toward a Bio-Refinery Model. Startups in this space act as vital intermediaries that close the loop through three primary entrepreneurial vectors: Waste-to-Value Valorization: Utilizing synthetic biology and microbial fermentation, entrepreneurs are converting agricultural "waste"—such as crop residues and food processing by-products—into bio-plastics, organic fertilizers, and alternative proteins.

Keywords: Bio- refinery, valorisation, circular economy business model, leveraging

Startups and Entrepreneurship for circular Economy

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ABSTRACT

The circular economy is an innovative economic model that focuses on reducing waste, reusing resources, and recycling materials to create a sustainable system of production and consumption. Unlike the traditional linear economy based on the "take, make, and dispose" approach, the circular economy emphasizes resource efficiency, environmental protection, and long-term sustainability. In recent years, startups and entrepreneurship have emerged as major driving forces in promoting circular economy practices across various sectors such as agriculture, manufacturing, energy, fashion, food processing, and waste management.Startups play a significant role in developing creative and technology-based solutions that minimize environmental impact while generating economic value. Entrepreneurs are introducing sustainable business models such as recycling, up cycling, product sharing, repair services, biodegradable packaging, renewable energy systems, and waste-to-wealth innovations. These ventures not only help conserve natural resources but also create employment opportunities and encourage green economic growth.The growth of digital technology, artificial intelligence, Internet of Things (IoT), and data analytics has further strengthened circular economy initiatives by improving resource tracking, waste management, and efficient production systems.

Keywords: Sustainable business, innovative economy, digital technology, technology based solutions.

Blockchain-Integrated Agri-Entrepreneurship: A Strategic Framework for the Circular Economy in India

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ABSTRACT

As India embarks on the “Viksit Bharat 2047” vision, the application of frontier technologies in agriculture has emerged as a strategic imperative. The amalgamation of agricultural systems and blockchain presents a transformative route to realize the "Waste-to-Wealth" objective, a key pillar of India's circular economy. Traditional supply chains are characterized by opacity and inefficient resource recovery, whereas blockchain provides the digital infrastructure through immutable traceability and smart contracts to address these structural inefficiencies.This research proposes an operational framework for Agri-entrepreneurship through blockchain. The research seeks to explore how decentralized governance and incentivization could help in waste valorisation and connecting waste generators to recyclers in the Indian agribusiness environment.Using PRISMA protocol, this study analyses the high-impact, peer-reviewed documents published between 2021 and 2026.The synthesis focuses on three thematic clusters: Agri-enterprises as lead adopters of blockchain; blockchain-enabled tracking of by-products; and the impact of digital traceability on Agri-MSME market valuation.Findings indicate that blockchain is foundational in "closing the loop" by verifying the provenance of agricultural residues. Traditionally treated as liabilities, Agri-wastes are being integrated into secondary markets for bio-energy and organic inputs. However, the ecosystem faces a complex SWOT profile; while transparency is enhanced, high technical barriers and digital literacy gaps in rural India remain significant weaknesses.Agri-startups are uniquely positioned to leverage tokenized reward systems to bypass intermediaries and incentivize sustainable practices like stubble management. Integrating “blockchain startups” with the “National Strategy on Blockchain” creates opportunities for converting waste into sustainable raw materials capable of fetching premium prices internationally.This study provides a roadmap for scaling blockchain-drivenAgri-enterprises, emphasizing that digital maturity is a prerequisite for a resilient circular economy. Overcoming regulatory uncertainty and interoperability challenges is essential to realizing a truly sustainable agricultural future for India.

Keywords: Agri-entrepreneurship, Blockchain, Circular Economy, Waste-to-Wealth, Viksit Bharat 2047, Agri-MSMEs.

New vista in Agriculture: Scenario of Agritech startups in Bihar

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ABSTRACT

The transition from traditional agriculture to agribusiness is essential for enhancing farm profitability and rural economic growth. However, the entrepreneurial ecosystem driving this transformation remains disproportionately concentrated in metropolitan areas. Despite these geographic disparities, an emerging wave of agritech start-ups is actively disrupting traditional agricultural systems supported by evolving regional initiatives, such as Bihar's vibrant start-up policy and growing co-working infrastructure, these enterprises are providing innovative, cost-effective solutions across the entire food value chain. Among the major institutions promoting agri startups in Bihar, Notably DeHaat is one of the fastest growing startups in the agritech sector in the state, recently these builds AI enabled technologies to revolutionize supply chains and production efficiency in the farming sector. DeHaat operates through vast network of over 11,000 centres and 503 FPOs catering to over 1.8 Million farmers. Under the Startup Bihar Portal, more than 1500 startups have been funded, showing the growing startup ecosystem supporting agriculture and rural employment in Bihar. Along with DeHaat, the incubation centre is operating in Bihar Agricultural University (BAU), Sabour named as SABAGRI (Sabour Agri Incubators) funded by RKVY RAFTAR (GoI), Since from its inception, it has incubated 97 startups in agriculture and allied activities and these startups has generated good revenue and also created employment opportunities. For agrarian states, these start-ups are not just businesses, but crucial engines for livelihood creation. To fully harness the potential of agritech in agrarian economies, several strategic policy interventions are necessary, the policies must explicitly incentivize the establishment of incubators, accelerators, and co-working spaces in rural areas to democratize access to entrepreneurial resources and also State governments should establish dedicated venture funds and seed capital programs specifically for agricultural innovations that address regional infrastructure and supply chain deficits.

Keywords: Start-up, Agritech, Livelihood, Bihar, Innovation

Economic Viability and Entrepreneurial Potential of Crop Residue Management in Eastern India: A Circular Economy Approach

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ABSTRACT

The transition from linear agricultural production to a circular economy is imperative for sustainable development in Eastern Bharat. This study evaluates the economic viability of utilizing crop residue as a primary input for rural entrepreneurial startups, focusing on its conversion into bio-briquettes, enriched compost, and biochar. Traditional practices of crop stubble burning not only degrade environmental quality but also represent a significant loss of potential economic value and soil nutrient capital. Drawing upon established frameworks in agricultural economics, including cost-benefit analyses, supply chain economics, and the valuation of environmental externalities, this paper systematically assesses the profitability of residue-based micro-enterprises. Market analysis indicates that while the initial capital investment for processing machinery poses a barrier to entry for individual farmers, the long-term marginal returns are highly favorable. This profitability is driven by the negligible cost of raw materials and the rapidly increasing market demand for sustainable energy alternatives. Furthermore, the integration of Farmer Producer Organizations (FPOs) into the biomass supply chain significantly reduces transaction and logistics costs while enhancing collective bargaining power. Referencing empirical studies on agricultural resource economics and institutional support structures, the analysis demonstrates that state-subsidized credit combined with targeted entrepreneurial training yields a high benefit-cost ratio. This transforms agricultural waste from a systemic liability into a lucrative revenue stream for rural youth. The paper concludes that establishing a robust circular economy framework in agriculture requires deliberate policy shifts that financially incentivize green startups. Fostering such innovative entrepreneurial ecosystems provides a scalable, economically sound model for value addition, mitigating environmental hazards while simultaneously generating sustainable rural employment and driving regional agricultural economic growth.

Keywords: Agricultural Economics, Circular Economy, Crop Residue Management, Rural Entrepreneurship, Cost-Benefit Analysis, Startups

Your Farm: An Agri-Tourism Venture Driven by Integrated Farming Systems for a Circular Economy

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ABSTRACT

"YOUR FARM" is an innovative startup inspired by the ideas of Integrated Farming Systems (IFS), agritourism, and the circular economy. Our goal is to build a sustainable and self-reliant ecosystem that brings together crop production, livestock, fisheries, horticulture, agroforestry, and small rural industries—all working in harmony. In this system, waste from one area becomes a resource for another, making the most of every input and reducing environmental impact. We blend cutting-edge agricultural technologies, like drones for fieldwork, with traditional farming practices and local cultural activities. This approach not only boosts productivity and profits but also helps preserve rural heritage. Through agritourism, visitors can enjoy authentic rural experiences: staying on the farm, relaxing in treehouses or by the pond, and trying hands-on activities such as traditional food processing, pottery, garland making, preparing dung cakes, or weaving straw baskets. These activities open up new employment and income opportunities for rural communities. Sustainability is at the heart of "YOUR FARM." Practices like recycling sewage, nutrient cycling, and managing organic waste reduce the need for outside resources and keep the system balanced. While we recognise there are challenges like the need for significant initial investment, longer setup times, and small land sizes we believe the adaptable IFS model can be expanded to suit different climates and regions. In short, "YOUR FARM" offers a forward-thinking way to combine agriculture, tourism, and the circular economy to support environmental conservation, rural development, and economic growth.

Keywords: Agritourism, Integrated Farming System, Circular Economy, Rural Entrepreneurship, Sustainability.

Contribution of Production Factors ToThe Yield and Economics of Barnyard Millet

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ABSTRACT

A field experiment entitled "Contribution of production factors to the yield and economics of Barnyard Millet" was conducted during *Kharif*, 2025, at Research Farm, TCA , RPCAU, Bihar. The experiment was laid out in Randomized Block Design (RBD) with seven treatments and replicated thrice to evaluate the individual contributions of major production factors on the yield and economic returns of Barnyard Millet. The treatments consisted of a complete package of practices (RDF + $ZnSO_4$ @ 12.5 kg/ha + bioinoculant seed treatment with *Azospirillum* + thinning and gap filling + weeding and hoeing at 3 and 5 weeks after sowing + earthing up) and successive omission of one factor at a time. The results revealed that the complete package (T_1) recorded significantly highest grain yield (20.45 q/ha), straw yield (41.95 q/ha), gross returns (98,219/ha) and net returns (53,219/ha) as compared to rest of the treatments but it was statistically at par with treatment T_3 (T_1 – $ZnSO_4$ @ 12.5 kg/ha) and T_4 (T_1 – seed treatment). Among the omission treatments, the lowest grain yield (11.04 q/ha) was observed in T_6, where weeding and hoeing were excluded, indicating that weed management was the most critical yield-determining factor, followed by T_2 (T_1 – RDF) and T_5 (T_1 – Thining and gap filling). Omission of RDF (T_2) and thinning and gap filling (T_5) also resulted in substantial yield reduction, highlighting the importance of balanced nutrition and optimum plant population. Omission of weed management resulted in highest yield loss followed by omission of RDF, omission of thining and gap filling. The study concluded that integrated application of balanced fertilizer, micronutrient supplementation, bioinoculant seed treatment, proper plant population management, and timely weed control significantly enhances the productivity and profitability of Barnyard millet. Among all production factors, weed management, recommended fertilizer, thining and gap filling were identified as the major contributors to yield improvement.

Keywords: Barnyard millet, production factors, omission technique, weed management, RDF, thinning and gap filling, integrated nutrient management.

Circular Bioeconomy Approach to Protein Recovery: Optimizing Green Extraction for Rice Bran

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ABSTRACT

Rice bran, a nutrient-rich by-product of rice milling, is an abundant yet underutilized source of plant protein. Developing sustainable extraction methods is essential to valorize this resource while reducing reliance on chemical-intensive processes. In this study, ultrasound-assisted extraction (UAE) using water as solvent was optimized through Response Surface Methodology (RSM) to enhance protein recovery and functional properties. The optimized UAE conditions (430 W sonication power, 0.3 g/ml solid–liquid ratio, 25 min) achieved a markedly higher protein yield (74.12%) compared to conventional alkali extraction (52.23%). Beyond yield, UAE significantly improved techno-functional attributes, including antioxidant activity (61.43% vs. 50.6%), total phenolic content (34.73 vs. 25.1 mg GAE/g), water absorption capacity (3.95% vs. 2.82%), emulsifying activity (71.4% vs. 62.3%) and stability (61.2% vs. 51.76%), foaming capacity (42.5% vs. 30.33%) and stability (38.56% vs. 32.53%), as well as solubility (65.23% vs. 49.40%). The RSM-based optimization confirmed UAE as a statistically robust, chemical-free, and economical process, eliminating the need for harsh reagents while delivering proteins with enhanced functional quality. Overall, UAE establishes itself as a superior green technology for rice bran protein extraction, aligning with circular bioeconomy principles and expanding opportunities for its incorporation into food systems requiring improved solubility, emulsification, and antioxidant functionality.

Keywords: Rice bran protein, Green extraction, Ultrasound-assisted extraction (UAE), Functional properties, Circular bioeconomy, Chemical-free process, Sustainable valorisation

Agriculture Cropping Pattern in Bihar: A Markov Chain Analysis of Major Crops over the Last 20 Years

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ABSTRACT

Agriculture plays a vital role in the economy of Bihar, where changes in cropping pattern significantly influence farm income, resource utilization, and regional agricultural development. Over the past two decades, the state has experienced considerable shifts in the cultivation of major crops due to changing climatic conditions, market demand, irrigation facilities, technological advancement, and government policies. In this context, the present study aims to examine the dynamics of cropping pattern shifts in Bihar during the period 2001–02 to 2020–21 using Markov Chain Analysis. The study is based on secondary data collected from sources such as the Directorate of Economics and Statistics Bihar□, Department of Agriculture Bihar□, Agricultural Statistics at a Glance□ and Indiastat□. Major crops considered in the analysis include rice, wheat, maize, pulses, oilseeds, sugarcane, and other commercial crops. The study employs descriptive statistics, compound annual growth rate (CAGR), and Markov transition probability matrices to estimate the stability and movement of cropped area among different crops over time.The results are expected to reveal significant changes in crop allocation patterns across Bihar, with increasing area under maize, sugarcane, and commercial crops, while some traditional cereal and pulse crops may show declining trends. The Markov transition matrix will identify stable crops through higher retention probabilities and unstable crops through greater area shifts toward competing crops. The findings of the study will help policymakers understand long-term agricultural transformation and formulate suitable strategies for crop diversification, sustainable resource management, and agricultural planning in Bihar. The study contributes to the literature on agricultural diversification and regional crop dynamics by providing empirical evidence on the nature and direction of cropping pattern changes in Bihar over the last twenty years.

Keywords: Markov transition probability matrices, compound annual growth rate (CAGR), cropping pattern, retention probabilities.

Flower Waste Recycling: An Emerging Sustainable and Profitable Enterprise

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ABSTRACT

India's floriculture sector has witnessed rapid expansion due to the increasing demand for flowers in weddings, festivals, religious ceremonies, hotels, markets, and household decoration. The Indian flower market was valued at nearly INR 323.8 billion in 2025 (IMARC Group, 2025). However, a major concern associated with this industry is the generation of enormous quantities of floral waste, with nearly 25–40% post-harvest losses reported in floriculture. Approximately 8 million tonnes of flower waste are discarded annually into rivers and other water bodies, causing severe environmental pollution, particularly in sacred rivers such as the Ganga. The sustainable utilization of flower waste has emerged as an innovative approach within the circular bioeconomy. One important method is the production of biogas through anaerobic digestion technology from floral residues. Floral debris can also be transformed into nutrient-rich organic manure and vermicompost containing significant amounts of nitrogen, phosphorus, and potassium. Marigold waste has been successfully converted into biochar after washing, drying, and thermal treatment, providing an eco-friendly soil amendment. Flower petals are further utilized for natural dye extraction in wool yarn processing, while sun-dried floral powders are used in the preparation of herbal colours for Holi celebrations. The conversion of floral waste into commercial products offers a promising business opportunity with a Benefit-Cost ratio ranging from 1.8 to 2.5. Thus, flower waste management not only minimizes environmental pollution but also generates sustainable income, employment opportunities, and eco-friendly products for society.

Keywords: Benefit-Cost ratio, Biochar, Circular bioeconomy, Flower waste utilization, Herbal colour,

Value Addition of Flowers Through Dehydration Technology

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ABSTRACT

Flower dehydration technology is an effective method for preserving highly perishable flowers by removing moisture while maintaining their natural color, shape, and texture. Fresh flowers have a short shelf life, leading to high post-harvest losses; however, dehydration converts them into durable and value-added products. Various methods such as air drying, press drying, embedded drying, hot air oven drying (40–50°C), microwave drying, glycerine drying, vacuum drying, and freeze drying are used depending on the flower type and quality requirements. Mandal and co-workers (2023) reported that hot air oven drying at 50°C resulted in the fastest drying (4.17 days) and maximum moisture reduction (up to 89.21%), while embedded drying methods showed better shape retention in chrysanthemum. Singh and Kumari (2023) found that dried flowers can be stored from 6 months to more than 3 years, and value-added products such as greeting cards, wall hangings, and bouquets exhibited benefit–cost ratios ranging from 1.5 to 3.0, with fine art products reaching up to 5.0. Visalakshi and co-workers (2015) observed that freeze drying preserved superior color, texture, and overall acceptability, while Megha and co-workers (2019) reported that glycerine treatment at 40% concentration using full dip method-maintained flexibility and improved foliage quality.

Keywords: Value addition, dry flowers, dehydration technology, B:C ratio

THEME: -4

AI and Digital Technologies for Agricultural Mechanization

AI Application in Harvesting Machinery: A Review

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ABSTRACT

Artificial Intelligence (AI) is rapidly transforming agricultural harvesting systems from conventional mechanized operations toward autonomous and intelligent machinery capable of addressing increasing labor shortages, rising production costs and the demand for precision agriculture. This review paper examines recent advancements in AI applications in harvesting machinery, with particular emphasis on autonomous combine harvesters and robotic fruit-picking systems. The study highlights the growing integration of Computer Vision technologies, especially advanced object detection models such as YOLOv8+ and multispectral imaging systems, for accurate crop identification, ripeness detection, disease recognition and selective harvesting under complex field conditions. These technologies enable real-time decision-making and improve harvesting precision while minimizing crop losses and mechanical damage. The review further discusses the role of Reinforcement Learning (RL) algorithms in autonomous navigation and path planning for harvesting robots operating in GPS-denied or unstructured agricultural environments. AI-driven navigation frameworks support adaptive obstacle avoidance, route optimization and efficient machine coordination, thereby improving operational efficiency and reducing fuel consumption. Significant advancements in mechanical integration are also examined, particularly the development of AI-controlled soft robotic grippers designed for delicate fruit handling. These systems utilize tactile sensing and adaptive gripping strategies to reduce bruising and maintain post-harvest quality in high-value horticultural crops. Emerging trends anticipated for 2026 include swarm robotics for coordinated multi-robot harvesting operations and 5G-enabled fleet management systems for real-time machine communication, cloud-edge data synchronization and remote supervision of autonomous harvesting units. Overall, AI-enabled harvesting technologies demonstrate substantial potential for improving productivity, reducing environmental impacts through optimized resource utilization and enhancing sustainability in modern agriculture. However, challenges related to data governance, high computational requirements, cybersecurity, and sensor robustness under harsh and dynamic field conditions continue to limit large-scale adoption and require further interdisciplinary research.

Keywords: Artificial Intelligence (AI), Agricultural Mechanization, Harvesting Machinery, Computer Vision, YOLOv8+, Multispectral Imaging, Reinforcement Learning

Assessment of surface and sub-surface ground water quality index for irrigation purpose of Araria district of Bihar using remote sensing and GIS

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ABSTRACT

Ground water is the most important natural resources in koshi region of Bihar. Ground water quality assessment is essential to maintain the soil and crop productivity to higher labels without damaging the soil health. Bihar, is primarily reliant on groundwater to meet its daily requirements, and overexploitation has placed significant strain on the quality and quantity of groundwater resources. Regular monitoring of groundwater (surface and sub-surface) quality for drinking and irrigational purposes can be useful to detect any undesirable change in its ionic composition. Therefore, the study has been put forward with an objective to monitor the current status of groundwater (surface and sub-surface) and give a comprehensive account of spatial and seasonal variation in its physico-chemical characteristics and irrigational suitability using GIS-based approach. Two forty-five groundwater samples were collected seasonally (pre-monsoon, monsoon and post-monsoon) from different locations of Araria district of Bihar in 2020–2023 and analyzed for physico-chemical characteristics using standard procedures. All the parameters were compared with the Bureau of Indian Standards 2012. Significant spatial variation was observed in pH, electrical conductivity, total dissolved solids, Mg2+, Na+, HCO3 −, and Cl− between sampling sites. The suitability of groundwater for irrigation was evaluated with the help of sodium adsorption ratio, percent sodium, residual sodium bicarbonate, magnesium hazard, and potential salinity. Based on different irrigational indices, 20% of surface water sample s of Araria district were unfit for irrigation in terms of PH, and 30% unfit in terms of TDS.30% of ground water samples of from tube well of 75-100 feet depths were unfit for irrigation in PH.35%,22.5 %,15%, and 22.5% sample from tube wells of 15-30 feet depth were unfit for irrigation in terms of EC,TDS,NA and Nitrate respectively.35%,22.5%,15% and 22.5% sample from tube wells of 15-30 feet depth were unfit for irrigation in terms of EC,TDS,Na,and Nitrate respectively in Narpatganj, Kursakarta block of Araria district.

Keywords: Groundwater, GIS, Spatial Variation, Seasonal Variation, Irrigational Suitability, Physico-chemical Parameters

Digital Twin Technology for Agricultural Machinery Management

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ABSTRACT

The worldwide agricultural system faces dual problems because it needs to boost crop production by 50% from its 2012 levels until 2050 in order to feed a growing population that will reach 10 billion people while also cutting down on agricultural water usage which currently accounts for 69% of global freshwater resources. Modern precision agriculture systems require advanced maintenance methods and automated management solutions because traditional maintenance methods and manual control techniques fail to solve the complex problems which arise when equipment functions in extreme environmental conditions that include cyclic mechanical loads and abrasive soil contacts and chemical hazards. Digital Twin (DT) technology establishes a new system which creates an active two-way connection that enables real-time data exchange between actual equipment and its digital twin model. This academic review examines the integration of multi-modal sensing, high-fidelity numerical modelling primarily Finite Element Analysis (FEA) and intelligent diagnostic algorithms including Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs) for machinery health assessment.The analysis synthesizes evidence from recent frameworks, which include the Smart Water Management Platform (SWAMP) and FIWARE-based IoT architectures, that enable operational asset synchronization with discrete event simulation environments which include Siemens Plant Simulation. The researchshows that agricultural machinery management through digital twin implementation results in 25% maintenance cost reduction and 70% equipment failure prevention and 35% unplanned downtime decrease and 20% operational productivity improvement. The system has improved performance yet it faces multiple technical challenges because environmental noise interferes with data acquisition while cloud processing in rural areas suffers from high latency and real-time multi-physics simulations require intensive computational resources. The review concludes by outlining future research trajectories, which focus on edge computing, blockchain to maintain data integrity, and Foundation Model integration to build autonomous self-aware agricultural machinery systems.

Keywords: Digital Twin Technology, Precision Agriculture, Agricultural Machinery Management, Predictive Maintenance, Smart Farming Systems

Statistical and Machine Learning Analysis of Growth Drivers and Risk Dynamics in the Global Makhana (*Euryale ferox*) Market

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ABSTRACT

Makhana (*Euryale ferox*), commonly known as Fox nut, is an emerging high-value agricultural commodity experiencing rapid market expansion due to changing Consumption patterns, increasing Health Awareness, and Digital market Expansion. Recent industry projections indicate that the Global Fox Nuts market is expected to reach approximately USD 4.7 billion by 2036, growing at a CAGR of around 11% during 2026–2036, highlighting its strong future potential. This study aimed to identify major growth drivers and AnalyzeRisk dynamics using an integrated framework of Statistical and Machine learning approaches.A constructed time-series dataset (2008–2025) was developed using CAGR-based trends and index-based variables representing Demand, Online Expansion, Health Awareness, and composite Risk factors. Multiple linear regression analysis in SPSS revealed that the model explained approximately 98.9% of variation in growth ($R^2 = 0.989$, $p < 0.001$), with Demand showing a strong positive association, while other variables exhibited limited individual significance due to Multicollinearity. Random Forest Analysis explained about 95.7% of variation and indicated that Demand, Online Expansion, and Health Awareness collectively influenced growth, whereas Risk factors showed comparatively lower direct importance. XGBoost results further identified demand as the dominant predictor, accounting for the highest predictive gain.To strengthen Risk interpretation, Growth Stability Index (GSI), Risk Zoning, and Demand–Risk Ratio (DRR) analyses were performed. The results indicated that growth persisted across moderate and high-risk environments, suggesting increasing Market Resilience where strong demand and digital expansion partially offset adverse market and supply-side risks. Overall, The findings support Resilience-Oriented Market analysis using integrated Statistical and Machine learning approaches.

Keywords: Makhana, Growth Drivers, Risk Analysis, Market Resilience, Random Forest, GBoost, CAGR

AI and Digital Technologies for Agricultural Mechanization

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ABSTRACT

Agricultural mechanization has always been a key factor in raising farm productivity, enabling to cultivate larger areas, produce higher yields and reduce dependency on labor. But traditional mechanisation is increasingly being limited by issues such as climate change, labour shortages and resource constraints. Thus, a new transformation is emerging, often referred to as Agriculture 4.0, which integrates artificial intelligence (AI), machine learning, Internet of Things (IoT), sensors, drones, and advanced data analytics into agricultural machinery and practices.This paper reviews the recent progress on AI and digital technologies for agricultural mechanization and their role in addressing the critical agricultural challenges. These technologies enhance precision in agricultural activities such as irrigation, fertilization, pest and weed management, and crop surveillance. They use real-time data analysis and predictive modeling to optimize resource use, reduce over-application of chemicals, improve soil health and support better decision-making. Also, innovations like automated irrigation systems and AI-based plant identification help in better crop management and productivity. Developed and emerging economies around the world are deploying these technologies to improve efficiency, sustainability and resilience in food production systems. While developed countries are focusing on autonomous machinery and predictive analytics, countries like India are utilizing cost-effective solutions such as drones and mobile-based AI platforms.But there are still some issues that need to be addressed even with these improvements including low digital literacy, lack of infrastructure, poor connectivity and issues around data privacy and accessibility.To sum up, AI and digital technologies have huge potential to revolutionize agricultural mechanization by improving productivity, sustainability and economic viability. Inclusive access, farmer training and strong policy support will be essential to achieve a resilient and sustainable global agricultural future to feed a growing population.

Keywords: Artificial Intelligence, IoT, Agricultural Mechanization, Precision Farming, Machine Learning

Spatio-Temporal Mapping of Soil Moisture using Geostatistical Techniques: A review

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ABSTRACT

Soil moisture, a critical factor influencing crop productivity and irrigation planning, exhibits considerable spatial and temporal variability. Soil moisture variability is influenced by factors such as soil texture, topography, vegetation, and rainfall, leading to heterogeneous patterns across agricultural landscapes. Temporal dynamics indicate rapid increases in soil moisture following precipitation events, followed by gradual depletion due to evapotranspiration and plant uptake (Robinson et al., 2008). Application of geostatistical techniques is now rapidly increasing to study the Spatio-temporal dynamics of any phenomenon due to its ability to portray continuous variation of any property or phenomenon. This review explores the potential of geostatistical techniques for spatial and temporal variability mapping of soil moisture to promote a precision irrigation system. Various researchers have utilised geostatistical approaches such as Ordinary Kriging (OK) and Inverse Distance Weighting (IDW) to transform point-based soil property observations into continuous spatial distributions (Webster & Oliver, 2007, Mondal et al., 2019). Among these, OK provides superior prediction accuracy to IDW by incorporating spatial dependence through semivariogram modelling (Hengl et al., 2007). Future studies should explore other advanced techniques, such as machine learning techniques to predict soil moisture by considering different environmental variables in an efficient way to assure precision irrigation management to crops. These advancements support precision irrigation, drought monitoring, and data-driven decision-making in modern agriculture.

Keywords: Geostatistics, Precision Irrigation, Soil Moisture, Spatial Variability

MRDANVAYA 0.1: A Modular Agribot for Smart and Sustainable Farming

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ABSTRACT

Modern agriculture faces critical challenges such as labor shortages, reduced operational efficiency, and the growing demand for sustainable and precision-based farming practices. To address these issues, MRDANVAYA 0.1 is proposed as a next-generation modular agribot designed for adaptability, efficiency, and affordability in agricultural operations.The system is built on a lightweight yet durable aluminium framework with standardized mounting slots, enabling seamless plug-and-play integration of multiple functional modules. Its intelligent sensing system continuously monitors crop health, detects obstacles, and evaluates environmental conditions, ensuring accurate real-time decision-making.MRDANVAYA integrates specialized modules for precision seed sowing, targeted weed removal, and efficient field mobility. The mobility system incorporates a robust drive mechanism along with interchangeable wheel configurations, allowing smooth operation across diverse terrains. A centralized control unit processes sensor data and coordinates all modules, enabling synchronized and semi-autonomous functionality.Additionally, the system features a voice control interface that allows farmers to operate the agribot using simple commands, improving accessibility and ease of use. By combining modular design, intelligent sensing, and automation, MRDANVAYA reduces dependency on manual labor, enhances productivity, and promotes sustainable agricultural practices.The proposed system represents a scalable and practical solution to modern farming challenges and contributes to the integration of smart technologies in agriculture.

Keywords: Agribot, Precision Farming, Modular Robotics, Sustainable Agriculture, Smart Farming

Autonomous Vehicle in Agriculture - A Review

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ABSTRACT

The global agricultural sector is under growing pressure to produce more food with less labour and lower environmental impact and higher resource efficiency. The autonomous vehicle system which includes self-guided tractors and field robots and precision sprayers and weeders and harvesters and unmanned aerial vehicles provides essential technological solutions needed to meet these requirements. The poster delivers an extensive evaluation of autonomous agricultural vehicles (AAVs) which demonstrates their development from basic automatic guidance systems and GPS-assisted auto-steering technology to present-day systems that utilize artificial intelligence and sensor fusion and machine learning.The poster systematically examines the core technological components enabling autonomy in field conditions: GNSS/RTK positioning, LiDAR, vision-based perception, inertial measurement, path-planning algorithms, and robust control strategies. It further analyses the trajectory of research focus over recent decades, documenting a clear shift from basic navigation accuracy toward integrated multi-sensor perception, real-time obstacle avoidance, and coordinated multi-robot operations.Commercialization status is critically evaluated across vehicle types and application domains. While auto-steering and precision guidance are now commercially mature, fully autonomous platforms remain at early deployment stages, constrained by high capital costs, limited robustness in real-world field environments, insufficient regulatory frameworks, and challenges in farmer adoption, particularly among smallholder and resource-limited farming communities.The poster presents essential performance benchmarks while showing ongoing technical and social economic challenges and recommending specific research areas which will investigate all weather perception systems and low cost modular systems and safety requirements and methods to evaluate social economic effects. The findings demonstrate that autonomous agricultural vehicles can achieve their maximum operational capacity when three specific areas: technology, policy, and context-based deployment methods are developed simultaneously.

Keywords: Autonomous Agriculture Vehicle, Field Robotics, Precision Agriculture, Commercialization of Autonomous Agricultural Vehicles, Farm Automation

Ai-Powered Smart Farming: Transforming Indian Agriculture Through Digital Technologies

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ABSTRACT

Agriculture is the backbone of the Indian economy and supports the livelihood of millions of people across the country. Despite significant advancements in agricultural production, Indian farmers continue to face several challenges such as climate change, water scarcity, pest attacks, labour shortages, declining soil fertility, and unstable market conditions. Traditional farming methods are often unable to address these growing challenges effectively. Therefore, the adoption of Artificial Intelligence (AI) and digital technologies has become increasingly important in modern agriculture.AI-powered smart farming uses advanced technologies such as drones, IoT sensors, machine learning, satellite imaging, GPS-enabled machinery, and mobile applications to improve agricultural productivity and sustainability. These technologies help farmers make data-driven decisions related to irrigation, crop monitoring, disease detection, weather forecasting, and resource management.

Keywords: Agriculture, advancements, IoT sensors, satellite imaging, sustainability

Transforming agricultural mechanization in eastern India through artificial intelligence and digital technologies: oppurtunities and challenges

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ABSTRACT

Indian agriculture is undergoing a transformation from manual labour to intelligent production systems with the help of agricultural mechanization.Eastern India is dominated by small holdings, high labour dependency, and heterogeneous agro-climatic zones. This region is highly in need of this transformation and also structurally complex.In this context, the integration of Artificial Intelligence (AI) and digital technologies presents an exciting opportunity to rethink how farms can be managed, but the challenge is to investigate and qualify the scaling up of global technology to local solutions.The present review highlights the transformation of the major mechanization areas such as autonomous crop scouting, variable-rate input applications, real-time disease diagnosis and predictive crop yield modelling enabled by machine learning algorithms, computer vision, IoT sensor networks and UAV based multispectral platforms.The use of agricultural robots and AI-powered farm management systems is showing tangible improvements in operational timeliness and efficiency of resource use, while geospatial analytics is opening up new possibilities for site-specific decision-making at scales that were unfeasible for smallholder systems in states such as Bihar, Jharkhand, West Bengal and Odisha.However, adoption is still limited due to high investment costs, lack of digital infrastructure in remote areas, limited digital skills, and land fragmentation that hampers economies of scale through machine usage.Certain schemes like SMAM and custom hiring centres provide partial solutions, but remember there are system gaps.This paper suggests that designing the technology, providing last mile extension services on digitalization and introducing access models supported by agri-fintech together can create an ecosystem where youths from eastern India act as agents of an AI-mechanization revolution in alignment with Viksit Bharat 2047.

Keywords: Agricultural Mechanization, Artificial Intelligence, UAV, Machine Learning, Eastern India, IoT

The significance of Precision Farming and Artificial Intelligence in Sustainable Agriculture

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ABSTRACT

Climate change, declining soil quality, increasing water scarcity, and high input prices are all major challenges for agriculture; therefore, contemporary agronomic practices such as Precision Farming and Artificial Intelligence (AI) will play a significant role in the future of sustainable agriculture. Precision Farming allows farmers to apply their water, fertilizer, and pesticide inputs in both the appropriate quantity and at the precise moment, thus maximizing efficiency and minimizing waste. Real-time monitoring of crop health, soil moisture, pest presence, and weather conditions is possible through AI-powered technologies such as drones, sensors, satellite imagery, and smart irrigation systems.This study examines how AI and Precision Farming will increase crop yields, optimize resource management, and promote ecological sustainability. The application of digital tools and Machine Learning will provide producers with better decisions regarding crop establishment, irrigation, fertilization, and harvesting. AI and Precision Farming will reduce reliance on labor, lower production costs, and increase revenues. By using Precision Farming techniques, farmers will conserve natural resources and be able to adapt to climate change. Although these technologies have numerous benefits, small and marginal producers will continue to face significant challenges due to limited knowledge and training, lack of technical support, and high up-front expenses. Therefore, government assistance, extension education, and technical assistance will be required to support the adoption of AI and Precision Farming by small and marginal producers.

Keywords: Climate Change, Technical Support, Precision Farming, Real-Time Monitoring

Hydroponics and Soil Less Farming

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ABSTRACT

Hydroponics and soilless farming are advanced agricultural techniques that enable the cultivation of plants without the use of natural soil. In these systems, plants are grown using nutrient-rich water solutions or inert growing media such as cocopeat, perlite, sand, or gravel. These innovative methods have emerged as sustainable alternatives to conventional farming due to increasing concerns regarding water scarcity, declining soil fertility, rapid urbanization, and the growing demand for food production. Hydroponic systems provide essential nutrients directly to plant roots in a controlled environment, resulting in improved nutrient absorption, faster plant growth, and higher crop productivity. Soilless farming also includes related technologies such as aeroponics and aquaponics, which further enhance resource-use efficiency and support sustainable cultivation practices. These systems minimize dependence on arable land and significantly reduce issues associated with soil-borne diseases, weeds, and excessive pesticide use. One of the major advantages of hydroponics is efficient water utilization, as the recirculation of nutrient solutions reduces water consumption compared to traditional farming methods. Additional advantages include year-round crop production, better space utilization, reduced labor requirements, higher yield per unit area, and the ability to cultivate crops in urban areas, rooftops, greenhouses, and regions with poor soil quality. Hydroponic farming also allows better control over environmental conditions, leading to improved crop quality and reduced risk of crop failure caused by adverse climatic conditions. Commonly cultivated hydroponic crops include lettuce, tomatoes, cucumbers, spinach, herbs, and strawberries. Despite its numerous benefits, hydroponic farming requires high initial investment, technical expertise, and continuous monitoring of nutrient and environmental conditions. However, rapid advancements in agricultural technology and growing awareness of sustainable farming practices are accelerating its adoption worldwide. Overall, hydroponics and soilless farming represent promising solutions for future agriculture by enhancing productivity, conserving natural resources, and contributing to global food security in an environmentally sustainable manner.

Keywords: Hydroponics, Soilless Farming, Global Food Security, Traditional Farming, Rapid

Autonomous Precision-Fertigation Systems: A Deep Learning Approach to Optimizing Nutrient Efficiency for Smallholder Farmers

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ABSTRACT

Global food security is increasingly threatened by soil degradation and inefficient resource management. Traditional "blanket" fertilization methods lead to high input costs and environmental runoff, particularly in the Eastern Bharat region. This study proposes the development of a low-cost, AI-integrated autonomous fertigation module designed for localized agricultural mechanization.The system utilizes a Convolutional Neural Network (CNN) trained on multispectral imagery to detect real-time crop nutrient deficiencies. By integrating these insights with an automated drip-irrigation framework, the prototype delivers precise macro-nutrient doses tailored to specific plant requirements. Preliminary results indicate a 25% reduction in fertilizer waste and a 15% increase in yield compared to conventional methods.Beyond technical efficacy, this innovation addresses the "Purvodaya Krishi Sangam" vision by offering a scalable business model for youth-led agritech startups. By reducing the barrier to precision technology, this system empowers young entrepreneurs to provide "Precision-as-a-Service" to small-scale farmers, ensuring both environmental sustainability and economic viability in the circular economy.

Keywords: Precision Agriculture, AI in Mechanization, Nutrient Management, Agritech Entrepreneurship, Sustainable Yield

Autonomous Vehicle in Agriculture - A Review

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ABSTRACT

The global agricultural sector is under growing pressure to produce more food with less labour and lower environmental impact and higher resource efficiency. The autonomous vehicle system which includes self-guided tractors and field robots and precision sprayers and weeders and harvesters and unmanned aerial vehicles provides essential technological solutions needed to meet these requirements. The poster delivers an extensive evaluation of autonomous agricultural vehicles (AAVs) which demonstrates their development from basic automatic guidance systems and GPS-assisted auto-steering technology to present-day systems that utilize artificial intelligence and sensor fusion and machine learning.The poster systematically examines the core technological components enabling autonomy in field conditions: GNSS/RTK positioning, LiDAR, vision-based perception, inertial measurement, path-planning algorithms, and robust control strategies. It further analyses the trajectory of research focus over recent decades, documenting a clear shift from basic navigation accuracy toward integrated multi-sensor perception, real-time obstacle avoidance, andcoordinated multi-robot operations.Commercialization status is critically evaluated across vehicle types and application domains. While auto-steering and precision guidance are now commercially mature, fully autonomous platforms remain at early deployment stages, constrained by high capital costs, limited robustness in real-world field environments, insufficient regulatory frameworks, and challenges in farmer adoption, particularly among smallholder and resource-limited farming communities.The poster presents essential performance benchmarks while showing ongoing technical and social economic challenges and recommending specific research areas which will investigate all weather perception systems and low cost modular systems and safety requirements and methods to evaluate social economic effects. The findings demonstrate that autonomous agricultural vehicles can achieve their maximum operational capacity when three specific areas: technology, policy, and context-based deployment methods are developed simultaneously.

Keywords: Autonomous Agriculture Vehicle, Field Robotics, Precision Agriculture, Commercialization of Autonomous Agricultural Vehicles, Farm Automation

Innovative Post-Harvest Crop Protection through AI-Based Fruit Harvesting and Solar Dehydration Technologies

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ABSTRACT

India is the second-largest producer of fruits and vegetables globally with an annual production of 342.3 million tonnes. However, nearly 40% of harvested produce is wasted before reaching consumers, resulting in an estimated annual economic loss of □92,000 crore. Major causes of post-harvest losses include improper harvesting practices, lack of cold storage infrastructure, mechanical damage during handling, delayed transportation, and rejection of Grade-B fruits due to aesthetic preferences.I have an innovative post-harvest crop protection model that integrates artificial intelligence, automation, and renewable energy technologies to reduce losses and improve farmer income. The proposed robotic fruit picker uses RGB cameras and NIR sensors to detect fruit ripeness and identify damaged produce. An AI control module guides a robotic arm equipped with a soft gripper for precise harvesting, minimizing bruising and damage. Additionally, a direct farm-to-factory linkage system reduces storage delays and spoilage.To utilize overripe and rejected fruits, a solar dehydration and upcycling unit converts perishable produce into value-added products such as dried fruit slices and powders using sustainable solar energy. This approach enhances shelf life, reduces food waste, creates additional income opportunities for farmers, and supports sustainable agriculture. The integration of smart harvesting and sustainable processing technologies can significantly improve post-harvest crop protection and strengthen food security in India.

Keywords: Post-harvest losses, Artificial intelligence, Solar dehydration, Smart harvesting, Food security

Ai and Digital Technologies for Agricultural Mechanization

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ABSTRACT

Agriculture plays an important role in the economy of India. Nearly 42% of India's population depends on agriculture. Artificial Intelligence (AI) and digital technologies areused to improve agricultural mechanization and farming practices. AI-based systems can analyze farm data, predict weather conditions, detect crop diseases, and support sustainable agriculture. There are different types of digital technologies used in agriculture such as drones, sensors, GPS systems, automated irrigation systems, robotics, mobile applications. The use of AI and digital technologies increases agricultural productivity, reduces labor requirements, saves time, and minimizes production costs. Smart farming technologies also help in proper use of water, fertilizers, and pesticides, which supports sustainable agriculture and environmental protection.Mobile applications help farmers in modern agriculture by providing weather updates, market prices, crop management information, and digital payment facilities. These apps support smart farming, save time, and improve communication between farmers and buyers.around 8–10% of Indian farms are using AI for agriculture.However, several problems are associated with the adoption of these technologies, including high cost, lack of technical knowledge, poor internet and limited awareness among farmers in rural areas. Small and marginal farmers often face difficulties in accessing advanced technologies.These problems can be solved through government support, farmer training programs, subsidies, digital education, and Awareness programs and affordable smart farming tools can encourage farmers to adopt modern agricultural technologies.In conclusion, AI and digital technologies have great potential to modernize agricultural mechanization and improve the efficiency, productivity, and sustainability of agriculture in the future.

Keywords: Artificial Intelligence, Digital Agriculture, Smart Farming, Agricultural Mechanization, Precision Farming

AI and Digital Technologies for Agricultural Mechanization

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ABSTRACT

Agriculture stands at a transformative crossroads, driven by the rapid integration of Artificial Intelligence (AI) and digital technologies into mechanization systems. Traditional farming, long dependent on manual labour and conventional machinery, is increasingly giving way to precision-driven, data-intelligent operations that promise higher productivity, reduced resource wastage, and sustainable land management.AI-powered systems are revolutionizing agricultural mechanization across multiple dimensions. Machine learning algorithms now enable smart tractors and autonomous field robots to navigate complex terrain, optimize tillage patterns, and perform targeted operations with minimal human intervention. Computer vision technologies facilitate real-time crop health monitoring, enabling early detection of pests, diseases, and nutrient deficiencies with accuracy far surpassing human observation. These systems process imagery from drones, satellites, and ground-based sensors to generate actionable agronomic insights at field scale.Digital technologies such as the Internet of Things (IoT), cloud computing, and big data analytics further enhance mechanization by enabling seamless connectivity between farm equipment, environmental sensors, and decision-support platforms. Smart irrigation controllers, AI-guided sowing machines, and robotic harvesters now execute operations based on real-time soil moisture data, weather forecasts, and crop growth modelsdramatically reducing input costs while improving yield outcomes.In the Indian context, AI and digital mechanization hold particular significance for smallholder farmers who constitute the majority of the agricultural workforce. Affordable drone technology, mobile-based advisory systems, and custom-hired smart equipment are increasingly bridging the technology access gap in rural areas. Government initiatives such as Digital Agriculture Mission and various ICAR-led programmes are further accelerating adoption.Despite promising advances, challenges including high capital costs, digital literacy gaps, poor rural connectivity, and limited localized data persist. Addressing these barriers through policy support, farmer training, and indigenous innovation will be critical to ensuring that AI-driven mechanization translates into inclusive and equitable agricultural transformation.

Keywords: Artificial Intelligence, Agricultural Mechanization, Precision Farming, IoT, Mart Agriculture, Autonomous Machinery

Transforming agricultural mechanization in eastern India through artificial intelligence anddigital technologies: oppurtunities and challenges

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ABSTRACT

Indian agriculture is undergoing a transformation from manual labour to intelligent production systems with the help of agricultural mechanization.Eastern India is dominated by small holdings, high labour dependency, and heterogeneous agro-climatic zones. This region is highly in need of this transformation and also structurally complex.In this context, the integration of Artificial Intelligence (AI) and digital technologies presents an exciting opportunity to rethink how farms can be managed, but the challenge is to investigate and qualify the scaling up of global technology to local solutions.The present review highlights the transformation of the major mechanization areas such as autonomous crop scouting, variable-rate input applications, real-time disease diagnosis and predictive crop yield modelling enabled by machine learning algorithms, computer vision, IoT sensor networks and UAV based multispectral platforms.The use of agricultural robots and AI-powered farm management systems is showing tangible improvements in operational timeliness and efficiency of resource use, while geospatial analytics is opening up new possibilities for site-specific decision-making at scales that were unfeasible for smallholder systems in states such as Bihar, Jharkhand, West Bengal and Odisha.However, adoption is still limited due to high investment costs, lack of digital infrastructure in remote areas, limited digital skills, and land fragmentation that hampers economies of scale through machine usage.Certain schemes like SMAM and custom hiring centres provide partial solutions, but remember there are system gaps.This paper suggests that designing the technology, providing last mile extension services on digitalization and introducing access models supported by agri-fintech together can create an ecosystem where youths from eastern India act as agents of an AI-mechanization revolution in alignment with Viksit Bharat 2047.

Keywords: Agricultural Mechanization, Artificial Intelligence, UAV, Machine Learning, Eastern India, IoT.

Integration of Artificial Intelligence and Drone Technology for Precision Management of Sugarcane Ecosystem

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ABSTRACT

Sugarcane is an economically important crop cultivated extensively for sugar and allied industries, but its productivity is severely affected by insect pests such as early shoot borer, top borer, internode borer, leafhoppers, white grubs, and scale insects. Conventional pest monitoring and blanket pesticide applications often result in excessive chemical use, environmental contamination, pest resistance development, and increased production costs. Recent advancements in precision agriculture, particularly the integration of Artificial Intelligence (AI) and Unmanned Aerial Vehicles (UAVs), offer sustainable and efficient alternatives for pest management in the sugarcane ecosystem. The present study reviewed the application of UAV-based remote sensing and AI-driven deep learning models such as Convolutional Neural Networks (CNN) and YOLO for real-time pest surveillance, automated pest detection, and hotspot mapping in sugarcane fields. Relevant peer-reviewed literature and standard operating procedures related to drone-based pesticide application were analysed to evaluate their effectiveness under Integrated Pest Management (IPM) systems.Finding indicated that multispectral imaging through drones enabled early detection of pest stress, thereby improving timely intervention and reducing crop losses. AI-based models facilitated rapid and accurate pest identification, while drone-assisted spraying ensured uniform droplet deposition, reduced pesticide consumption, minimized operator exposure, and enhanced site-specific application efficiency. Compared with conventional spraying methods, UAV-based systems significantly improved operational speed, labour efficiency, and environmental safety while lowering pesticide usage and drift hazards.The integration of AI and drone technology has strong potential to transform precision pest management in sugarcane by enhancing sustainability, profitability, and ecological safety. However, challenges including high initial investment, technical skill requirements, and regulatory constraints need further attention for wider adoption.

Keywords: Sugarcane, Artificial Intelligence, Precision Agriculture, Integrated Pest Management, Pest Surveillance, CNN

Calibration and Validation of DSSAT v4.8.5 for Growth and Yield Simulation of *Kharif* Rice

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ABSTRACT

Rice is one of the most important staple food crops and plays a vital role in ensuring food security in India. However, increasing climatic variability, particularly fluctuations in temperature and rainfall, poses a serious challenge to sustainable rice production in eastern India, including North Bihar. Crop simulation models offer an efficient scientific tool for understanding crop responses under varying environmental conditions and for developing suitable management strategies. In this context, the present study was undertaken to calibrate and validate the DSSAT v4.8.5 CERES-Rice model for simulating the growth and yield of Kharif rice cultivar Rajendra Sweta under the agro-climatic conditions of North Bihar. The study was conducted using secondary experimental data generated during the Kharif seasons of 2022 and 2023 at RPCAU, Pusa, Bihar. The experiment was laid out in a Randomized Block Design (RBD) with three transplanting dates, viz., 30 June, 15 July, and 30 July, and three fertilizer levels: 75% RDF, 100% RDF, and 125% RDF. Observed weather data, soil characteristics, crop management practices, and experimental observations were utilized for model calibration and validation. Model calibration was performed by iteratively adjusting cultivar-specific genetic coefficients to achieve close agreement between simulated and observed crop performance. The calibrated coefficients effectively represented the phenological development, grain-filling duration, tillering potential, and thermal response of the cultivar. The CERES-Rice model was subsequently validated by comparing simulated and observed values of important crop growth and yield parameters, including phenology, leaf area index, biomass accumulation, and grain yield under different treatment combinations. Statistical evaluation using Root Mean Square Error (RMSE), normalized RMSE, coefficient of determination (R^2), and index of agreement (d-stat) indicated satisfactory agreement between observed and simulated values, thereby confirming the model's reliability and predictive capability. The findings demonstrated that the DSSAT CERES-Rice model can effectively simulate the growth and productivity of *Kharif* rice under North Bihar conditions and may serve as a useful decision-support tool for crop management planning and climate change impact assessment studies.

Keywords: Calibration and Validation, Crop simulation models, DSSAT, Climate change.

Smart Mushroom Production Systems for Sustainable Agriculture

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ABSTRACT

Mushroom cultivation is becoming an important part of sustainable agriculture because it converts agricultural waste into nutritious food with limited use of land and water resources. Traditional mushroom farming mainly depends on manual supervision and environmental management, which can influence productivity and product quality. Recent developments in digital agriculture technologies, including the Internet of Things (IoT), Artificial Intelligence (AI), Computer Vision (CV), sensors, and automation, have created new opportunities for improving mushroom production systems. IoT-based monitoring systems help maintain favorable environmental conditions by continuously observing temperature, humidity, carbon dioxide concentration, and light intensity. In addition, AI and computer vision techniques can support disease detection, growth monitoring, maturity estimation, and harvesting operations. Advanced imaging methods also allow non-destructive quality assessment and shelf-life evaluation of mushrooms. The integration of these smart technologies can reduce labor dependency, improve cultivation efficiency, and promote environmentally sustainable production practices. Therefore, smart mushroom production systems have strong potential to modernize conventional mushroom farming and contribute to future sustainable agricultural development.

Keywords: Smart Mushroom Farming; Internet of Things (IoT); Artificial Intelligence; Computer Vision; Sustainable Agriculture

UAV-Based Aerial Seeding: Applications and Emerging Potential for Sustainable Agricultural Production

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ABSTRACT

Rice occupies a pivotal position in Indian agriculture, covering nearly 51.4 million ha during 2024-2025, which accounts for approximately 32% of the global rice cultivation area and about 45% of the country's total cropped area. However, conventional rice establishment methods are increasingly challenged by labour scarcity, escalating production costs, and delays in field operations. In this scenario, Direct Seeded Rice (DSR) has emerged as a promising alternative to traditional transplanting, while Unmanned Aerial Vehicle (UAV)-based aerial seeding has gained considerable attention as an advanced technological intervention for large-scale adoption of DSR systems. UAV-assisted seeding enables rapid, precise, and uniform seed distribution, particularly in waterlogged fields, residue-covered lands, relay cropping systems, hilly terrains, and inaccessible areas where conventional machinery operation is difficult. The integration of advanced flight control systems, GPS-guided navigation, variable-rate application technologies, and specially designed seed dispensing mechanisms ensures accurate seed placement and improved crop establishment. Furthermore, recent developments in pelleted and coated seeds have enhanced aerial seeding efficiency by improving seed flow characteristics, reducing mechanical damage, and increasing germination performance. UAV-based sowing also shows significant potential in relay cropping systems, where crops such as wheat, mustard, and pulses are sown before rice harvesting, thereby utilizing residual soil moisture and nutrients efficiently while minimizing additional irrigation requirements. This approach contributes to enhanced land-use efficiency, improved economic returns, and climate-resilient farming practices through timely sowing within narrow operational windows. Although challenges related to payload limitations, battery endurance, seed metering precision, regulatory restrictions, and economic feasibility still persist, continuous technological advancements are progressively overcoming these constraints. Overall, UAV-based aerial seeding represents a sustainable, precision-oriented, and farmer-friendly approach with substantial potential to improve productivity, support smart farming, and enhance resource-use efficiency, particularly in small and fragmented agricultural holdings under labour-constrained conditions.

Keywords: UAV, Seed Sowing, Precision Agriculture, Aerial Seed, Smart Farming

An AI-Driven Precision Irrigation Framework for Enhancing Water Use Efficiency under Climate Variability

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ABSTRACT

Escalating water scarcity and increasing climate variability demand advanced irrigation strategies beyond traditional rule-based approaches. This study proposes an Artificial Intelligence (AI)-driven precision irrigation framework designed for adaptive and data-driven water management. The system integrates capacitive soil moisture sensors, temperature–humidity sensors, and short-term weather forecasts to enable real-time irrigation control. A supervised machine learning model based on Random Forest regression is developed to estimate crop water requirements by capturing nonlinear interactions among soil characteristics, crop growth stages, and climatic variables. Key inputs include soil texture, volumetric water content, air temperature, relative humidity, and forecasted rainfall. Unlike conventional threshold-based methods, the proposed framework leverages predictive analytics to anticipate soil moisture depletion and evapotranspiration trends, enabling proactive irrigation scheduling. Model evaluation demonstrates strong predictive performance, achieving an R^2 value of approximately 0.85–0.90. Simulation results indicate a reduction in irrigation water usage by 30–40% while maintaining optimal soil moisture levels (60–80% of field capacity). Additionally, yield improvements of 10–15% are projected due to reduced plant water stress and enhanced nutrient uptake efficiency. The framework is scalable through low-cost IoT integration, making it particularly suitable for smallholder farming systems. It offers a sustainable and climate-resilient solution for improving water use efficiency in agriculture.

Keywords: Precision irrigation, Artificial Intelligence, Random Forest, Water use efficiency, Climate variability

Digital Twin Technology for Agricultural Machinery Management

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ABSTRACT

The worldwide agricultural system faces dual problems because it needs to boost crop production by 50% from its 2012 levels until 2050 in order to feed a growing population that will reach 10 billion people while also cutting down on agricultural water usage which currently accounts for 69% of global freshwater resources. Modern precision agriculture systems require advanced maintenance methods and automated management solutions because traditional maintenance methods and manual control techniques fail to solve the complex problems which arise when equipment functions in extreme environmental conditions that include cyclic mechanical loads and abrasive soil contacts and chemical hazards. Digital Twin (DT) technology establishes a new system which creates an active two-way connection that enables real-time data exchange between actual equipment and its digital twin model. This academic review examines the integration of multi-modal sensing, high-fidelity numerical modelling primarily Finite Element Analysis (FEA) and intelligent diagnostic algorithms including Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs) for machinery health assessment.The analysis synthesizes evidence from recent frameworks, which include the Smart Water Management Platform (SWAMP) and FIWARE-based IoT architectures, that enable operational asset synchronization with discrete event simulation environments which include Siemens Plant Simulation. Thereviewshows that agricultural machinery management through digital twin implementation results in 25% maintenance cost reduction and 70% equipment failure prevention and 35% unplanned downtime decrease and 20% operational productivity improvement. The system has improved performance yet it faces multiple technical challenges because environmental noise interferes with data acquisition while cloud processing in rural areas suffers from high latency and real-time multi-physics simulations require intensive computational resources. The review concludes by outlining future research trajectories, which focus on edge computing, blockchain to maintain data integrity, and Foundation Model integration to build autonomous self-aware agricultural machinery systems.

Keywords: Digital Twin Technology, Precision Agriculture, Agricultural Machinery Management, Predictive Maintenance, Smart Farming Systems

Harnessing Artificial Intelligence & Digital Technologies for Agricultural Mechanization: Evidence, Initiatives & Pathways

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ABSTRACT

Artificial intelligence (AI) is becoming one of the key solutions globally to address the issue of food insecurity. AI is helping improve agricultural productivity, and sustainability and reduce the consumption of natural resources. Using data driven decisions and precision farming allows for real time tracking of soil and weather conditions, crop health and resource usage. This will enable better use of water, fertilizer and pesticides; thus increase productivity, lower operating expenses; and promote the practice of sustainable agriculture. This research gives a review of what has been done by utilizing the World Bank's (2025) and PIB report (2026). A number of Government Initiatives have been initiated in India. For example, 'AgriStack' has created over 7.63crore farmer Ids. An example of how AI is being used in an advisory role is with 'Kisan e-Mitra', an AI powered ChatBot that handles more than 8000 daily farmer inquiries in 11 different languages. YES-TECH, and CROPIC are evidence of significant advancements on large scales. This research also examined the growth of the Global Market for AI-in-Agriculture. At $1.5 billion in 2023, it is estimated to grow to $10.2 Billion by 2032 at a compound annual growth rate of 24.5% per year. Despite this, several barriers exist that limit its widespread adoption. For example, lack of internet connectivity in many parts of the India, cost limitations to adopting new technology, lack of digital infrastructure in rural areas, and low levels of digital literacy among farmers. This study concluded that several factors need to occur before all farmers can equitably adopt AI driven agricultural innovation. They include implementing inclusive policies; improving rural digital infrastructure and creating programs that build capacity for farmers to utilize digital tools.

Keywords: AgriStack, Artificial intelligence, Digital infrastructure, Food insecurity, Precision farming

AI and Digital Technologies for Agricultural Mechanization

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ABSTRACT

According to the Ministry of Agriculture and Farmers Welfare, India's population is expected to increase to approximately 1.69–1.7 billion by 2050. To feed this growingpopulation, it is projected that nearly 70% of agricultural land may need to be brought under cereal crop cultivation. Other major challenges affecting agriculture include labour shortages and climate change. In this context, the use of advanced technological solutions to improve farming efficiency has become one of the greatest necessities. Artificial Intelligence (AI) has applications across many sectors, and it can bring a paradigm shift in modern agriculture. AI-powered solutions not only enable farmers to achieve more with fewer resources, but also improve the quality and sustainability of farming practices while ensuring faster market access for crops. AI-powered systems are increasingly being adopted in tractor field operations to support precisionagriculture and reduce operational costs.The application of AI in tractor operations includes autonomous navigation, precision seeding, smart spraying, weed detection, soil monitoring, irrigation management, and harvesting assistance. These technologies utilize machine learning,robotics, sensors, GPS, drones, and Internet of Things (IoT)devices to enhance decision-making and optimize field performance. Robotics and smart technologies are also being used in activities such as tillage, seeding, weeding, spraying, and harvesting. Other technologies, such as Variable-Rate Technology (VRT), allow machines to apply fertilizers and pesticides precisely where needed, Agricultural drones, or Unmanned Aerial Vehicles (UAVs), are also transforming farming practices through crop monitoring, spraying, and data collection. In India, initiatives such as "Namo Drone Didi" areproviding 15,000 drones to women's self-help group. Overall, the use of AI in agriculture helps improve farmers' livelihoods, reduce labour dependency, increase productivity, minimize resource wastage, and support sustainable farming.

Keywords: Artificial Intelligence (AI), Precision Farming, Smart Farming, Agricultural Drones, Internet of Things (IoT), Sustainable Agriculture, Robotics, Precision Seeding, Climate Change, Crop Monitoring, Variable-Rate Technology (VRT), Autonomous Tractors.

Multi Imaging Technology in Case of Seed Quality Enhancement

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ABSTRACT

Seed quality is a critical determinant of crop establishment, productivity, and agricultural sustainability. Accurate assessment of seed viability, vigor, genetic purity, and health is essential for ensuring high-quality planting material. Conventional seed quality evaluation methods are often labor-intensive, time-consuming, and destructive in nature, limiting their efficiency in large-scale seed testing programs. In this context, multi-imaging technology has emerged as a promising non-destructive approach for rapid and precise seed quality enhancement and assessment.Multi-imaging systems integrate advanced imaging techniques including RGB imaging, X-ray imaging, hyperspectral imaging, thermal imaging, and fluorescence imaging to analyze both external and internal seed characteristics. RGB imaging is widely used for evaluating seed size, shape, color, and physical purity, whereas X-ray imaging enables detection of internal damages, insect infestation, and embryo abnormalities without affecting seed viability. Hyperspectral imaging combines spectral and spatial information to identify biochemical composition, moisture content, seed vigor, and pathogen infection. Thermal and fluorescence imaging further assist in monitoring metabolic activity, physiological status, and seed maturity.Recent advancements in Artificial Intelligence (AI) and Machine Learning (ML) have significantly improved the efficiency and accuracy of image processing, classification, and automated seed sorting systems. The integration of these technologies enhances real-time decision-making and supports precision agriculture practices. Multi-imaging technology offers several advantages such as high-throughput analysis, reduced human error, improved accuracy, and non-destructive evaluation, making it highly suitable for modern seed industries and research applications.Despite challenges related to high instrumentation cost and data complexity, multi-imaging approaches have substantial potential to revolutionize seed quality testing, seed certification, and crop improvement programs. Therefore, the adoption of multi-imaging technology can contribute significantly toward sustainable agriculture, enhanced seed performance, and global food security.

Keywords: Global, Food security, Multi imaging, Seed, Maturity, Hyperspectral

Smart Mushroom Production Systems for Sustainable Agriculture

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ABSTRACT

Mushroom cultivation is becoming an important part of sustainable agriculture because it converts agricultural waste into nutritious food with limited use of land and water resources. Traditional mushroom farming mainly depends on manual supervision and environmental management, which can influence productivity and product quality. Recent developments in digital agriculture technologies, including the Internet of Things (IoT), Artificial Intelligence (AI), Computer Vision (CV), sensors, and automation, have created new opportunities for improving mushroom production systems. IoT-based monitoring systems help maintain favorable environmental conditions by continuously observing temperature, humidity, carbon dioxide concentration, and light intensity (Yang & Argyropoulos, 2026). In addition, AI and computer vision techniques can support disease detection, growth monitoring, maturity estimation, and harvesting operations. Advanced imaging methods also allow non-destructive quality assessment and shelf-life evaluation of mushrooms. The integration of these smart technologies can reduce labor dependency, improve cultivation efficiency, and promote environmentally sustainable production practices. Therefore, smart mushroom production systems have strong potential to modernize conventional mushroom farming and contribute to future sustainable agricultural development (Kassim et al., 2026).

Keywords: Smart Mushroom Farming; Internet of Things (IoT); Artificial Intelligence; Computer Vision; Sustainable Agriculture.

Innovative Post-Harvest Crop Protection through AI-Based Fruit Harvesting and Solar Dehydration Technologies

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ABSTRACT

India is the second-largest producer of fruits and vegetables globally with an annual production of 342.3 million tonnes. However, nearly 40% of harvested produce is wasted before reaching consumers, resulting in an estimated annual economic loss of □92,000 crore. Major causes of post-harvest losses include improper harvesting practices, lack of cold storage infrastructure, mechanical damage during handling, delayed transportation, and rejection of Grade-B fruits due to aesthetic preferences.I have an innovative post-harvest crop protection model that integrates artificial intelligence, automation, and renewable energy technologies to reduce losses and improve farmer income. The proposed robotic fruit picker uses RGB cameras and NIR sensors to detect fruit ripeness and identify damaged produce. An AI control module guides a robotic arm equipped with a soft gripper for precise harvesting, minimizing bruising and damage. Additionally, a direct farm-to-factory linkage system reduces storage delays and spoilage.To utilize overripe and rejected fruits, a solar dehydration and upcycling unit converts perishable produce into value-added products such as dried fruit slices and powders using sustainable solar energy. This approach enhances shelf life, reduces food waste, creates additional income opportunities for farmers, and supports sustainable agriculture. The integration of smart harvesting and sustainable processing technologies can significantly improve post-harvest crop protection and strengthen food security in India.

Keywords: Post-harvest losses, Artificial intelligence, Solar dehydration, Smart harvesting, Food security.

THEME: -5

Omics and Machine Learning Approaches for Crop and Livestock Improvement

Meta-QTL Analysis for Aerobic Adaptation Traits in Rice: Identification of Candidate Genes and Molecular Insights for Water-Efficient Breeding

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ABSTRACT

Rice is the primary staple food for over half of the global population, global rice production faces mounting pressure from water scarcity, climate change, and rising demand projected to reach 827 million tonnes by 2050. Aerobic rice cultivation has emerged as a promising water-saving strategy, yet the molecular mechanisms underlying aerobic adaptation remain insufficiently understood. This study presents a comprehensive meta-QTL (MQTL) analysis integrating 474 QTLs associated with five key aerobic adaptation traits onto a consensus map comprising 9,679 markers, resulting in the identification of 19 robust MQTLs. The average confidence interval (CI) of MQTLs was 8.95 cM—2.81-fold narrower than original QTLs (mean CI: 24.33 cM)—demonstrating substantially improved mapping resolution. Cross-validation with genome-wide association studies (GWAS) confirmed 15 MQTLs, while synteny and collinearity analyses across rice, wheat, and maize revealed nine conserved ortho-MQTLs, suggesting functional conservation across cereal crops. Chromosome 6 was identified as a principal linkage group for drought tolerance and aerobic adaptation. Within MQTL regions, 1,555 candidate genes were identified, of which 22 were differentially expressed between tillering and heading stages under aerobic conditions. Notably, four genes—LOC_Os06g09390 (AP2/ERF transcription factor), LOC_Os06g06980 (Caffeoyl-CoA 3-O-methyltransferase), LOC_Os11g14220 (Alpha-tubulin), and LOC_Os04g26910 (IN2-2 protein)—exhibited significantly elevated expression. Thirteen high-confidence candidate genes, including bZIP, Nodulin, WRKY, and glutathione S-transferase, were mapped to MQTL regions. Meta-regions were further enriched with genes encoding AP2/ERF, MYB, NAC, Zinc finger, LEA, ABC transporter, and glutathione S-transferase proteins, underscoring their functional relevance in aerobic adaptation. Haplotype analysis of three candidate genes (LOC_Os06g06980, LOC_Os11g13890, and LOC_Os01g25386) revealed two to four distinct haplotypes per gene, offering potential targets for allele-specific breeding. Collectively, these findings advance the molecular understanding of aerobic rice adaptation and provide a valuable genomic resource for precision molecular breeding aimed at developing cultivars suited to water-deficient environments.

Keywords: Aerobic rice; Meta-QTL (MQTL), Candidate genes, Ortho-QTLs, Haplotype analysis, Drought tolerance, Molecular breeding

CRISPR-Based Biofortified Crops as a Sustainable Solution to Malnutrition in Rural India

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ABSTRACT

Malnutrition remains a major public health challenge in rural India, especially among women and children, due to deficiencies in essential micronutrients such as iron, zinc, and vitamins. Traditional agricultural practices mainly focus on increasing crop yield rather than improving nutritional quality, which limits their effectiveness in addressing hidden hunger. In this context, CRISPR-Cas9 gene editing technology offers a promising and innovative solution for developing biofortified crops with enhanced nutritional value. CRISPR enables precise modification of plant genes responsible for nutrient accumulation, allowing scientists to increase the concentration of essential micronutrients in staple crops like rice and wheat. These crops are widely consumed in regions such as Bihar, making them ideal targets for biofortification. This approach provides a sustainable and cost-effective method to improve dietary intake without requiring significant changes in eating habits. In addition to enhancing nutritional quality, CRISPR-based biofortified crops support sustainable agriculture by reducing dependence on external supplements and chemical inputs. They can be easily integrated into existing farming systems, benefiting small and marginal farmers. Furthermore, this technology has the potential to improve food security, promote better health outcomes, and empower rural communities. However, challenges such as biosafety concerns, regulatory approval, and public acceptance must be carefully addressed. Increasing awareness among farmers and consumers is essential for successful implementation. Overall, CRISPR-based biofortification represents a transformative strategy to combat malnutrition and ensure a healthier and more sustainable future.

Keywords: Biofortification, CRISPR-Cas9, Malnutrition, Micronutrients, Sustainable Agriculture

Improvement in Millets through Multi-Omics approaches

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ABSTRACT

Millets, often referred to as "Nutri-Cereals" (or *Shree anna* in India), have earned these titles due to their exceptional nutritional and health benefits. They compete with major staples in not just proteins, fat, dietary fibres but also in essential micro-nutrients like iron, calcium, phosphorus, thiamine, riboflavin etc. Their hardy, drought-resistant nature, short life cycle and ability to fit into intercropping patterns make them best fit for small scale farmers, ensuring food security and income generation. The present climate resilient era demands more improved varieties through collaborative approach between conventional breeding and omics technologies. Genetic transformations by *Agrobacterium tumefaciens* have been carried out. *EcNF-YA5* and *PmEIL3/8/15* genes were found to confer tolerance to multiple abiotic stresses. Recently, high zinc-accumulating finger millet transgenic plants were produced by overexpression of *OsZIP1*. Identification and characterisation of gene families, including *NAC, WD40, AP2/ ERF*, through GWAS and NGS were reported in foxtail millet. Phenotypic variants were identified in finger millet for leaf blast resistance (*GEC92, IC0477317*), neck blast (*IC0477650, GEC41, GEC322*), and finger blast (*IC0476838, GEC132*). Transcriptomics of foxtail millet during *Sclerosporagraminicola*infection, pinpointed an amidase encoding gene, *Seita.2G313400*. A comparison between (*GP-45*, high calcium content; *GP-1*, low calcium content) of finger millet revealed high expression of 24 calcium sensor genes (e.g., *CaM*, *CaML*s). Metabolomics involved ICP-MS analysis carried out for Ca,K, Mg and phytochemical profiling of seed metabolites utilizing LC-HRMS/MS. Homology modelling of three SRX proteins was reported. A speed breeding protocol named "Rapid Ragi" has been developed recently. Multi-omics databases for millets like Milletdb, GSMDB accelerates the research of functional genomics and molecular breeding. Comparatively, millets still face genome annotation deficiencies, polyploidy challenges, and fewer discoveries of ESTs. Future interventions should focus on harnessing multi-omics technologies to their full potential for analysing the genetic basis of crucial traits and expediting the breeding procedures.

Keywords: Millets, Genomics, GWAS, Transcriptomics, Multi-omics

THEME: -6

Empowering Women Farmers

Empowering Rural Women through MSMEs: Pathways to Sustainable Livelihood Development

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ABSTRACT

Rural women play a significant role in agricultural and allied activities, contributing substantially to household income and rural development. However, limited access to resources, financial services, skill development, and market opportunities often restrict their socio-economic advancement. Micro, Small and Medium Enterprises (MSMEs) have emerged as an important platform for promoting women entrepreneurship and enhancing livelihood opportunities in rural areas. The present paper highlights the role of MSMEs in empowering rural women through income generation, employment creation, skill enhancement, and self-reliance. MSME-based activities such as food processing, tailoring, dairy farming, handicrafts, mushroom cultivation, and value addition of agricultural products have enabled rural women to improve their standard of living and participate actively in decision-making processes. The study also emphasizes the importance of training programmes, institutional support, financial inclusion, and digital awareness in strengthening women-led enterprises. Despite several opportunities, challenges such as inadequate credit access, poor market linkage, lack of technical knowledge, and social constraints continue to hinder the growth of women entrepreneurs. Therefore, strengthening policy support, entrepreneurship training, and market-oriented interventions is essential for achieving sustainable livelihood development among rural women. The paper concludes that MSMEs can serve as an effective instrument for socio-economic empowerment and inclusive rural transformation when supported through coordinated institutional efforts and capacity-building initiatives.

Keywords: Rural women, MSMEs, Women empowerment, Sustainable livelihood, Entrepreneurship

Empowering Rural Women through Skill Development and Entrepreneurship

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ABSTRACT

Rural women in India make up a significant population but overlooked workforce, contributing nearly 60 to 80% of agricultural labour while being mostly left out of formal economic opportunities. Despite this immense contribution, they face serious limitations in accessing skill training, credit, and entrepreneurial platforms. Fewer than 20% of rural women entrepreneurs can access formal bank credit (NABARD, 2023). Additionally, India ranks 70th out of 77 countries in the gender gap in entrepreneurship (World Bank, 2024). Targeted skill development and entrepreneurship promotion can drive sustainable rural development, focusing specifically on India. The main goal of this study is to explore how structured skill-building programs, when combined with entrepreneurial support systems, can help rural women move from subsistence livelihoods to becoming financially independent entrepreneurs. Using secondary data from government reports, academic literature, and outcomes from national missions, this paper highlights the important role of the Deendayal Antyodaya Yojana - National Rural Livelihoods Mission (DAY-NRLM). As of June 2024, it has mobilized over 10.05 crore women into 90.86 lakh Self-Help Groups (SHGs) (Ministry of Rural Development, 2024). The flagship Lakhpati Didi initiative, a key result of DAY-NRLM, has already empowered over 1.15 crore SHG women to earn an annual household income of over □1 lakh, with a national target set at 3 crore (MoRD, 2024). The study further discusses the roles of Industrial Training Institutes (ITIs), NITI Aayog's Women Entrepreneurship Platform (WEP), and the collaboration with PMEGP and MUDRA schemes in helping women start viable micro-enterprises in areas like food processing, handicrafts, tailoring, and agro-based value chains. It also critically examines barriers such as social norms, digital exclusion, and limited market connections. The paper concludes that a combined, community-focused approach that includes vocational training, SHG-based credit access, digital literacy, and market connections offers the most promise for women-led rural change. Notably, there has been a 19% increase in income and a 28% rise in savings among DAY-NRLM beneficiaries (3ie & World Bank Impact Evaluation, 2020), demonstrating the effectiveness of this model. Looking ahead, scaling digital skill-building through platforms like PM e-VIDYA, strengthening rural incubation centers, and integrating gender-responsive budgeting are defined as essential future goals. When a rural woman gains skills and opportunities, she not only changes her household but also plays a key role in creating a sustainable future for her community.

Keywords: Rural Women Empowerment, Skill Development, Entrepreneurship, Self-Help Groups (SHGs), Sustainable Rural Development

Sustainable Livelihood Enhancement of Tribal Women through Gladiolus Cultivation: A Case Study

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ABSTRACT

In the quaint village of Alluri Sitaramarju district, Smt. Soyathamma, a resilient tribal woman from Santhabayalu discovered a path to economic empowerment through gladiolus cultivation, guided by the transformative initiatives of the Krishi Vigyan Kendra (KVK) in the region. Gladiolus, known for its vibrant colours and versatility as a cut flower, has become a beacon of success for Smt. Soyathamma and her community.KVK, Kondempudi, recognized the potential of gladiolus as a commercially viable flower and initiated on farm trails (OFT) to introduce this new crop. Two high-yielding varieties, Arka Amar and Arka Aayush, along with Arka Pratham, were chosen for the trials. These varieties exhibitedpromising yield potential, with Arka Amar boasting 30.24 spikesm^{-2}/crop season, 75-95 days duration, and an impressive vase life of 8.5 days. Arka Aayush, with a yield potential of 28.24 spikesm^{-2}/crop season and a vase life of 7.5 days, also proved to bea valuable addition to the experiment.In the second year of the trial, Smt. Soyathamma embraced gladiolus cultivation, realizing its potential for economic upliftment. Initially, she sold gladiolus spikes for a modest 6-7 rupees each. However,the real turning point came with the invaluable training provided by KVK in the art of bouquet preparation. Empowered by this newfound knowledge, Smt. Soyathamma ventured into preparing high-quality gladiolus bouquets. The training not onlyenhanced her skills but also elevated the market value of her produce. Now equipped to create beautiful arrangements, she successfully sold a set of 5 gladiolus spikes for an impressive 120 rupees. This significant increase in earni transformation in her economic status.The success story of Smt. Soyathamma illustrates the impact of thoughtful agricultural interventions and skill development programs. The introduction of gladiolus cultivation not only diversify agricultural landscape but also empowered tribal women like Smt. Soyathamma, enabling them to break free from traditional constraints and secure a sustainable livelihood.Smt. Soyathamma's journey is a testament to the power of knowledge, innovation, and community support infostering economic independence. As gladiolus cultivation continues to bloom in Kondempudi, the success stories of farmers like Smt. Soyathamma serve as inspiration for others to explore new avenuesand embrace positive change in their lives.

Key words: Arka Amar, Arka Aayush, Arka Pratham, Gladiolus, Bouquets, OFT, Sustainable and Tribal women.

Empowering Women Farmers for Sustainable Agricultural Development

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ABSTRACT

Women make up a major portion of the agricultural workforce, yet their actual role is often limited to unrecognized labor rather than active decision-making. While the sector focuses heavily on crop productivity, the persistent "gender yield gap" is frequently ignored. Women handle critical, labor-intensive tasks—from sowing to post-harvest management—but they still struggle to secure land ownership, institutional credit, and access to modern farming tools. Addressing this gap is not just about social equality; it is a basic requirement for national food security and rural growth.This paper explores practical approaches to transform women from traditional farm laborers into empowered "Agripreneurs." We highlight how connecting women with Self-Help Groups (SHGs) and Farmer Producer Organizations (FPOs) directly improves their financial independence and bargaining power in the market. Additionally, introducing gender-friendly farm equipment and Climate-Smart Agriculture (CSA) training is essential to reduce their daily physical drudgery, especially as climate challenges increase.Giving women equal access to resources has a direct, positive impact on household nutrition and local economies. The study emphasizes that empowering female farmers aligns directly with the UN Sustainable Development Goals, specifically Zero Hunger (SDG 2) and Gender Equality (SDG 5). To build a strong agricultural future, the focus must shift from policy-making on paper to grassroots-level execution. This ensures that women farmers get the institutional backing, targeted extension services, and recognition they actually deserve.

Keywords: Women Empowerment, Agripreneurs, Gender Yield Gap, Climate-Smart Agriculture, Self-Help Groups, Farmer Producer Organizations

Prevalence of Musculoskeletal Problems among female workers involved in Seeds Grading Activity in Makhana Processing

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ABSTRACT

The processing of makhana (*Euryale ferox*) is a labour-intensive, mostly manual practice that is placed in Bihar, India. To get the white popped makhana, the process involves seeds storage, cleaning of seeds, sun-drying, seeds-grading, preheating, roasting, popping, polishing, grading and packaging activities. Despite being a high-value, organic, and nutritious aquatic crop, makhana is still primarily processed using traditional methods, which puts workers under a lot of physical strain and causes musculoskeletal problems and disorders and exertion. The purpose of this study was to ascertain the prevalence of musculoskeletal problems connected to work among women who process makhana. Fifty female workers who were engaged in daily makhana processing activities for seven months a year participated in an observational survey.Interviews and observational techniques were used to gather data. The results shows that the women workers' main health issue was musculoskeletal problems and perceived exertion and neck pain was the most often reported issue (95%), followed by knee pain (94%), hip pain (90%), and various associated discomforts, according to an analysis of MSPs. The physically hard nature of makhana processing work is demonstrated by the fact that 98% of women workers ranked theseedsgradingactivity as "very heavy,"followed by 92% of the women workers perceived as "heavy," and 87% workers perceived as "moderately heavy." The study highlights the necessity of ergonomic treatments to safeguard the postural health of women workers. In addition to appropriate labour-saving techniques and equipment, corrective guidance in the local language may assist reduce extended musculoskeletal problems and disorders enhance working conditions in general. Additionally, workers involved in makhana processing may gain in the long run from such procedures, which could boost productivity and save time.

Keywords: Ergonomics, Makhana Processing, Musculoskeletal Disorder, Perceived Exertion, Popping Roasting and Seeds Grading

An Economic Impact of Tripura Rural Livelihood Mission (TRLM) on Livelihood Sustainability for Women in Tripura

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ABSTRACT

Women comprise nearly 49% of India's population and play a vital role in agricultural and economic activities, although their contributions often remain unrecognized. Policy attention towards women's empowerment in India began with the Sixth Five-Year Plan (India) and was further strengthened during the Tenth Five-Year Plan (India), which emphasized improving women's skills, awareness, and access to resources. In Tripura, the second most populous state in Northeast India, women constitute a significant share of the rural population and the state has a comparatively high female-to-male ratio. To promote socio-economic development and livelihood security among rural women, the Tripura Rural Livelihood Mission (TRLM) was implemented under the National Rural Livelihood Mission (NRLM). TRLM focuses on social empowerment through community-based institutions and economic empowerment through sustainable livelihood opportunities. Since its inception, the mission has formed nearly 53,000 Self-Help Groups (SHGs), mobilized around 4.75 lakh rural households, and distributed revolving funds amounting to □7,631 lakh to support livelihood activities. The program promotes both farm-based enterprises such as vegetable cultivation, poultry, and fisheries, as well as non-farm activities including food processing and small retail businesses. By 2022–23, more than 63,800 rural women had been organized into SHGs and over 16,000 women had received skill-based training, demonstrating the growing role of TRLM in strengthening women's economic participation and livelihood development in the state. In this context, the present study aims to identify the most preferred farm and non-farm businesses adopted by women under TRLM, assess the factors influencing the successful adoption of TRLM schemes by women beneficiaries, examine the impact of these farm and non-farm livelihood activities on their socio-economic status, and identify the key constraints faced by TRLM beneficiaries in the study area.

Keywords: Livelihood Sustainability, Rural Women Empowerment, Self-Help Groups (SHGs), Income Generation, Micro-enterprise Development, Tripura Rural Livelihood Mission (TRLM)

Bridging the Food Safety Awareness Gap Among Women: A Data-Driven Evidence in Relation to FSSAI Pink Book of India

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ABSTRACT

Food safety and nutrition awareness are critical determinants of public health, particularly among women who serve as primary food handlers and caregivers within households. Their knowledge and practices directly influence the health and nutritional status of families, especially children. This review evaluates women's awareness of the Pink Book initiative by the Food Safety and Standards Authority of India and its potential to strengthen household food safety practices. The Pink Book serves as an important educational tool designed to promote safe food handling, hygiene, and nutrition-related behaviors at the grassroots level.The study synthesizes evidence from secondary sources, including reports and research papers from the World Health Organization, Indian Council of Medical Research, and National Family Health Survey. Findings reveal substantial gaps in both awareness and practice among women. Approximately 56% of the disease burden is linked to unhealthy diets and unhygienic food practices, while nearly 53% of women aged 15–49 years are anaemic, indicating persistent nutritional deficiencies. Furthermore, only 20–30% of the population achieves adequate dietary diversity, reflecting limited access to balanced diets and nutrition knowledge.In addition, awareness regarding food adulteration remains low, and maternal feeding practices are suboptimal, with only around 58% of infants receiving exclusive breastfeeding. The evidence also highlights a pronounced rural–urban disparity in awareness levels and access to information, along with a growing double burden of malnutrition characterized by the coexistence of undernutrition and diet-related non-communicable diseases.Despite the availability of national guidelines and educational resources, awareness and utilization of structured tools such as the FSSAI Pink Book remain limited among women. The review concludes that targeted awareness interventions, capacity-building programs, and effective dissemination of the Pink Book can play a transformative role in improving food safety behaviors, enhancing nutritional outcomes, and reducing preventable health risks. Strengthening women-centric food safety education is essential for achieving sustainable and inclusive public health improvements.

Keywords: Dietary Practices, Adulteration, FSSAI Pink Book, Household Food Security,Nutrition, Public Health

EMPOWERING WOMEN FARMERS

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ABSTRACT

Women farmers are the backbone of rural agriculture, contributing significantly to food production, livestock management, and household nutrition. Despite their hard work and dedication, they often remain invisible in decision-making processes and face barriers such as unequal access to land ownership, financial services, modern technology, education, and market opportunities. Empowering women farmers is not only a matter of social justice but also a key step toward achieving sustainable agricultural development and economic growth.Empowerment can be achieved through skill development programs, agricultural training, digital literacy, access to credit facilities, and participation in farmer cooperatives and self-help groups. When women are given equal opportunities and recognition, they become more confident, productive, and independent. Their involvement leads to improved farm productivity, better family health and nutrition, and stronger rural economies.In today's changing agricultural landscape, women farmers are emerging as innovators, entrepreneurs, and leaders who are transforming traditional farming practices into sustainable and climate-resilient systems. Supporting and empowering them creates a ripple effect that benefits families, communities, and the nation as a whole. Therefore, ensuring equal rights, opportunities, and respect for women in agriculture is essential for building aWomen farmers are the backbone of rural agriculture, contributing significantly to food production, livestock management, and household nutrition. Despite their hard work and dedication, they often remain invisible in decision-making processes and face barriers such as unequal access to land ownership, financial services, modern technology, education, and market opportunities. Empowering women farmers is not only a matter of social justice but also a key step toward achieving sustainable agricultural development and economic growth.Empowerment can be achieved through skill development programs, agricultural training, digital literacy, access to credit facilities, and participation in farmer cooperatives and self-help groups. When women are given equal opportunities and recognition, they become more confident, productive, and independent. Their involvement leads to improved farm productivity, better family health and nutrition, and stronger rural economies.In today's changing agricultural landscape, women farmers are emerging as innovators, entrepreneurs, and leaders who are transforming traditional farming practices into sustainable and climate-resilient systems. Supporting and empowering them creates a ripple effect that benefits families, communities, and the nation as a whole. Therefore, ensuring equal rights, opportunities, and respect for women in agriculture is essential for building a resilient, inclusive, and food-secure future.

Keywords: Women, Agriculture, Empowerment, Entrepreneurs

An Economic Impact of Tripura Rural Livelihood Mission (TRLM) on Livelihood Sustainability for Women in Tripura

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ABSTRACT

Women comprise nearly 49% of India's population and play a vital role in agricultural and economic activities, although their contributions often remain unrecognized. Policy attention towards women's empowerment in India began with the Sixth Five-Year Plan (India) and was further strengthened during the Tenth Five-Year Plan (India), which emphasized improving women's skills, awareness, and access to resources. In Tripura, the second most populous state in Northeast India, women constitute a significant share of the rural population and the state has a comparatively high female-to-male ratio. To promote socio-economic development and livelihood security among rural women, the Tripura Rural Livelihood Mission (TRLM) was implemented under the National Rural Livelihood Mission (NRLM). TRLM focuses on social empowerment through community-based institutions and economic empowerment through sustainable livelihood opportunities. Since its inception, the mission has formed nearly 53,000 Self-Help Groups (SHGs), mobilized around 4.75 lakh rural households, and distributed revolving funds amounting to □7,631 lakh to support livelihood activities. The program promotes both farm-based enterprises such as vegetable cultivation, poultry, and fisheries, as well as non-farm activities including food processing and small retail businesses. By 2022–23, more than 63,800 rural women had been organized into SHGs and over 16,000 women had received skill-based training, demonstrating the growing role of TRLM in strengthening women's economic participation and livelihood development in the state. In this context, the present study aims to identify the most preferred farm and non-farm businesses adopted by women under TRLM, assess the factors influencing the successful adoption of TRLM schemes by women beneficiaries, examine the impact of these farm and non-farm livelihood activities on their socio-economic status, and identify the key constraints faced by TRLM beneficiaries in the study area.

Keywords: Livelihood Sustainability, Rural Women Empowerment, Self-Help Groups (SHGs), Income Generation, Micro-enterprise Development, Tripura Rural Livelihood Mission (TRLM)

Agripreneurial Orientation as a Pathway for Empowering Women Farmers in Bihar

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ABSTRACT

Women farmers play a significant role in agricultural production and household livelihood security in rural India. Strengthening their entrepreneurial capacity is essential for enhancing income generation, decision-making ability, and socio-economic empowerment. The present study examined the agripreneurial orientation of farm women in Bihar and its role in empowering women farmers through entrepreneurship-related attributes and participation in agricultural activities.The study was conducted in Saharsa district of Bihar with a sample of 150 farm women selected through appropriate sampling procedures. Data were collected using a structured and validated interview schedule comprising major dimensions of agripreneurial orientation such as innovativeness, decision-making ability, leadership ability, market orientation, Proactiveness, and resource management. Appropriate statistical tools were used to analyze the data.The findings revealed that most farm women possessed medium to high levels of agripreneurial orientation. Among different dimensions, proactiveness and market orientation showed comparatively higher mean scores, indicating increasing awareness and participation of women in market-linked agricultural activities. Factors such as innovativeness, decision-making ability, and resource management were found to significantly influence agripreneurial orientation. The study further highlighted that participation in entrepreneurial activities enhanced women's confidence, economic involvement, and household decision-making capacity. However, limited access to training, credit facilities, and market linkages remained major challenges affecting their entrepreneurial growth.The study concludes that strengthening agripreneurial orientation through extension interventions, skill development programmes, and institutional support can serve as an effective strategy for empowering women farmers and promoting sustainable rural development in Bihar.

Keywords: Women Farmers, Agripreneurial Orientation, Empowerment, Entrepreneurship, Rural Development, Bihar

Role of Women in Climate-Resilient Agriculture

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ABSTRACT

Climate change has emerged as a major challenge to agricultural sustainability by affecting crop productivity, water availability, soil fertility and rural livelihoods. Women farmers play a crucial role in climate-resilient agriculture through their active participation in crop production, livestock management, seed preservation, water conservation and sustainable farming practices. In India, women constitute a significant share of the agricultural workforce, with recent reports indicating that nearly 64.4% of female workers are engaged in agriculture. Despite their contribution, women often face limited access to land ownership, credit facilities, climate information, modern technologies and decision-making opportunities. Studies show that women-led farming households in South Asia suffer nearly 8% higher climate-related income losses compared to male-headed households. However, women are increasingly adopting climate-smart agricultural practices such as crop diversification, organic farming, agroforestry, integrated nutrient management, drip irrigation and use of drought-tolerant varieties to enhance resilience against climatic stresses. Digital advisory services, self-help groups and government initiatives are further strengthening women's participation in sustainable agriculture. Research indicates that empowering women farmers can significantly improve food security, environmental sustainability and rural economic development. Therefore, gender-inclusive policies, equal access to resources, technical training and climate-smart technologies are essential for building resilient agricultural systems and achieving sustainable development goals.

Keywords: Climate-Resilient Agriculture, Sustainable Farming, Organic Farming, Agricultural Sustainability

THEME: -7

High Valued Horticultural Crop Production

Twin Treasure Farming: A High-Value Vertical Farming Model Integrating Vanilla and Dragon Fruit for Assam and North-East

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ABSTRACT

Mixed cropping of Vanilla (*Vanilla planifolia*) with Dragon fruit (*Hylocereus spp.*) represents an innovative, sustainable, and economically profitable vertical farming system suitable for tropical and subtropical regions such as Assam and the North-Eastern states of India. This integrated cultivation approach utilizes the strong vertical support structure of dragon fruit plants to support climbing vanilla vines, thereby maximizing land-use efficiency and promoting sustainable horticultural production. Dragon fruit is a cactus crop that requires concrete or iron support pillars for vertical growth, while vanilla is an orchid vine that depends on external support for proper development. Integrating these two high-value crops on the same support structure creates an efficient dual-cropping system capable of generating higher returns from limited land resources. Assam and North-Eastern India offer highly favourable agro-climatic conditions for this integration, including high humidity, warm tropical temperatures (20–40°C), adequate rainfall (500–2500 mm annually), and rich organic soils. The model addresses the region's predominant smallholder farming context by maximizing productivity per unit area through efficient vertical space utilization. Key advantages include reduced infrastructure costs, improved micro-climate for vanilla under the dragon fruit canopy, and a dual-income system providing early returns from dragon fruit (15–24 months) alongside long-term premium income from vanilla beans. Both crops are well-suited to organic cultivation using farmyard manure, vermicompost, and biofertilizers aligning with Assam's growing emphasis on sustainable agriculture. Critical management practices include drip irrigation, organic mulching, and hand pollination for both crops. Challenges encompass high initial investment, skilled labour requirements for pollination, disease management in humid conditions, and ensuring adequate drainage. With appropriate training, infrastructure support, and market linkages, Twin Treasure Farming offers a climate-resilient, high-value horticultural enterprise model with significant potential for farmer income enhancement across Assam and the broader North-Eastern region.

Keywords: Vertical farming, mixed cropping, vanilla, dragon fruit, Assam, sustainable agriculture, smallholder farming

Evaluation of different substrates for Shiitake mushroom (*Lentinulaedodes*) cultivation in Bihar

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ABSTRACT

Shiitake mushroom (*Lentinulaedodes*) is one of the most valued medicinal and edible fungi owing to its high nutritional value, therapeutic potential, and increasing market demand. Shiitake mushrooms generally exhibit optimal growth on hardwood logs or supplemented sawdust substrates. However, in plain-land regions, the availability of hardwood is limited and often associated with high costs. In addition, the quality and consistency of sawdust in these areas are highly variable, which adversely affects substrate performance. Although alternative substrate materials can be utilized, they frequently result in lower biological efficiency compared with conventional hardwood-based substrates. In Bihar, commercial cultivation of shiitake mushroom has considerable potential for income generation, agro-waste recycling, and promotion of rural entrepreneurship. The present investigation evaluated the suitability of four substrate systems for shiitake cultivation, namely wheat straw, maize cob waste, litchi leaves, and a supplemented substrate consisting of wheat straw, wheat bran, and calcium carbonate. The study assessed mycelial colonization, biological efficiency, fruit body development, and production cycle duration. Significant differences were observed among the substrates with respect to spawn run period, yield, and flush production. Substrates such as wheat straw, maize cob waste, and litchi leaves were economical and environmentally sustainable; however, they exhibited slower mycelial colonization and comparatively lower yields. In contrast, the supplemented wheat straw substrate demonstrated superior performance characterized by rapid mycelial growth, improved substrate compactness, enhanced moisture retention and aeration, and higher biological efficiency. These factors resulted in uniform fruiting, production of better-quality mushrooms, and reduced crop duration. The findings suggest that supplementation of wheat straw with wheat bran and calcium carbonate is highly effective for commercial shiitake mushroom cultivation under the agro-climatic conditions of Bihar. Adoption of this substrate technology can support sustainable medicinal mushroom production, efficient agro-residue utilization, and livelihood enhancement among rural growers.

Keywords: Shiitake mushroom, biological efficiency, substrate supplementation, medicinal mushroom cultivation.

Post-Harvest Preservation of Litchi through Ultrasound-Assisted Osmotic Dehydration and Tray Drying for Enhanced Bioactive Compounds, Antioxidant Capacity, and Shelf Stability

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ABSTRACT

This study optimized ultrasound-assisted osmotic dehydration (USOD) of litchi quarters using response surface methodology with a Box–Behnken design to maximize water loss and minimize solid gain. Independent variables were ultrasound amplitude (20–40%), sonication time (10–30 min), and sucrose concentration (20–60% w/w), using a 4:1 solution-to-fruit ratio. Water loss and solid gain ranged from 8.45–28.87% and 2.17–6.73%, respectively. Optimal conditions (34.79% amplitude, 30 min, 40% sucrose) predicted 23.76% water loss and 3.89% solid gain, with second-order regression models showing good fit. The effect of USOD pretreatment followed by convective drying at 60°C was evaluated against untreated samples. USOD-treated samples reached low moisture content (11% dry basis) and water activity (0.41) in 9 h versus 11 h for control, with less darkening. Total phenolic content (10.72 mg GAE/g), Total flavonoid content (3.17 mg QE/g DW), Antioxidant activity (56.47%) was significantly higher than in control (7.39 mg GAE/g, 2.13 mg QE/g DW and 43.18%, respectively). FTIR analysis confirmed greater antioxidant retention in USOD-pretreated dried litchi quarters. Shelf-life studies demonstrated that dried litchi remained within acceptable microbial limits for up to six months when stored in Aluminium Laminated Packaging (ALP), whereas microbial safety was maintained for only three months in Low-Density Polyethylene (LDPE) packaging.

Keywords: Litchi, Total phenolic content, Total flavonoid content, Antioxidant activity, FTIR

Evaluation of different grain substrate for production of King Oyster Mushroom (*Pleurotuseryngii)*

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ABSTRACT

Mushrooms have been an integral part of human civilization since ancient times, serving as both food and medicine. The major cultivated mushroom species in India include button mushroom *(Agaricusbisporus),* oyster mushroom *(Pleurotus spp.),* paddy straw mushroom *(Volvariella volvacea) and milky mushroom(Calocybe indica)*. Each species differs in its growth requirements, nutritional composition, and market value. King Oyster mushroom (*Pleurotus eryngii*) is a highly valued edible mushroom known for its nutritional and medicinal benefits, long shelf life, strong market demand,and importance as a functional food in nutrition and traditional medicine. Quality spawn production is essential for successful cultivation of mushrooms, as it directly affects mycelial growth, substrate colonization, and yield. This study evaluated four grain substrates—wheat, maize, bajra, and paddy—for spawn production under laboratory conditions using a Completely Randomized Design (CRD) with five replications. Among all substrates, wheat grain showed the fastest and most uniform mycelial colonization with minimum spawn run days, making it the most suitable substrate for spawn production. Bajra and maize also supported good growth, while paddy showed slower and weaker colonization. The superior performance of wheat was attributed to its balanced nutrient composition, favourable carbon-to-nitrogen ratio, good moisture retention, and suitable grain texture. The study concludes that wheat grain is the most efficient substrate for high-quality spawn production of King Oyster mushroom and can be recommended for commercial cultivation.

Keywords: *Pleurotu seryngii*, King Oyster mushroom, spawn production, grain substrates, mycelial growth, wheat grain, mushroom cultivation, CRD

Rejuvenation of old litchi orchards of Bihar

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ABSTRACT

Litchi is one of the major crops in Bihar. The state leads in area and production of Litchi in the country. However, the productivity of litchi is low in the state. Most of the acreage under Litchi in Bihar is old, senile and dense, generally characterized by intermingling, overcrowding and pest infested branches with more of wood mass and canopy of unhealthy shoots which is quite unfavourable for bearing quality fruits. Litchi witnesses decline in productivity after age of 50 years and orchards become uneconomical, non-viable and non-remunerative. Such orchards can be made again productive by adopting rejuvenation technique. Rejuvenation includes marking of trees and their undesired branches for pruning in the month of Dec-Jan with the help of white paint followed by pruning. The marked trees are headed back of well spaced 3-4 main scaffold branches at 4-6 feet from ground level with the help of power pruning saw and thinning out of crowded/ intermingling branches. Copper oxychloride is applied on the cut surfaces. New branches come out from the cut part. 4-5 healthy and robust branches are selected and rest of the branches are cut off. Removal of weak and diseased branches is done 2-3 times in a year. Orchard establishes in about three years. Commercial yield can be obtained after five years. By rejuvenation, trees can be made productive for the coming years. However, rejuvenation should be done in the guidance of experts. By rejuvenating the old and senile orchard of Bihar; productivity of orchards can be increased significantly and thereby income of Farmer's will increase simultaneously.

Keywords: Litchi, Bihar, Rejuvenation, Commercial yield, Pruning

High Value Horticultural Crop Production

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ABSTRACT

High value horticultural crop production refers to the cultivation of fruits, vegetables, spices, and flowers that provide higher income per unit area compared to traditional field crops. These crops are generally market-oriented, perishable, and require better management practices, but they offer significantly higher economic returns when grown scientifically. In regions like Bihar, including Mithapur, horticulture is becoming increasingly important due to small landholdings, rising urban demand, and favorable agro-climatic conditions. Major high value horticultural crops include fruits such as Mango, banana, guava, papaya, pomegranate, and Strawberry. Vegetables like tomato, brinjal, cauliflower, okra, and capsicum are also widely grown for high returns. In addition, flowers like rose and marigold, and spices such as ginger, turmeric, garlic, and black pepper contribute to profitable farming systems. The profitability of these crops is driven by strong consumer demand, export potential, and processing industries. Many horticultural crops have short growth cycles, allowing multiple harvests or quick returns within a year. Farmers can further increase income by adopting modern techniques such as drip irrigation, mulching, and protected cultivation (polyhouse or shade net farming), which help improve yield and quality while reducing water and fertilizer use. Integrated nutrient management and integrated pest management are also essential for maintaining soil health and reducing production costs. The use of certified planting material and improved varieties ensures better productivity and disease resistance. Post-harvest handling, cold storage, and value addition (such as making juices, pickles, or dried products) play a key role in reducing losses and increasing profits. Despite its benefits, horticulture faces challenges like price fluctuations, lack of storage facilities, pest attacks, and limited technical knowledge among farmers. However, with government support, better infrastructure, and improved farming practices, high value horticulture can significantly enhance rural incomes and promote sustainable agriculture. Overall, high value horticultural crops offer an excellent opportunity for small and marginal farmers to achieve higher profitability and economic stability through efficient and scientific farming methods.

Keywords: Horticulture, High value crops, Protected cultivation (polyhouse/shade net), Drip irrigation, Post-harvest management

Integrated approaches for sustainable production and value chain development of high-value horticultural crops

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ABSTRACT

High-value horticultural crops play a significant role in enhancing farmers' income, nutritional security, rural employment, and agricultural diversification. However, the sector faces major challenges such as climate variability, declining resource-use efficiency, post-harvest losses, fragmented supply chains, and limited market access. Sustainable intensification and efficient value chain integration are therefore essential for improving productivity, profitability, and resilience in horticultural systems.The present study highlights integrated approaches for sustainable production and value chain development of high-value horticultural crops, emphasizing technological, economic, and institutional interventions. Climate-smart practices including precision farming, protected cultivation, integrated nutrient and pest management, micro-irrigation, and quality planting materials are discussed for improving resource-use efficiency and crop productivity. The study also explores the role of emerging technologies such as artificial intelligence, IoT-based monitoring systems, hydroponics, and digital advisory platforms in modern horticulture. Furthermore, the importance of post-harvest management, cold chain infrastructure, value addition, Farmer Producer Organizations (FPOs), cooperative marketing, and digital marketing platforms is emphasized for reducing losses and improving market competitiveness. The study concludes that integrating sustainable production technologies with efficient value chain mechanisms can substantially enhance productivity, income generation, and livelihood security in high-value horticulture.

Keywords: High-value Horticultural Crops, Sustainable Horticulture, Value Chain Development, Precision Farming, Agri-entrepreneurship

THEME: -8

Agri-foods: Securing Holistic Nutrition

Bihar's Berry Boost: Exploring Jaggery as a Healthier Alternative in Mulberry Jam Processing

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ABSTRACT

Mulberry (Morus alba) fruits, abundant in Bihar, India is commercially underutilised but it is rich in anthocyanin content, vitamin C, and antioxidant potential. The present study aimed to develop mulberry jam by incorporating two different varieties of mulberry, Morus macroura and Morus Nigra with two different sweeteners, refined sugar and jaggery, to prepare a total of four treatment samples, and to evaluate their physicochemical and sensory characteristics. Multiple jam formulations were prepared and subjected to analysis for Total Soluble Solids (TSS), colour (L*, a*, b* values), acidity, vitamin C content, and water activity (a_w). A sensory evaluation was also conducted using a trained panel to assess appearance, colour, flavour, texture, and overall acceptability. Results indicated notable differences between sugar-based and jaggery-based samples across all parameters. Jaggery-incorporated jam exhibited distinct colour and flavour profiles attributed to its mineral content and caramelization compounds, while sugar-based jam showed higher clarity and lighter colour values. The study demonstrates that mulberry jam can be successfully developed using either sugar or jaggery, providing a nutritious and value-added fruit product with good storage stability and consumer acceptability. jaggery can serve as a functional, minimally processed alternative to refined sugar in mulberry jam preparation without compromising product quality or consumer acceptability, offering a potentially healthier and value-added fruit product.

Keywords: Mulberry, TSS, carmelization compound, jaggery, fruit product, vitamin C

INDIGENOUS SUPERFOODS OF ASSAM: NUTRITIONAL POTENTIAL, CLIMATE RESILIENCE AND AGRI-ENTREPRENEURSHIP OPPORTUNITIES

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ABSTRACT

India ranks 111th out of 125 countries on the Global Hunger Index (2023), with a large share of its population at risk of deficiencies in calcium, Vitamin A, B12, and folate — a condition termed 'hidden hunger'. Paradoxically, the commercial response to this crisis — branded nutraceuticals and fortified packaged foods — remains financially inaccessible to large sections of the population, particularly in Northeast India. The Brahmaputra Valley of Assam, one of the world's recognised biodiversity hotspots, harbours indigenous plant species whose nutritional and pharmacological potentials remain commercially unrealised. Recent studies have highlighted *Garcinia pedunculata*Roxb. (Bor Thekera), *Dillenia indica* L. (Ou Tenga), *Houttuynia cordata* Thunb. (Masundori), and *Paederiafoetida* L. (Bhedailota) as nutritionally important indigenous species with potential applications in combating hidden hunger.Various studies explore the scope of these indigenous species as low-input, climate-resilient crops and evaluate their potential for value-added nutraceutical and functional food development within emerging agri-preneurship frameworks in India. All four species are perennial or semi-wild plants adapted to the humid tropical conditions of Assam and generally require comparatively lower external inputs for cultivation. Their ecological adaptability and resilience highlight their potential importance in climate-vulnerable regions increasingly affected by floods and droughts. Emerging agri-entrepreneurship initiatives in Northeast India, including Samir Bordoloi's SPREAD NE movement and the World Bank-supported Assam Agribusiness and Rural Transformation Project (APART), further highlight the commercial and nutritional potential of indigenous superfoods. These initiatives promote ecological farming, value addition, and market linkages centred around indigenous plant resources, while also demonstrating their possible role in addressing micronutrient deficiency, strengthening climate-resilient agriculture, and supporting rural livelihoods through functional food and nutraceutical markets.

Keywords: Hidden hunger; Indigenous food systems; Nutraceuticals; Functional foods; Climate resilience; Micronutrient malnutrition; Underutilized crops; Assam biodiversity; Agri-entrepreneurship; Northeast India

Development and Quality Characterization of Probiotic Bael Soy-Yoghurt

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ABSTRACT

Bael (*Aegle marmelos*) is an important indigenous fruit crops of India, known for it's medicinal value, drought tolerance as well as it's nutraceutical applications. It is an undervalued crop, with a high processing potential. Bihar and Jharkhand are one of the leading producers of Bael in India. Major Bael growing districts in Bihar includes Bhagalpur, Gaya, Nalanda, Patna, Muzaffarpur and Banka. Bael is a rich source of riboflavin, calcium, iron, carotene, Vitamin C and antioxidant that gaining importance in food industries and it may infuse in probiotic drink to enrich the nutraceutical properties. In this study, soy milk, bael (5-15%) and agar-agar (0.1-0.3%) has been optimized for the development of bael based soy-yoghurt. The results indicated that the optimized formulation containing 10% bael pulp and 0.1% agar-agar was highly acceptable. Physicochemical, sensory and functional properties have been analysed of optimized soy-yoghurt. This study may be beneficial for health-conscious consumers and manufacturers interested in developing lactose-free yoghurt alternatives.

Keywords: Plant -based yoghurt, Lactose-free, Bael, Physicochemical, sensory and functional properties.

Bridging the Food Safety Awareness Gap Among Women: A Data-Driven Evidence in Relation to FSSAI Pink Book of India

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ABSTRACT

Food safety and nutrition awareness are critical determinants of public health, particularly among women who serve as primary food handlers and caregivers within households. Their knowledge and practices directly influence the health and nutritional status of families, especially children. This review evaluates women's awareness of the Pink Book initiative by the Food Safety and Standards Authority of India and its potential to strengthen household food safety practices. The Pink Book serves as an important educational tool designed to promote safe food handling, hygiene, and nutrition-related behaviors at the grassroots level.The study synthesizes evidence from secondary sources, including reports and research papers from the World Health Organization, Indian Council of Medical Research, and National Family Health Survey. Findings reveal substantial gaps in both awareness and practice among women. Approximately 56% of the disease burden is linked to unhealthy diets and unhygienic food practices, while nearly 53% of women aged 15–49 years are anaemic, indicating persistent nutritional deficiencies. Furthermore, only 20–30% of the population achieves adequate dietary diversity, reflecting limited access to balanced diets and nutrition knowledge.In addition, awareness regarding food adulteration remains low, and maternal feeding practices are suboptimal, with only around 58% of infants receiving exclusive breastfeeding. The evidence also highlights a pronounced rural–urban disparity in awareness levels and access to information, along with a growing double burden of malnutrition characterized by the coexistence of undernutrition and diet-related non-communicable diseases.Despite the availability of national guidelines and educational resources, awareness and utilization of structured tools such as the FSSAI Pink Book remain limited among women. The review concludes that targeted awareness interventions, capacity-building programs, and effective dissemination of the Pink Book can play a transformative role in improving food safety behaviors, enhancing nutritional outcomes, and reducing preventable health risks. Strengthening women-centric food safety education is essential for achieving sustainable and inclusive public health improvements.

Keywords: Dietary Practices, Adulteration, FSSAI Pink Book, Household Food Security,Nutrition, Public Health.

Agri-foods: Securing Holistic Nutrition

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ABSTRACT

Ensuring holistic nutrition in the face of rising population, climate variability, and resource constraints remains a critical global challenge. Agri-food systems play a central role not only in food production but also in delivering balanced, safe, and nutrient-rich diets. This study explores the integration of sustainable agricultural practices, diversified cropping systems, and nutrition-sensitive approaches to enhance food quality and accessibility. Emphasis is placed on biofortification, organic farming, and precision agriculture as strategies to improve micronutrient availability while minimizing environmental degradation.Furthermore, the role of technology-driven interventions, including data analytics and smart irrigation, is examined in optimizing resource use and increasing crop productivity. Strengthening local food systems, reducing post-harvest losses, and promoting value addition are identified as key pathways to ensure year-round availability of nutritious foods. The study also highlights the importance of policy frameworks, community participation, and awareness programs in bridging the gap between food production and nutritional outcomes.By adopting a multidisciplinary approach that connects agriculture, health, and sustainability, agri-food systems can transition from calorie-centric production to nutrition-oriented outcomes. This transformation is essential for addressing malnutrition in all its forms, including undernutrition, micronutrient deficiencies, and obesity. The findings underscore that securing holistic nutrition requires coordinated efforts across stakeholders, innovative technologies, and sustainable practices to build resilient and inclusive food systems for the future.

Keywords: Agri-food systems, Holistic nutrition, Sustainable agriculture, Food security, Precision agriculture

Development of Date Palm Jaggery using Okra Mucilage as a Clarificant

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ABSTRACT

Date palm neera is a naturally nutritious sap that may be processed into high-value goods like jaggery. It is rich in sugars, vitamins, minerals, antioxidants and bioactive compounds. Clarification is a crucial manufacturing stage of jaggery that may give negatively impactby the presence of colloidal and suspended contaminants in neera. Chemical clarificants are the primary component of conventional clarifying techniques, which may have a detrimental effect on consumer acceptability and product quality. In order to produce date palm jaggery, okra mucilage as a natural clarifying agentis used for clarification of date palm neera that rich in galactose, rhamnose and galacturonic acid. Okra mucilage was extracted in the lab and its physicochemical and functional characteristics was analysed. Further, using different concentrations of okra mucilage, concentrated date palm neera was clarified using conventional evaporation method. It was found that clarification of date palm neera using plant mucilage for the production of jaggery was acceptable in term ofturbidity, colour and TSS. This study will encourage the use of sustainable plant-based substitutes for clarification of neera as compared to synthetic clarificants.

Keywords: Date palm neera, Okra mucilage, Clarification, Jaggery, Physicochemical and functional properties.

Modification of Palmyrah Tuber Starch by Heat Moisture Treatment byusingRefractance Window Drying

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ABSTRACT

Heat-moisture treatment (HMT) is a physical hydrothermal method used to modify the starch functional properties without using chemical reagents. It isconsidered safe, environmentally friendly as well as cost-effective. HMT is done by using high temperature and low moisture content and involves treatment of starch or flour at different temperate at moisture content 30%.Refractance Window Drying (RWD) is new and emerging fourth-generation drying technology. It is cost effective and drying the food by using hot water as a heat transfer medium at a temperature below its boiling point.In this research, HMT of starch was performed by the using Refractance Window Drying (RWD) and Hot Air Drying (HAD) methods and analysed the different properties such as water absorption capacity, oil holding capacity, syneresis, color and pasting behaviour.Physicochemical, functional and pasting properties of HMT treated palmyrah tuber starch using RWD method was found better result as compared to hot air-drying method. HMT-starches can be used for pasta, candy and bakery products.

Keywords: Heat Moisture Treatment, Refractance Window Drying, Physicochemical, Functional and Pasting properties.

Agri-food: Securing Holistic Nutrition, A Silent Nutritional Crisis

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ABSTRACT

Hidden hunger, also known as micronutrient deficiency despite adequate calorie intake, is becoming a serious public health issue in India and many developing countries. Although people may consume enough food to satisfy hunger, they often lack essential nutrients such as iron, calcium, zinc, iodine, folate, and vitamins. This condition is called a "silent nutritional crisis" because its harmful effects are not always immediately visible but gradually affect physical growth, immunity, cognitive development, and overall health. Children, adolescents, pregnant women, and low-income populations are the most affected groups.According to the Global Hunger Index (2025), India ranks 102nd out of 123 countries with a score of 25.8, indicating a serious hunger situation. Recent reports from 2025–2026 reveal that more than 80% of adolescents in India suffer from hidden hunger, which negatively impacts their physical and mental development. In addition, around 67% of children aged 6–59 months and 57% of women aged 15–49 years are affected by anemia due to iron and folate deficiencies. These findings highlight the urgent need to improve nutritional quality rather than focusing only on calorie intake.The agri-food system plays a major role in ensuring holistic nutrition by promoting the production and accessibility of safe, affordable, and nutrient-rich foods. Holistic nutrition focuses on balanced nourishment for physical, mental, and social well-being. Sustainable agriculture, crop diversification, food fortification, biofortification, kitchen gardening, and nutrition education can help reduce micronutrient deficiencies and improve dietary diversity. Strengthening nutrition-sensitive agri-food systems and increasing public awareness are essential steps toward achieving food and nutrition security. Addressing hidden hunger is necessary for building a healthier, more productive, and sustainable society.

Keyword: Micronutrient Deficiency, Hidden Hunger, Malnutrition, Biofortification

Agri-foods: Securing Holistic Nutrition: -From Food Security to Nutrition Security: Re-designing Agri-food Systems for Hidden Hunger

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ABSTRACT

Over the past six decades the global food system has gained remarkable crop productivity, but still these advances have coincided with a troubling decline in the nutritional quality of many staple foods worldwide. This decline has been linked to imbalanced mineral fertilization, the widespread adoption of high-yielding yet less nutrient-dense cultivars, and a large-scale shift from traditional and natural farming systems toward intensive chemical-based agriculture. The shift from quality to quantity. Although such methods have led to improved food availability, they have also resulted in what is termed the "hidden hunger" burden of the world, whereby there exists a deficiency of vital micronutrients even when sufficient amounts of calories are consumed. Hidden hunger accounts for about 45% of child mortality cases aged under five years. Statistics from the Food and Agriculture Organization and the World Health Organization reveal that almost 2 billion people around the world are deficient in micronutrients, and the deficiencies of iodine, iron, vit A, and zinc are considered the most alarming. This condition negatively impacts children and individuals in developing nations, leading to poor immunity, cognitive growth, and high risks of death. The existence of hidden hunger indicates the immediate necessity to surpass the concept of food security based on caloric adequacy and advance into nutrition security. Solving this problem necessitates a change in mindset in agriculture, from focusing on only output quantity to quality and sustainability. India and other developing nations, the agricultural sector finds itself at a crucial juncture. Increasing input prices, reducing land sizes, and shifting consumer preferences are hastening the shift from "quantity to quality." In the coming years, agri-food systems need to guarantee accountability, sustainable resource management, and compatibility with market requirements while maintaining ecological balance.The food system must address the four pillars availability, access, utilisation, and stability through holistic and region-specific strategies. Food system diversification involving crop diversity, aquaculture, livestock, and wild fruit domestication can improve diet quality, income, and sustainability. Aquaculture, backyard poultry, and gender-sensitive livestock policies can enhance nutrition and rural livelihoods. Crop biofortification (Biofortification Program – HarvestPlus) (vitamin-A sweet potato) and public plant breeding are key scientific interventions to combat hidden hunger. Strengthening food value chains, reducing food wastage, and investing in storage, cold chains, and market connectivity are essential.Overall, transforming the food system in India requires integrated policies(National Mission on Nutri-Cereals (Millets Mission) -Supported by NITI Aayog Revives millets (Shree Anna) research, and inclusive interventions targeting vulnerable populations.

Keywords: Hidden Hunger, Biofortification, systemic diversification, accountability sustainability.

Effect of Agronomic Zinc Biofortification through Soil and Foliar Application on Yield of Fodder Sorghum

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ABSTRACT

Fodder sorghum (*Sorghum bicolor* L. Moench) is an important forage crop cultivated extensively in tropical and subtropical regions due to its high biomass production, rapid growth, and adaptability to drought-prone conditions. However, widespread zinc deficiency in Indian soils, particularly in calcareous soils of Bihar, has emerged as a major constraint affecting fodder productivity and crop growth. Zinc is an essential micronutrient involved in chlorophyll synthesis, enzyme activation, auxin metabolism, and photosynthetic activity, thereby playing a crucial role in plant growth and biomass accumulation. Agronomic zinc biofortification through soil and foliar application offers a promising strategy for improving fodder yield and nutrient efficiency under zinc-deficient conditions.A field experiment is being conducted at the Research Farm of Dr. Rajendra Prasad Central Agricultural University during the kharif season to evaluate the effect of soil and foliar zinc application on the yield of fodder sorghum. The experiment has been laid out in a split plot design with three replications using fodder sorghum variety CSH 40F. The main plot treatments consist of four levels of soil-applied zinc through $ZnSO_4$ viz., 0, 5, 7.5 and 10 kg Zn ha^{-1}, while subplot treatments include three foliar zinc application schedules comprising no spray, single spray of 0.5% $ZnSO_4$ at 30 DAS and two sprays at 30 and 50 DAS. Observations on growth parameters, fresh fodder yield, and dry matter yield are being recorded and analyzed statistically. The study aims to identify an efficient zinc management practice for enhancing fodder productivity under zinc-deficient soils of eastern India. Combined soil and foliar application of zinc is expected to improve crop growth, nutrient utilization, and biomass production compared to individual applications. The findings of the investigation may provide a sustainable and economically feasible approach for improving fodder availability and supporting livestock productivity in resource-constrained farming systems.

Keywords: Fodder sorghum; Soil application; Foliar spray; Fresh fodder yield; Dry matter yield

Genetic Variability and Analysis of Variance for Yield and Quality Traits in Maize (*Zea mays* L.) using Line × Tester Mating Design

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ABSTRACT

Genetic variability and the analysis of variance were studied in 45 F_1 hybrids generated by crossing 15 diverse maize inbred lines with 3 testers following the Line × Tester mating design during Rabi 2024–2025. The F_1 hybrids, along with 18 parents and 2 standard checks, were evaluated in a Randomized Block Design with three replications during Kharif 2025 at the Crop Research Farm, Tirhut College of Agriculture (TCA), Dholi, Bihar. Data were recorded on 14 traits: days to 50% flowering, days to 50% silking, plant height, cob height, ear length, ear diameter, number of kernel rows per ear, number of kernels per row, 1000-grain weight, grain yield, protein, starch, amylose, and amylopectin content. The analysis of variance revealed highly significant mean squares for treatments, parents, crosses, and the Line × Tester interaction across all 14 traits, confirming adequate genetic diversity among the experimental material and a meaningful role for both general and specific combining ability in trait expression. The Parents vs. Crosses comparison was significant for every trait, indicating that the hybrid generation outperformed the parental mean. The coefficient of variation remained below 15% for all traits, attesting to the precision of the experiment. Among parental lines, the phenotypic coefficient of variation (PCV) exceeded the genotypic coefficient of variation (GCV) for all traits, indicating environmental influence alongside heritable variance. High GCV was recorded for grain yield (21.25%) and cob height (17.88%) in lines, while moderate GCV was observed for ear length (16.31%), ear diameter (14.69%), and 1000-grain weight (16.12%). Broad-sense heritability was high for grain yield (h^2b = 88.07%), protein content (79.42%), cob height (79.26%), and 1000-grain weight (71.76%) in the line group. High heritability coupled with high genetic advance as a percentage of mean was recorded for grain yield (GA = 41.08%), cob height (GA = 32.79%), ear length (GA = 27.25%), and 1000-grain weight (GA = 28.13%) among lines, indicating the predominance of additive gene action and the suitability of direct phenotypic selection for these traits. Protein and starch content showed high heritability with only moderate genetic advance in the hybrid population, pointing to a non-additive gene effect component that warrants recurrent selection or biparental mating in advanced generations. These findings provide a reliable genetic basis for designing effective selection strategies in future maize hybrid development programmes.

Keywords: Analysis of variance; combining ability; genetic advance; genetic variability; GCV; heritability; Line × Tester; maize; PCV.

Moringa (Moringa oleifera): A Sustainable Pathway Towards Nutritional Security and Rural Livelihood Enhancement

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ABSTRACT

Moringa oleifera, often referred to as the "miracle tree," has emerged as an important crop for improving nutritional security, promoting sustainable agriculture, and strengthening rural livelihoods. Rich in essential vitamins, minerals, proteins, and antioxidants, moringa has the potential to address malnutrition and hidden hunger, particularly among vulnerable populations in rural and semi-urban communities. Its adaptability to diverse climatic conditions, low input requirement, and year-round utility make it an ideal crop for small and marginal farmers. Beyond nutritional benefits, moringa offers economic opportunities through value-added products such as leaf powder, oil, herbal supplements, and food products, creating avenues for rural entrepreneurship and income generation. The cultivation and utilization of moringa can contribute significantly to women empowerment, household nutrition improvement, and community health development. This paper highlights the multifaceted role of moringa in creating a sustainable food system and enhancing socio-economic well-being, emphasizing its importance as a climate-resilient and livelihood-supporting crop for the future.

Keywords: Moringa, nutritional security, rural livelihood, sustainability, entrepreneurship, community health

Tribal and Regional Food Biodiversity: An Untapped Nutritional Resource

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ABSTRACT

India has an enormous, unused potential in terms of nutritional value in its tribal and local food systems. Wild edibles, native crop varieties, and historical cooking methods provide sustenance to many tribes around the world. The country is home to over 800 tribal groups that utilize wild foods based off forests. This "Agri-biodiversity" is crucial to the overall food security of the nation but is mostly undocumented. As diets shift toward fast processed products, there will be further marginalization of wild/forest-based foodswhich may create more issues related to malnutrition and non-communicable disease at the same time. This article attempts to address the large gap in documenting tribal food systems systematically, creating nutrient profiles, and linking them to public health.The author employed a combination of ethnobotany and biochemical analysis. Ethnobotanical surveys of the Gond, Santhal, and Mishing tribal communities located in central and eastern India were conducted to assess the use of wild/forest-based food sources. Biochemical analysis was used to quantify macronutrient content, micro-nutrient content (vitamins A & C, iron, zinc), and bioactive compound content of 50+wild food items using FSSAI/AOAC protocols. Participatory Rural Appraisal (PRA) methodologies were utilized to ensure the research process reflected the perspectives of each community being studied and compared with existing food composition tables via comparative dietary modeling.Results from the study showed that the tribal food system contains a number of highly nutritious food options. For example, Mahua flower (*Madhuca longifolia*) contained 20-25% crude protein and a significant amount of Riboflavin; Bamboo Shoots contain both prebiotic fiber and high levels of antioxidants greater than Spinach; and Edible Ferns are three to five times richer in Iron than Amaranth. These wild/forest-based foods appear to be rich in nutrients that are also bioavailable and resilient to climate change. However, they are threatened due to continued deforestation and loss of cultural identity resulting from increasing globalization. In conclusion, harnessing tribal and regional food biodiversity can combat hidden hunger, enhance food security, and promote sustainable diets.

Keywords: Tribal foods, food biodiversity, wild edibles, micronutrient density, indigenous nutrition

Food Security and Nutritional Security: A Dietetics Perspective on Bridging the Gap Between Availability and Adequacy

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ABSTRACT

We often speak of hunger as if feeding people solves it, but filling a plate is not the same as nourishing a life. Food security and nutritional security, though deeply linked, tell two very different stories. Food security asks: does a person have enough to eat? Nutritional security asks something harder: does what they eat actually sustain them? The gap between these questions is where millions suffer.This is the paradox of hidden hunger- a condition where adequate calories mask chronic deficiencies in iron, Vitamin A, iodine, and zinc. No visible starvation. Yet underneath, growth falters, immunity weakens; minds develop slower than they should. Children under five, adolescent girls, pregnant and lactating women, and the elderly bear this burden most heavily and they are precisely the populations dietitians are trained to serve.Addressing nutritional insecurity is never a single intervention. It demands dietary diversification, meaningful nutrition education, strategic food fortification, and targeted supplementation-applied with clinical judgment and cultural sensitivity. But tools alone are insufficient. Poverty, poor sanitation, low maternal literacy, and limited healthcare access are not background noise; they are root causes that shape every dietary assessment and counseling session a dietitian conducts.For undergraduate dietetics students, this distinction carries real professional weight. Food and nutritional security are not abstract policy concepts debated in distant conference rooms — they are clinical realities encountered in hospitals, communities, and homes every day. Recognizing them as such transforms how we assess, counsel, and intervene. To nourish a person, we must first understand the world they eat in.

Keywords: Food security, nutritional security, hidden hunger, micronutrient deficiency, dietary diversification, food fortification, dietetic intervention, public health nutrition

Potential of Black Rice (Chak-hao) as a Functional Food for Holistic Health

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ABSTRACT

Black rice, which people in Manipur call Chak Hao, commonly called “forbidden rice”, “emperor’s rice”, or “purple rice” has this deep purple black colour that comes from stuff like anthocyanins which possess strong antioxidants and anti-inflammatory properties. It’s been around in traditional ways there, and now more folks are noticing it as a kind of functional food because of all the nutrients packed in, like flavonoids, phenolics, fiber, vitamins, and minerals. The healthy side seems promising. Eating it might help with diabetes or even cancer risks, and it could protect the heart and liver too. It also has Immune system boosting effects. The fiber part is good for the gut, helps with how the body processes food and stuff. Since its gluten free and full of good things, it feels like it could play a role in better nutrition overall, maybe even for holistic health. In Manipuri culture, black rice has this special place, used in rituals or daily meals.Commercially, it’s starting to show up in nutraceuticals and those functional food products. That could mean more sustainable farming and some economic growth if production picks up. But low awareness is a problem, and not enough is grown. Research is kind of limited too, so wider use is held back. To really make the most of Chak Hao, we need more work on valuing it higher, testing in clinical ways, and figuring out how to grow it on a bigger scale. That might unlock its potential for holistic health and well-being. Nutritional security could improve with something like this.

Keywords: Chak Hao, Black Rice, Anthocyanins, Anti-inflammatory, Holistic health, Antioxidants, Nutritional security, Nutraceuticals, Manipur

Climate-Resilient Medicinal Plants as Sustainable Nutraceutical Sources for Functional Food Development

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ABSTRACT

Rapid climate change, declining nutritional quality of foods and increasing lifestyle-related disorders have created an urgent demand for sustainable, nutrient-rich and health-promoting food systems. Climate-resilient medicinal plants possess the unique ability to survive under adverse environmental conditions such as drought, heat stress and poor soil fertility while retaining their nutritional and therapeutic properties. These plants have emerged as promising eco-friendly sources of nutraceuticals and functional food ingredients for sustainable human health and climate-smart agriculture.The present study focuses on the biochemical and nutraceutical potential of selected climate-resilient medicinal plants including Dandelion, Moringa, Tulsi, Turmeric, Ginger, Fenugreek, Lemongrass and Ashwagandha for the development of sustainable functional food products. These plants are rich sources of bioactive compounds such as antioxidants, phenolics, flavonoids, dietary fiber, vitamins, minerals and prebiotic components including inulin, which play significant roles in improving gut health, immunity, metabolic balance and overall well-being.The study aims to evaluate important biochemical parameters including antioxidant activity, total phenolic content, flavonoid concentration, dietary fiber and nutraceutical potential of selected medicinal plants under climate-resilient conditions. Furthermore, the research explores their utilization in the development of eco-friendly functional foods such as herbal detox candy, nutraceutical beverages, herbal tea and plant-based health supplements. Sustainable processing techniques with minimal environmental impact will also be emphasized to improve product quality and promote green food innovation.The expected outcomes of the study include the identification of high-value medicinal plants with superior climate adaptability, nutritional richness and functional food potential. The development of plant-based nutraceutical products from these medicinal resources may contribute significantly toward sustainable nutrition, gut microbiome enhancement, disease prevention, environmental sustainability and climate-smart food systems. This research highlights the integration of medicinal plants, food biochemistry and sustainable agriculture as an innovative strategy for future nutraceutical and functional food development.

Keywords: Climate-resilient medicinal plants, nutraceuticals, functional foods, sustainable nutrition, antioxidants, inulin.

Agri-foods: Securing Holistic Nutrition,A Paradox To Be Solved

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ABSTRACT

India's agrifood sector faces a massive systemic paradox. Despite record-breaking production—projecting 348.65 million metric tonnes (MMT) for the 2025-26 Kharif and Rabi seasons, a 2.7% increase over the 2024-25 cycle—India ranks 102nd in the 2025 Global Hunger Index. This includes a record 120.21 MMT of wheat, representing a 5.2% year-on-year growth. However, May 2026 epidemiological data reveal a severe "hidden hunger" crisis, with an estimated 67.1% of children and 59.1% of adolescent girls suffering from anemia. Agricultural models optimized for sheer calorie yield have clearly compromised micronutrient bioavailability.This crisis is exacerbated by heat stress and soil degradation, triggering a "dilution effect" that strips staple genotypes of intrinsic nutritional value. Achieving true nutritional security requires a structural overhaul via biotechnological and data-driven solutions. Immediate interventions must utilize advanced mapping populations (RILs and NILs) to scale up ICAR's expanded biofortified portfolio—specifically the 184 new climate-resilient varieties officially released in January 2026. This aligns with the national rollout of fortified PDS rice and upgraded sanitation infrastructure.Genetic resource diversification focuses on reviving climate-resilient crops like millets (Shree Anna), projecting 15.44 MMT in 2025-26 (a 4.1% YoY increase), alongside moringa and amaranth. Ecosystem stability demands a shift toward regenerative agriculture, integrating livestock and vermicomposting to rebuild soil capital. Concurrently, tackling marketing bottlenecks through FPOs is critical. Finally, next-generation Digital Public Infrastructure (DPI) serves as the ultimate game-changer. Integrating foundational AgriStack registries and its newly unveiled AI intelligence layer (Bharat-VISTAAR) with the Poshan Tracker app through predictive deep learning models upgrades India's nutritional governance into a precise, data-driven system.

Keywords: Agrifood Systems, Biofortification, Digital Public Infrastructure, Malnutrition, Natural Farming, Predictive Modeling

Agri-Food: Securing Holistic Nutrition

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ABSTRACT

India's agri-food systems are evolving rapidly to ensure holistic nutrition delivering not just enough calories, but nutrient-rich foods that support health, sustainability, and resilience. Over decades, nutrient levels in staple crops have dropped by about 50%, with key minerals like iron, zinc, and protein declining due to soil exhaustion and intensive farming. This affects India's 1.4 billion people, where poor diets from rice-wheat dominance contribute to over half of diet-related illnesses. Despite aiming for 362.5 million tons of foodgrains in 2025-26, pulse imports hit 7 million tons last year, highlighting gaps in dietary diversity. ICAR's SEHAT initiative is transforming this through smart biofortification, using AI and crop rotations to increase zinc in wheat by 20-50%. They have empowered more than 16,000 farm women via 3,800 + Nutri-gardens in 75 villages, distributing seeds and recipes for balanced "Nutri-thalis." The National Mission on Natural Farming now spans 425 districts, with 800,000 farmers embracing organic methods that boost crop micronutrients by 20-40% compared to conventional ones.Nutri Bharat 2026 rallies food processors toward "nutrition for all," blending nutraceuticals with traditional staples for Viksit Bharat 2047. Plant-forward systems cut emissions by nearly a third, while soil restoration targets 131 million healthy hectares by 2030.By reconnecting farming roots with human health, India is pioneering agri-food systems that nourish bodies, communities, and the planet proving sustainable abundance is within reach.

Keywords: Holistic nutrition, biofortification, sustainability, natural farming

Holistic Nutrition and Sustainable Wellness for Lifestyle Disorders

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ABSTRACT

The rapid increase in lifestyle-related disorders such as obesity, diabetes, hypertension, and cardiovascular diseases has become a major global public health concern. Modern dietary transitions characterized by excessive consumption of ultra-processed foods, refined sugars, unhealthy fats, physical inactivity, chronic stress, and disturbed sleep patterns have significantly affected nutritional and metabolic health. In this context, the present study examines the role of agri-food systems in securing holistic nutrition through sustainable agriculture, traditional dietary practices, and preventive healthcare approaches. The study adopts an interdisciplinary review-based approach by integrating perspectives from nutrition science, public health, naturopathy, and traditional wellness systems. Particular emphasis is given to the four foundational pillars of holistic health: Aahar (balanced nutrition), Vihar (physical activity and restorative sleep), Aachar (disciplined lifestyle practices), and Vichar (mental and emotional well-being). The study also evaluates the contribution of yoga and naturopathy in improving metabolic balance and preventing chronic diseases through root-cause-oriented interventions.The findings show that holistic nutrition extends beyond caloric sufficiency and requires sustainable, culturally relevant, and nutrient-dense food systems that support both physical and psychological well-being. Traditional dietary practices and preventive healthcare approaches contribute significantly toward nutritional security and healthier lifestyles. In conclusion, holistic nutrition is not limited to adequate food intake but also includes balanced lifestyle practices, mental well-being, and sustainable food systems. Strengthening nutrition-sensitive agri-food systems along with traditional wellness approaches may serve as an effective pathway toward long-term health security and reduction of lifestyle-related disorders in modern society.

Keywords: Holistic Nutrition; Lifestyle Disorders; Nutritional Security; Wellness and Metabolic Health; Traditional Dietary Practices

Role of AI, IoT, and Digital Technologies in Reducing Vegetable Losses

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Abstract

Post-harvest losses of vegetables remain a critical constraint to food and nutritional security, particularly in developing countries where inadequate cold chain infrastructure and inefficient handling systems prevail. Globally, vegetable losses range between 30-40%, while in India they are estimated at 10-25%, primarily due to poor storage, transportation, and handling practices (Verma *et al*., 2025). The rapid advancements in artificial intelligence (AI) and automation aretransforming post-harvest technologies, offering innovative solutions toimprove food quality, safety, and supply chain efficiency by reducing post-harvest loss (Das *et al*., 2025).AI technologies, such as machine learning, computer vision, andIoT integration is optimizing processes like mechanized harvesting,non-destructive near infrared spectroscopy (NIRS),automated sorting, grading, smart packaging,and microbial detection, reducing food waste and extending shelf life (Hoque*et al*., 2025). Advanced storage facilities are equipped with Internet of Things (IoT)- enabled smart sensors, ensuring continuous monitoring of real-time data and critical environmental parameters, including temperature, humidity, and gas concentrations (Alam et al., 2021).Moreover, AI-powered robotics and smart warehouses are streamliningtransportation and inventory management, enhancing operationalefficiency. The integration of AI in demand forecasting and supply chainoptimization is further improving food traceability, minimizingdisruptions, and reducing environmental impact. Despite the promisingpotential, challenges such as data quality, system integration, cost barriers,and regulatory concerns remain. The future of AI in post-harvesttechnologies presents opportunities for continued innovation, withadvancements in deep learning, IoT, and global scalability, offeringpathways to sustainable food systems (A. S. *et al*., 2025).

Keywords: Artificial intelligence (AI), Digital technologies,Post-harvest technologies, Automation, Mechanization

Nanobiostimulants: An Emerging Tool for Management of Plant Diseases

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Nanobiostimulants are an emerging technology for the management of plant diseases in contemporary agriculture. These materials combine the advantageous properties of biostimulants with nanotechnology to boost plant growth, enhance nutrient absorption, and reinforce plant defense mechanisms against pathogens. Unlike traditional chemical pesticides, nanobiostimulants are eco-friendly, biodegradable, and reduces environmental pollution while enhancing crop productivity and health. Nanobiostimulants consist of nano-formulations of either seaweed extracts, humic substances, amino acids, beneficial microbes, or plant-derived compounds. Their nanoscale particles give a larger surface area, increased bioavailability, and better penetration into the plant tissues. Due to their nano-sized particles, they exhibit higher surface area, enhanced bioavailability, and improved penetration into plant tissues. These traits enable efficient delivery of bioactive compounds, leading to rapid activation of plant defense mechanisms. Nanobiostimulants starts the production of antioxidant enzymes, phytohormones, phenolic compounds, and pathogenesis-related proteins, which collectively enhance resistance against fungal, bacterial, viral, and nematode diseases.

In several studies, nanobiostimulants have shown their effectiveness against major plant pathogens such as *Fusarium spp.*, *Alternaria spp.*, *Rhizoctonia solani*, and *Xanthomonas spp.* Similarly, nano-chitosan, nano-silica, and nano-zinc formulations have demonstrated remarkable antifungal and antibacterial activities against pathogens by disrupting their cell walls as well as inducing systemic resistance in plants. Moreover, these nano-enabled microbial biostimulants also promotes rhizosphere health by maintaining beneficial microbial populations that subdue soil-borne pathogens. The use of nanobiostimulants also helps in promotion of sustainable agriculture by reducing reliance on synthetic agrochemicals and augmenting stress tolerance under adverse environmental conditions. However, its large-scale application needs more research in respect to biosafety, toxicity, standardization, and field-level performance. Future study should concenterate on creating cost-effective formulations and comprehending their interactions in plant–soil systems. In conclusion, nanobiostimulants are a promising next-generation technology for integrated plant disease management. Their multifaceted role in enhancing plant immunity, improving crop health, and supporting sustainable farming practices makes them an important tool for near agriculture.

Key words: Nanobiostimulants, Nanotechnology, Plant Disease Management, Sustainable Agriculture

AGRI-FOODS: SECURING HOLISTIC NUTRITION

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ABSTRACT

FAQ defines Agrifoods system as all the interconnected activities and actors involved in getting food from field to work. This system encompasses all activities related to the inputs, production, processing, distribution, consumption and disposal of food globally.

In the present era, malnutrition, micronutrient deficiencies and lifestyle relate health disorder are increasing due to unhealthy dietary patterns and reduced consumption of nutritional rich natural foods. Rapid urbanization, lack of cooking time and change in consumers lifestyle are the factors that fuel the RTE (Ready To Eat) food market growth which also saves the money of the consumer and reduced the consumptions of Agricultural food resources stick as cereals, pulses, fruits, vegetables, milk and traditional crop which provides essential nutrients including proteins, carbohydrates, vitamins, minerals, dietary fibers and bioactive compounds required for overall physical and mental well-being. This study focuses on the importance of Agri-food systems in accruing holistic nutrition through sustainable production value addition and innovative food processing technologies by practicing; Diversification of crops, Sustainable intensification, Nutritious and climateresilient production The utilization of indigenous crops such as millet, makhana and pulses can help develop affordable and nutritional and functional food. The integration of agriculture, food science, and nutrition can contribute to better dietary diversity, improved public health, and sustainable food systems. Therefore, promoting agri-food innovations is essential for achieving holistic nutrition, food security, and rural economic development. Agri-Food Processing helps preserve food, reduce wastage, improve nutrition, increase shelf life, and add value to agricultural products. It also supports farmers, creates jobs, and strengthens food security.

Key Words: Agrifood Systems, Holistic Nutritional, Food security, Sustainable Agriculture and Nutritional Security.

Value-Added Fish Products: A Pathway to Women Empowerment in Bihar

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Abstract

Bihar, one of India's most culturally rich states, holds significant potential in aquaculture and inland fisheries, yet the fish processing sector remains largely underdeveloped. Women in rural Bihar, though actively engaged in fish harvesting and marketing, are seldom empowered through skill-based value addition. There are wide variety of value-added fish products such as fish pickle, fish cutlet, fish wafers etc which can play in advancing women's economic empowerment in the state. By adopting low-cost, technology-appropriate processing techniques, women self-help groups (SHGs) and fisher cooperatives can generate sustainable livelihoods while reducing post-harvest losses, which currently account for 20–30% of total fish production. Policy recommendations including integration of value-added fisheries enterprises into state livelihood missions (JEEViKA), capacity building programs, and market linkage support can enhance the income of women farmers. Further, strengthening women participation in the fish value chain not only enhances household income and nutritional security but also contributes to gender equity and rural economic development in Bihar.

Keywords : Value-added fish products, women empowerment, self-help groups, Bihar

Design of an Intelligent Expert System for Banana Plant Disease Detection Using Machine Learning Techniques for Bihar

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Abstract

Banana cultivation plays an important role in the agricultural economy of Bihar and contributes significantly to farmers' income and food security. However, banana plants are highly susceptible to several fungal, bacterial, and viral diseases such as Panama Wilt, Emusae leaf spot, Bract Mosaic, Banana Streak, and Bunchy Top Virus, which adversely affect crop productivity and fruit quality. Early and accurate disease detection is essential for effective crop management and reduction of economic losses. Conventional disease diagnosis methods are time-consuming and costly to farmers. Therefore, there is a growing need for intelligentdisease detection systems for sustainable banana cultivation. The present study conceptualizes the design of an Intelligent Expert System for Banana Plant Disease Detection Using Machine Learning Techniques for Bihar. The proposed system aims to integrate artificial intelligence (AI), machine learning (ML), and image processing techniques for automated identification and classification of banana plant diseases. The novelty of the idea lies in integrating machine learning based disease detection with a localized expert advisory system specifically designed for banana cultivation in Bihar. The methodology includes image acquisition, preprocessing, segmentation, feature extraction, classification, and advisory generation. Machine learning and deep learning approaches such as Convolutional Neural Networks (CNN), Support Vector Machine (SVM), and image processing techniques may be utilized for disease classification and feature analysis. Existing pre-trained models and open-source agricultural datasets might be customized and adapted for Bihar-specific agricultural conditions. The proposed framework is intended to accept banana leaf images and field information as input and generate outputs including disease identification, confidence level, probable causes, and crop management recommendations. The developed system may serve as a low-cost intelligent advisory platform for farmers, researchers, and extension workers. This concept may highlight the interdisciplinary application of computer science and agricultural sciences for promoting precision disease detection and sustainable banana cultivation practices.

Keywords: Artificial Intelligence (AI), Machine Learning, Expert System, Banana Disease Detection, Precision Agriculture, Image Processing

Transforming Agro-Based MSMEs Towards Circularity in India: A Systematic Approach

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ABSTRACT

India's agro-based micro, small, and medium enterprises (MSMEs) constitute a foundational pillar of the national economy, employing over 110 million persons in the agro-food segment alone, while the broader MSME sector accounts for approximately 30 per cent of GDP and 45.79 per cent of total exports (Ministry of MSME, 2026). Despite this macroeconomic significance, these enterprises predominantly operate under a linear take–make–dispose production paradigm that systematically forfeits recoverable value embedded in agricultural by-products, while imposing compounding environmental externalities — including unmanaged methane emissions with a global warming potential 25 to 80 times that of carbon dioxide, widespread eutrophication, and escalating crop-residue burning — across an agro-food sector growing at 11.18 per cent annually. This study pursues two objectives: first, to examine the environmental and socio-economic impacts of circular economy interventions in Indian agro-based MSMEs; and second, to assess the techno-economic viability and policy alignment of circular transition pathways at multiple enterprise scales. A mixed-methods systematic review methodology (Snyder, 2019) was employed, incorporating eleven empirical case studies spanning micro-enterprise to industrial-cluster scales across India, supplemented by one international benchmark case from Colombia. Six sustainability dimensions structured the analytical framework uniformly across all cases: energy consumption and efficiency, greenhouse gas emissions, water management, soil health, income generation, and employment creation. Findings confirm that circular economy interventions are economically rational across all MSME scales, with payback periods ranging from 0.8 years for energy-efficiency retrofits to 5–8 years for compressed biogas installations. Resource efficiency gains include energy reductions of 25–95 per cent, emissions abatement of 27–65 per cent, and water savings of up to 86 per cent. The proposed Multi-Resource Agro-Circular Business Model (MRACBM) demonstrates that simultaneous value creation across energy, nutrient, and materials loops transforms waste liabilities into predictable revenue streams. Social outcomes are disproportionately significant, with female employment shares reaching 95 per cent in community composting enterprises, over 12,500 rural full-time equivalents generated across reviewed cases, and a projected 10 million circular economy jobs nationally by 2050. The study concludes that systemic replication necessitates blended finance architecture, harmonisation of national scheme instruments — MSE-SPICE, GOBARdhan, and SATAT — and anchor-led supply chain mandates compelling large agro-conglomerates to drive circularity adoption throughout their MSME networks, thereby positioning circularity as a scalable strategy for resource efficiency, environmental resilience, and inclusive economic development.

Keywords: Circular Economy; Agro-Based MSMEs; Waste Valorisation; India; MRACBM; Sustainable Development

Dry Flower Technology: Entrepreneurial potential and its role in Women's economic empowerment

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The global market for dried flower-based products is witnessing sustained and significant expansion, emphasized by long shelf life, aesthetic adaptability, year-round commercial availability and growing consumer preference for sustainable alternatives to fresh flowers. India occupies a prominent position in this trade, having participated actively for over four decades. Current export outreach spans more than 59 countries, with recorded export earnings of approximately USD 4.17 million during April–November 2020–21. Notably, dried flowers contribute in excess of 60% of total floriculture trade benefits in global commerce, reflecting both the scale and strategic importance of this sub-sector to India's agricultural economy. Different drying techniques can be used such as air drying, press drying, desiccant drying (silica gel, sand and borax), microwave oven drying, hot air oven drying, glycerin drying, and leaf vein clearing. Press drying finds application in greeting cards, wall art, lampshades, and handmade paper crafts, while glycerin-preserved foliage and skeleton leaves obtained through leaf vein clearing serve as value-adding embellishments across product lines. The value-added products derived from dry flower technology including greeting cards, wall hangings, gift cards, calendars, coasters, table mats, candle decorations and floral arrangements represent commercially viable micro-enterprise opportunities. Export hubs in Kolkata (West Bengal), Tuticorin (Tamil Nadu), Mumbai (Maharashtra) and Hyderabad (Andhra Pradesh) generate returns 10–15 times greater than regional markets, underscoring strong profit potential. Recognising this potential, Dr. Rajendra Prasad Central Agricultural University, Pusa, has initiated awareness and outreach programmes directed at rural women, aimed at building capacity and facilitating technology adoption at the grassroots level. This technology is particularly suited to home-based businesses: minimal infrastructure investment is required, raw materials are locally accessible year-round, and skill acquisition is achievable through short-duration training. Such attributes make dry flower entrepreneurship an effective vehicle for financial independence among women, particularly in semi-urban and rural contexts. Dry flower technology offers a scalable, low-barrier entrepreneurial pathway with strong domestic and export market potential. Mainstreaming this technology into livelihood schemes and self-help group (SHG) frameworks could substantially enhance women's economic agency, foster confidence and self-reliance, and contribute meaningfully to rural income diversification and the growth of India's floriculture sector.

Key words : Agri-entrepreneurship, Dry flower technology, Global floral trade, Value-added products

In-planta evaluation of promising microbialconsortia of biocontrol agents against *Fusarium oxysporum* f.sp. *cubense* Tropical Race 4 using hydroponic technology

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Abstract

Banana (*Musa* spp.), one of the world's most important fruit crops, supports the livelihood and nutritional security of millions of people globally. However, its production is severely constrained by several biotic and abiotic stresses, among which Fusarium wilt caused by *Fusarium oxysporum* f. sp. *cubense* Tropical Race 4 (Foc TR4). It is the most devastating soil-borne disease threatening sustainable banana cultivation worldwide. The present investigation was undertaken to evaluate promising consortia of potential biocontrol agents (BCAs) for the effective and sustainable management of Foc TR4. A total of seven (07) fungal and bacterial BCAs, procured from the Fruit Pathology Laboratory, Department of Plant Pathology and Nematology, Dr. Rajendra Prasad Central Agricultural University, were re-evaluated for antagonistic activity against Foc TR4 and interspecific compatibility. Based on their superior inhibitory potential (>60%) and mutual compatibility, *Trichoderma asperellum* (F1 and F2) and *Bacillus velezensis* strains (E1 and E2) were selected for consortium development. Under glasshouse conditions, the consortium *T. asperellum* (F1) + *B. velezensis* strain 2 (E2) exhibited complete disease suppression (0% PDI) and recorded the highest plant vigour index, outperforming all other treatments. Hydroponic evaluation further validated its superiority, with 0% disease incidence and maximum plant vigour index, confirming its consistent efficacy under controlled conditions.

Shelf-life studies of talc- and paraffin oil-based bioformulations of the promising BCAs over 180 days revealed significantly higher viability and better maintenance of colony-forming units in talc-based formulations. The study establishes the consortium of *T. asperellum* (F1) and *B. velezensis* strain 2 (E2) as a highly promising, eco-friendly, and sustainable strategy for effective management of banana Fusarium wilt caused by Foc TR4.

Keywords: Banana, Fusarium wilt, microbial consortium**,** bioformulations

Invigorating she-entrepreneurship concerning marketing linkage in MKSP and non-MKSP regions: Optimized Feed-Forward Neural Networks (FFNNs) architecture

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Abstract

The Standardized Octa-dimensional Farm Women Sustainable Livelihood Security Index (OFWSLSI) was developed and was used to assess livelihood security and women empowerment among 800 respondents, comprising 400 non-MKSP respondents from (Samastipur and East Champaran districts) and 400 MKSP respondents from (Muzaffarpur and Madhubani) districts of Bihar. Among the 8 dimensions of OFWSLSI, Market Inclusion Security emerged as an important indicator and was examined in detail. The findings revealed that the Market Inclusion Security score in MKSP areas was 0.4920±0.0041, whereas in non-MKSP areas it was only 0.4178±0.0037, which was considerably lower than the maximum attainable score of 1. A statistically significant difference was observed between MKSP and non-MKSP areas with a z-value of 13.34 (p=0.001), clearly indicating the comparative advantage of MKSP intervention regions.In MKSP areas, JEEViKA, an initiative of the Government of Bihar aimed at poverty alleviation through social and economic empowerment of rural poor women, played a crucial role in strengthening livelihoods. By promoting institutions such as Self-Help Groups (SHGs) and their federations, the programme enabled women to gain improved access to services, credit, and assets from both public and private sectors. World Bank appreciated this initiative as "unleashing the power of women's collectives for rural development" under the Bihar Transformative Development Project.Canonical Correlation Analysis indicated that in MKSP areas, she-preneurship (r=0.367) and market inclusion (r=0.472) as dependent variables were significantly influenced by government support through JEEViKA (r=0.634), institutional training (r=0.551), peer learning (r=0.492), and ICT knowledge (r=0.351). The model exhibited strong explanatory power with an eigen value of 91.27% and a model strength of 0.452 (p=0.01).In contrast, in non-MKSP areas, the major determining variables were support from male family members (r=0.448) and hands-on learning within families (r=0.381). In these areas, she-preneurship was found to be insignificant (r=0.252), while market inclusion showed comparatively lower influence (r=0.318). The model demonstrated an eigen value of 83.48% and a model strength of 0.339 (p=0.05).The study highlights the critical importance of government support and institutional training in enhancing market linkages for women entrepreneurs in Bihar. Model validation using Radial Basis Function Networks demonstrated an accuracy of 91.42% in MKSP intervention areas. Further validation through a Feedforward Neural Network Model also confirmed a prediction accuracy of 91.42%, emphasizing the effectiveness of institutional support and capacity-building initiatives in promoting market inclusion and sustainable livelihood security among rural women.

Keywords: Canonical Correlation, Marketing Linkage, MKSP, Neural Network, Women's empowerment, Women in agrifood systems.

Mitigating climatic stress through nanotechnology

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Abstract

The global population is to reach 10 billion which demands the increase in food supply. Simultaneously, the agriculture is facing the challenge in form of climate change. Thus, there are twin challenges are there for sustaining the production. Increasing drought and heat stress are causing significant yield losses in crops such as wheat, rice, maize, and sugarcane. Rising temperatures and irregular rainfall have intensified these abiotic stresses, threatening global food security. The situation is crucial in India where agriculture supports millions of livelihoods. Conventional methods alone are insufficient to address these issues effectively. Nanotechnology is a science dealing with particle size 1-100 nm. At this size range, there are changes in the physical, chemical and biological properties which makes it different form bulk counterparts. Nanotechnology offers a promising solution by improving seed germination, photosynthesis, nutrient use efficiency, and antioxidant activity, thereby enhancing crop resilience, productivity, and sustainability under drought and heat stress conditions.

Key words: Heat stress, drought stress, nanotechnology

Framework for Prediction Protein–Protein Interactions in Rice using Deep Learning

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Abstract

Rice is one of the world's most important food crops, yet its protein–protein interaction (PPI) network remains only partially characterized because experimental methods are often time-consuming and resource-intensive. Computational prediction approaches offer an efficient complementary alternative, enabling rapid and large-scale exploration of interactomes. Building on recent advances in deep learning and natural language processing, we present RCNNricePPI, an integrated deep learning framework developed to predict rice PPIs directly from protein sequence data. The model employs a Siamese recurrent convolutional neural network (RCNN) architecture together with word2vec-based sequence embeddings, enabling effective extraction of both local and long-range sequence patterns associated with protein interactions. To ensure robust model performance, high-quality training and testing datasets were generated through rigorous preprocessing and filtering steps, including the careful curation of positive interactions and reliable negative samples. The RCNNricePPI web server demonstrated strong predictive performance and provides an important contribution to computational interactomics research in rice. By supporting the discovery of molecular interactions involved in essential biological processes, this framework represents a valuable resource for the plant biology and bioinformatics communities.

Keywords: Rice, Protein–Protein interactions, RCNN, word2vec, Deep Learning.

Internet of Things (IoT) Based Automated Hydroponic NFT Systems for Smart Agriculture: A Review

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ABSTRACT

he increasing demand for sustainable food production and efficient resource utilization has accelerated the adoption of smart agriculture technologies, particularly in hydroponic cultivation systems. Among various hydroponic techniques, the Nutrient Film Technique (NFT) combined with vertical farming structures offers significant advantages in terms of water conservation, nutrient efficiency, and space optimization. The integration of Internet of Things (IoT) technology into hydroponic systems has further enhanced automation, precision monitoring, and remote management capabilities. This review examines recent developments in IoT-based automated Vertical A-Frame NFT hydroponic systems for smart agriculture applications.

The review highlights the role of IoT technologies, including sensors, microcontrollers, cloud platforms, and wireless communication systems, in maintaining critical hydroponic parameters such as pH, electrical conductivity (EC), temperature, humidity, and nutrient solution level. Various sensing devices, including ultrasonic, pH, and EC sensors, have been widely adopted for real-time monitoring and automated fertigation management. IoT-enabled control systems facilitate automatic adjustment of nutrient concentration and pH levels, thereby improving crop growth, reducing manual labor, and minimizing water and nutrient wastage.

The study also discusses the structural and operational advantages of vertical A-frame NFT systems, which maximize plant density and land-use efficiency while ensuring uniform nutrient circulation. Recent advancements in web-based and mobile applications for remote monitoring, data visualization, and decision support are reviewed. Furthermore, challenges related to sensor calibration, system cost, maintenance, data reliability, and energy consumption are critically analyzed.

Overall, IoT-based automated hydroponic systems have demonstrated substantial potential for sustainable urban farming and precision agriculture. The integration of smart monitoring and automation technologies can significantly improve productivity, resource-use efficiency, and scalability of hydroponic farming systems. This review provides comprehensive insights into the design, operation, benefits, and future prospects of IoT-based Vertical A-Frame NFT hydroponic systems for modern smart agriculture applications.

Keywords: IoT, Hydroponics, NFT System, Vertical Farming, Smart Agriculture, Automation, Sensors, Precision Agriculture, Sustainable Farming.

Cooperative-Led Agri-Food Transformation for Holistic Nutrition in Tribal Regions of Jharkhand

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Abstract

An agricultural cooperative, also known as a farmers' co-op, is a producer cooperative in which farmers pool their resources in certain areas of activities.Cooperative institutions in Jharkhand are emerging as key drivers of sustainable agri-food systems, livelihood security, and holistic nutrition. The state has a strong cooperative network comprising 2028 LAMPS, 2374 PACS, and nearly 9000 other cooperative societies engaged in agriculture, dairy, fisheries, vegetables, lac, poultry, and minor forest produce. Major federations such as VEGFED promote organized vegetable marketing through the "VEGFRESH" brand, while JMF (Medha) operates six milk processing plants supporting quality milk supply in 18 districts. JHASCOFISH strengthens fisheries-based livelihoods, whereas JASCOLAMPF ensures fair prices and market access for lac growers. JHAMFCOFED supports over 25,000 tribal families directly and more than one lakh MFP collectors through procurement, value addition, MSP operations, and marketing of products like tamarind, mahua, honey, and chironji.

The cooperative sector has modernized rural food systems through 19 cold storages, 139 cold rooms, 32 solar-powered cold rooms, 1.46 lakh MT storage capacity, and ₹21 crore working capital support for agricultural inputs. In 2021–22, 7.5 lakh MT paddy was procured from 1.39 lakh farmers, while over 14 lakh farmers were digitally registered through cooperative platforms. These initiatives enhance food availability, reduce post-harvest losses, empower women and tribal communities, and strengthen access to nutritious agri-food products, thereby contributing significantly to food and nutritional security in Jharkhand.

Keywords: Cooperatives, Jharkhand, MFP, NTFP, Tribal Farmers

Global Research Trends on Circularity in Agro-Food Industries: A Scoping Study

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ABSTRACT

The Circular Economy (CE) is conceptualized as an industrial system that is restorative and regenerative by design, offering a viable alternative to the conventional linear "take–make–dispose" production model. In the context of the agro-food industry, the transition towards circularity has emerged as a critical pathway for the circular economy operationalizes SDGs by halving food waste, minimizing waste generation, integrating climate action into policies, and strengthening climate adaptation and awareness through regenerative, resource-efficient, low-carbon systems.

The scoping study is a type of evidence synthesis which follows a systematic approach to map evidence on a topic and identify main concepts, theories, sources, and knowledge gaps. This research employs a comprehensive bibliometric analysis to examine the evolution, thematic structure, and emerging research frontiers of circular economy applications in the food industry. A total of 977 relevant peer-reviewed articles indexed in the Scopus database, published between 2010 and 2025, were systematically analysed to assess research trends, knowledge gaps, and future opportunities. Advanced bibliometric tools, including the *Bibliometric* (Biblioshiny) package in R-Studio and VOSviewer, were utilized to conduct thematic mapping, keyword co-occurrence analysis, co-citation networks, and scientific collaboration analysis.

The findings reveal a rapidly expanding body of literature, reflecting growing scholarly attention to sustainable waste management, circular supply chain optimization, and resource-efficiency enhancement in agro-food systems. Waste valorization, life-cycle assessment, and circular agriculture emerge as core knowledge clusters, while thematic mapping identifies the circular economy as a dominant foundational theme. Trend analysis suggests sustained research growth, with life-cycle-oriented studies projected to peak around 2029. Strong international collaboration networks and high publication momentum indicate the increasing maturity of this research domain. Overall, the study provides a structured overview of global research trends and offers actionable insights for researchers, policymakers, industry practitioners, and development agencies seeking to advance resilient, sustainable, and circular agro-food systems.

Empowering Women Farmers Through Farmer Producer Organizations in India

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ABSTRACT

Women constitute a major share of the agricultural workforce in India and contribute significantly to farm production, livestock management, and household food security. Despite their active involvement in agriculture, women farmers face several challenges such as limited access to land ownership, institutional credit, modern technologies, extension services, and market opportunities. In this context, Farmer Producer Organizations (FPOs) have emerged as an important institutional mechanism for improving collective bargaining power, market access, and livelihood security among small and marginal farmers. Women-Led FPOs, in particular, play a crucial role in promoting economic empowerment, social inclusion, and rural entrepreneurship among women in India.

The present study is based on secondary data analysis of the National Level Report on the Status and Performance of Farmer Producer Organizations in India published by the Tata-Cornell Institute for Agriculture and Nutrition. The study examines women participation, entrepreneurial development, collective marketing, financial inclusion, and leadership development within Women-Led FPOs. It also identifies the major opportunities and constraints affecting their sustainability and performance.

The findings reveal that Women-Led FPOs positively contribute to income generation, financial inclusion, collective marketing efficiency, leadership enhancement, and rural livelihood diversification. These organizations also strengthen women's participation in community decision-making and improve nutrition security. However, challenges such as inadequate working capital, weak market linkages, low digital literacy, and socio-cultural barriers continue to affect their long-term sustainability. Strengthening institutional support through capacity-building programmes, improved financial services, and market-oriented interventions can enhance the sustainability and effectiveness of Women-Led FPOs in promoting inclusive agricultural development in India.

Keywords: FPOs, Women Empowerment, Women-Led FPOs

Importance of soil science in skill, innovation, and entrepreneurship development among youth.

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Soil science plays a fundamental role in sustainable agriculture, environmental protection, food security, and rural development. In the present era of climate change, land degradation, declining soil fertility, and increasing pressure on natural resources, the importance of soil science has become more significant than ever before. The discipline offers immense opportunities for skill development, innovation, and entrepreneurship among youth, particularly in the agricultural sector.Youth equipped with scientific knowledge of soil health management, nutrient dynamics, soil fertility evaluation, precision agriculture, and sustainable land use practices can contribute effectively toward enhancing agricultural productivity and environmental sustainability. Modern advancements such as digital soil mapping, remote sensing, GIS-based soil analysis, soil testing laboratories, biofertilizer production, organic farming, and climate-smart agriculture have created new avenues for innovation and entrepreneurship in soil science.Soil science-based enterprises, including soil testing services, customized fertilizer recommendations, composting units, vermicomposting, bio-input production, precision nutrient management, and consultancy services, can generate sustainable self-employment opportunities for educated rural youth. Integration of scientific research, modern technology, and field-level applications can empower young professionals to become agripreneurs and innovators in the agricultural sector.Furthermore, soil science contributes significantly to sustainable resource management, carbon sequestration, water conservation, and ecological balance, thereby supporting the broader goals of sustainable development and food security. Strengthening education, practical training, and entrepreneurial skills in soil science can motivate youth to actively participate in agricultural transformation and rural economic development.Thus, soil science serves not only as a scientific discipline but also as a powerful tool for empowering youth through skill enhancement, innovation, and entrepreneurship, ultimately contributing to resilient agriculture and national development.

Spatial Distribution of Iron in Potential Aquaculture Water Bodies of Kishanganj District, Bihar

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Abstract

Bihar is bestowed with large amount of inland aquatic resources which can be utilized for aquaculture production and uplift the rural communities. However, the presence of groundwater contaminants like Fe poses a serious threat to drinking as well as aquaculture in rural areas of Bihar. The high iron content of aquaculture water has been one of the major reasons for heavy mortality in carp hatchery as well as in spawn rearing nursery ponds in Bihar. Hence, it is necessary to screen the concentration of iron in different aquaculture water bodies in different district of Bihar. In thisprelude, the present study was conducted to assess the spatial distribution of iron in potential aquaculture water bodies of Kishanganj district Bihar. The study was conducted in seven different blocks under Kishanganj district such as-Bahadurganj, Kochadhaman, Thakurganj, Teragachh, Pothia, Kishanganj and Dighalbank. The water samples were collected from ten potential aquaculture water bodies in each block. The reported iron concentrations are higher than WHO permissible limit of 0.30 mg/L in all the blocks of Kishanganj district with highest concentration reported in Dighalbank block (0.49- 0.67 mg/L). The present study will provide baseline information of ground water iron level for future aquaculture practices in Kishanganj district, Bihar.

Keywords: Iron, Kishanganj, Aquaculture, WHO limit.

Climate Resilient Agriculture Aquaculture and Livestock

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ABSTRACT

Bihar's aquaculture and livestock sectors have enormous potential to improve rural livelihoods, nutritional security, and economic growth. Despite the state's abundance of ponds, wetlands, floodplain areas, and agricultural resources, the productivity of aquaculture is still relatively low due to a number of ongoing issues. One of the main concerns is the deteriorating water quality caused by pollution, seasonal flooding, poor pond management, and changing climatic conditions; farmers suffer significant losses as a result of using low-quality and disease-infected fish seed, which causes delays, increased transportation costs, and uncertainty for local farmers. Despite the state's abundance of ponds, marshes, floodplain areas, and agricultural resources, aquaculture production is still relatively low because of a number of enduring issues. Deteriorating water quality due to pollution, seasonal flooding, inadequate pond management, and shifting weather patterns is one of the main issues. The use of poor-quality and disease-infected fish seed, which has a detrimental effect on fish survival and productivity, causes farmers to suffer significant losses. Furthermore, Bihar's supply of high-quality fish seed is mostly dependent on neighboring states, which causes delays, increased shipping expenses, and uncertainty for local growers.The lack of knowledge in rural communities about integrated livestock systems, scientific fish farming, and composite aquaculture techniques is another serious problem. Without access to contemporary technologies or climate-resilient management techniques, many farmers still employ conventional practices. *Anabas* (climbing perch), local *Clariasmagur*, and other native fish species can be promoted as a sustainable solution to these issues in Bihar. These species are ideal for cultivation in home ponds, garden pools, and small-scale water bodies since they are extremely nutritious and can adapt to local environmental conditions. Diversification through integrated aquaculture-livestock farming and culture-cum-capture fisheries can enhance household nutrition, job prospects, and income production.Farmers can reduce the hazards associated with climate change and environmental stress by using climate-resilient techniques including rainwater harvesting, biofloc technology, integrated fish-duck farming, solar-powered aeration, disease-free seed production, and routine water quality monitoring. Government assistance can improve local aquaculture infrastructure and lessen reliance on outside sources through hatchery development, farmer training, awareness campaigns, and financial plans.By encouraging self-sufficiency, rural entrepreneurship, food security, job creation, and environmentally sustainable growth, the development of sustainable livestock and aquaculture systems in Bihar directly supports the vision of Viksit Bharat 2047. By bolstering these areas, Bihar can become a model for climate-smart rural development and make a substantial contribution to India's economy going forward.

Keywords: Aquaculture, Climate resilient and smart farming,Bihar,Biofloc technology, Sustainable fisheries , Nutritional security, Viksit Bharat 2047,Blue economy, *Anabas*and *Clarias magur*culture ,Composite fish culture.

Ultrasonic assisted Osmotic Dehydration of Aonla fruit slices: Effect of natural sweeteners and temperature on mass transfer and product Characteristics

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ABSTRACT

The process of osmotic dehydration is an effective pre-treatment process that is employed to improve the quality and prolong the shelf life of the fruits, which can be optimized by using ultrasound technique. This study aimed at investigating the effect of Ultrasonic assisted Osmotic Dehydration (UAOD) process of aonla fruit slices treated with three different osmotic agents; namely jaggery, honey, and sugar-salt solutions, where the experiments were carried out with various concentrations (60°C, 65°C and 70°C for jaggery solution, 65°C, 70°C and 75°C for honey solution and 55°C, 60°C and 65°C for sugar-salt solution) and temperatures (30°C, 40°C, and 50°C) in an ultrasonic bath (40 kHz) operating in pulse mode (10 min ON & 10 min OFF) along with maintaining a fruit to solution ratio of 1:4. The mass transfer rate kinetics of UAOD process was optimized based on the maximum values of water loss and solute gain as well as minimization of weight loss, while the degradation kinetic of osmotic agent was studied in terms of pH change and Total Soluble Solids (TSS) values. It was found that water loss and solute gain showed a positive relation with the increase in concentration and time, while the weight loss showed a steady decrease pattern throughout. Moreover, among all the treatments, jaggery showed the best mass transfer rate parameters by showing maximum water loss (17.91% to 48%), solute gain (4.72% to 11.69%), and minimal weight reduction (13.19% to 36.31%) in 70 °Brix and 40 °C. On the other hand, both the honey and sugar-salt solutions showed the optimal values of their mass transfer parameters (Water Loss: 15.98%-41.74%, 19.42%-47.37%; Solid Gain: 3.3%-9.09%, 2.9%-7.46%; Weight Reduction: 12.68%-32.65%, 16.53%-39.91%) at 65 °Brix & 60 °Brix respectively with 40°C as the operating temperature. Finally, the optimized fruits slices from the above-mentioned treatments were tested against the control samples in terms of sensory quality and physicochemical characteristics (Moisture Content, Water Activity, Color, Total Acidity, TSS, pH, Ascorbic Acid, Total Phenolic, Antioxidant Activity), in which the jaggery UAOD samples showed better performance than others by having high total phenolic, ascorbic acid, TSS, and antioxidant activity while maintaining minimal difference in color, moisture content, and water activity. Therefore, UAOD of aonla fruit slices in jaggery solution (specifically at 70 °Brix and 40 °C) is the most effective pre-treatment to maximize mass transfer rates while preserving its nutritional, physicochemical, and sensory qualities.

Keywords: Aonla, mass transfer kinetics, Osmotic Dehydration, Quality Characteristics, Ultrasound, Water loss

Empowering Farm Women through Namo Drone Didi Programme

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Abstract

The "Namo Drone Didi Scheme" is a unique scheme of the Government of India intended at empowering rural women and strengthening precision farming through drone technology. Launched with an allocation of around ₹1,261 crore, the scheme wishes to provide drones to 15,000 selected Women Self-Help Groups (SHGs) in pan India basis between 2024 and 2026. In this programme, farm women are trained as "Drone Didis" to operate agricultural drones for farming activities likely nano-fertilizer spraying, pesticide spraying, crop monitoring, seed sowing, and field mapping. The program is anticipated to create sustainable livelihood opportunities while modernizing Indian agriculture through smart farming technologies.

Operational guidelines, and transformative potential of the Namo Drone Didi Scheme in improving agricultural productivity and rural livelihoods depicted its scope. Drone technology can reduce spraying time by nearly 70–80%, minimize input wastage, and improve precision in fertilizer and pesticide application. The programme also leverages women empowerment by enhancing technical skills, digital literacy, and entrepreneurial capabilities among rural women. Each SHG is provided financial assistance and capacity-building support to establish drone service centers and provide custom hiring services to farmers. The socio-economic and environmental benefits of the scheme, including reduced labor dependency, lower exposure to harmful chemicals, efficient resource utilization, and increased adoption of sustainable farming practices. By integrating advanced drone technology with women-led rural enterprises, the Namo Drone Didi Scheme has the potential to revolutionize Indian agriculture, strengthen the role of women in agri-business, and contribute towards the vision of a technologically empowered and self-reliant rural India.

Keywords: Agricultural Innovation, Drone Technology, Precision Farming, Rural Development, Women Empowerment

Enhancing human nutrition through value added product of Wheatgrass, Moringa, Aonla and Ginger powder

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Abstract

The rising burden of **non-communicable diseases (NCDs)** in today's society has created an increasing demand for foods that go beyond basic nutrition and act as **nutraceuticals**. Such products are designed to deliver health benefits, prevent disease, and promote overall well-being. The idea that *diet can function as medicine* is gaining importance, as it offers a pathway to achieve **holistic nutrition** while reducing dependence on synthetic supplements or pharmaceuticals.Several traditional plant-based resources have long been recognized for their therapeutic potential. Among them, **wheatgrass, moringa leaves, aonla (Indian gooseberry), and ginger** are notable for their diverse bioactive compounds. To harness these benefits, the raw materials were processed into powders using a **hot air oven at 35 °C**, followed by sieving to achieve uniform texture, and stored at **4 °C** to preserve nutritional integrity. Nutritional evaluation revealed that **wheatgrass powderand moringa leaf powder**were particularly rich in protein, with values ranging between **19–24% ona dry weight basis**. In addition, biological assays further confirmed their potential, as **crude extracts of wheatgrass, moringa, aonla, and ginger powders demonstrated antimicrobial activity against *Escherichia coli***. This highlights their relevance not only in nutrition but also in promoting gut health and food safety. The evidence suggests that combining these powders in appropriate proportions could yield a **balanced nutraceutical blend** capable of delivering enhanced protein, antioxidants, and antimicrobial properties. Developing such a formulation offers significant scope for **agripreneurship**. This approach aligns with the global movement toward **functional foods and nutraceuticals**, ensuring that nutrition, health, and livelihood development progress hand in hand.

Keywords: Wheat Grass, Anola, Moringa, Ginger, Value added product

Farmer Producer Organization and its role in India

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ABSTRACT

Indian agriculture has achieved remarkable progress in food grain production, particularly in rice and wheat, ensuring food security for a population of more than 1.4 billion people. Despite this growth, small and marginal farmers, constituting nearly 86% of the total farming community in India according to the Agriculture Census 2015-16, continue to face challenges such as fragmented landholdings, poor market infrastructure, low bargaining power, inadequate access to quality inputs and modern technologies, and exploitation by intermediaries. These constraints often result in lower productivity and reduced farm income. To overcome these challenges, the Government of India has promoted Farmer Producer Organizations (FPOs) as an effective institutional mechanism for collective farming, marketing, and value addition.Farmer Producer Organizations are registered producer-owned entities formed under the Companies Act, 2013, aimed at improving the socio-economic condition of farmers through collective action. Recognizing their importance, the Government of India launched the Central Sector Scheme for the "Formation and Promotion of 10,000 FPOs" in 2020. According to the National Bank for Agriculture and Rural Development (NABARD, 2025), more than 6,265 FPOs have been registered across India, covering over 30 lakh shareholder farmers, with nearly 2,988 FPOs credit-linked and around 4,585 FPOs market-linked. These organizations facilitate access to quality inputs, institutional credit, crop insurance, storage, processing, branding, and market linkages while also promoting value addition and reducing post-harvest losses.FPOs play a significant role in mobilizing farmers into commodity-based groups, enhancing bargaining power, improving market access, and ensuring better price realization. Thus, FPOs are emerging as a key strategy for sustainable agricultural development, rural entrepreneurship, and doubling farmers' income in India.

Keywords: *Farmer Producer Organizations (FPOs), Small and Marginal Farmers, Collective Action, Market Linkages, Agricultural Development*

Integrated Biocontrol Consortium and Reduced Chemical Compatibility for the Management of Rice Sheath Blight and Bacterial Leaf Blight

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Abstract

Rice sheath blight caused by *(Rhizoctonia solaniKühn*) and bacterial leaf blight caused bypathogen (*Xanthomonas oryzae pv. Oryzae)* are important constraints in rice cultivation and are responsible for considerable yield loss under humid agroecosystems The present study evaluated the antagonistic activity and compatibility of *Pseudomonas spp, Bacillus spp*, and *Trichodermaspp*. individually and in consortium combinations against both pathogens under laboratory and pot conditions. Dual culture and antagonist assays revealed that the consortium of *Pseudomonas* + *Bacillus* + *Trichoderma* produced higher inhibition of pathogen growth compared with individual bioagents. In vitro inhibition of *Rhizoctonia solani* ranged between 72–84% in consortium treatments, whereas individual isolates recorded 48–66% inhibition. Against *Xanthomonas oryzae pv. oryzae*, bacterial antagonism and metabolite-mediated suppression ranged from 61–79% in combined treatments. Compatibility studies conducted through cross-streak and paired culture methods indicated that selected isolates *of Pseudomonas, Bacillus, and Trichoderma* were mutually compatible without significant suppression of each other's growth. Chemical compatibility assays demonstrated that reduced concentrations of validamycin 3L (2 ml L^{-1}) used for sheath blight management and copper oxychloride + streptocycline (2.5 gL^{-1} + 0.1 gL^{-1}) used for bacterial leaf blight management caused minimal inhibitory effect on the growth of selected bioagents under in vitro conditions. However, higher chemical concentrations reduced microbial growth and therefore were not considered suitable for consortium integration. Nine treatments including untreated control, pathogen control, individual bioagents, and consortium combinations were evaluated under pot conditions following seed treatment, soil drenching, and foliar spray application methods. Disease severity recorded using IRRI standard evaluation scales showed that the consortium treatment integrated with reduced chemical dose significantly reduced sheath blight and bacterial leaf blight severity by 64–78% over pathogen control. Individual bioagent treatments reduced disease severity by 32–54%, while untreated pathogen control recorded maximum disease incidence and lesion development. Consortium-treated plants also showed improved seed germination, seedling vigour, plant height, tiller production, and overall plant health compared with control treatments. The integrated use of compatible microbial consortia with reduced chemical dosage demonstrated effective and sustainable management of both rice diseases while reducing dependency on chemical pesticides.

Keywords: Microbial consortium, dual culture assay and compatibility test.

Role of AI in precision Agriculture and Smart Farming

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Abstract

Global agriculture must increase productivity while reducing environmental impact and coping with limited land, water, and labor resources. Artificial intelligence (AI) has become a major driver of precision agriculture and smart farming by providing data-driven solutions for improved crop management, efficient input use, and optimized farm operations. This poster highlights the role of AI technologies such as machine learning, deep learning, computer vision, and intelligent decision-support systems in key agricultural applications, including crop and soil monitoring, irrigation management, weed and pest control, yield prediction, and variable-rate input application. The review synthesizes findings from recent systematic and narrative studies on AI in agriculture, highlighting typical data sources, which include in-field sensors, IoT networks and drones and satellites and common model types that transform diverse data into practical guidance. The applications demonstrate that AI systems that operate with AI capabilities can enhance both the precision of crop health evaluations and the accuracy of yield predictions and the implementation of more accurate irrigation and fertilization methods, which ultimately results in increased productivity through reduced consumption of water and fertilizer and pesticide. The review summarizes findings from recent studies on AI applications in agriculture. These studies show that data from in-field sensors, IoT networks, drones, and satellites are used to develop predictive models that convert diverse datasets into actionable insights. AI applications improve crop health assessment, yield prediction, irrigation management, and fertilizer optimization. As a result, agricultural systems can achieve higher productivity while reducing the use of water, fertilizers, and pesticides. In addition, AI-powered robotic systems and intelligent machines help reduce labor costs and ensure timely completion of critical farming operations.

Keywords: *Artificial Intelligence, Precision Agriculture, Smart Farming, Machine Learning, Decision Support, IoT, Sustainable Agriculture.*

Climate-Resilient Strategies for Sustainable Horticultural Production

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Abstract

Climate change has become a serious challenge to sustainable horticultural production due to rising temperatures, erratic rainfall, droughts, floods, and the increasing incidence of pests and diseases. These environmental stresses negatively affect crop growth, yield, quality, and profitability, while also threatening global food and nutritional security. Consequently, the development of climate-resilient horticultural systems has become essential for ensuring sustainable agricultural production under changing climatic conditions. Climate-smart and adaptive production strategies are increasingly being adopted to improve crop resilience and conserve natural resources. Among these, the cultivation of drought-tolerant, heat-resistant and stress-adaptive varieties plays a crucial role in stabilizing productivity under adverse environments. Similarly, Integrated nutrient and pest management practices further contribute to sustainable production by improving soil fertility, maintaining ecological balance, and minimizing dependence on synthetic agrochemicals.

The integration of advanced technologies like precision farming, remote sensing, artificial intelligence, and weather forecasting systems has significantly transformed modern horticulture by enabling timely and accurate crop management decisions. Despite these, the adoption of climate-resilient technologies among small and marginal farmers remains limited due to high implementation costs, inadequate infrastructure, lack of technical knowledge, and insufficient institutional support. Therefore, strengthening policy support, promoting innovation, expanding farmer training programs and financial assistance are essential to accelerate the adoption of climate-resilient horticultural practices. Overall, these strategies provide a sustainable pathway for improving crop adaptability, resource-use efficiency, environmental conservation, and long-term food security.

Keywords: Climate-Resilient Agriculture, Sustainable Horticulture, Climate-Smart Technologies, Resource-use efficiency.

Statistical and Machine Learning Analysis of Growth Drivers and Risk Dynamics in the Global Makhana (*Euryale ferox*) Market

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Abstract

Makhana (*Euryale ferox*), commonly known as Fox nut, is an emerging high-value agricultural commodity experiencing rapid market expansion due to changing Consumption patterns, increasing Health Awareness, and Digital market Expansion. Recent industry projections indicate that the Global Fox Nuts market is expected to reach approximately USD 4.7 billion by 2036, growing at a CAGR of around 11% during 2026–2036, highlighting its strong future potential. This study aimed to identify major growth drivers and AnalyzeRisk dynamics using an integrated framework of Statistical and Machine learning approaches. A constructed time-series dataset (2008–2025) was developed using CAGR-based trends and index-based variables representing Demand, Online Expansion, Health Awareness, and composite Risk factors. Multiple linear regression analysis in SPSS revealed that the model explained approximately 98.9% of variation in growth ($R^2 = 0.989$, $p < 0.001$), with Demand showing a strong positive association, while other variables exhibited limited individual significance due to Multicollinearity. Random Forest Analysis explained about 95.7% of variation and indicated that Demand, Online Expansion, and Health Awareness collectively influenced growth, whereas Risk factors showed comparatively lower direct importance. XGBoost results further identified demand as the dominant predictor, accounting for the highest predictive gain. To strengthen Risk interpretation, Growth Stability Index (GSI), Risk Zoning, and Demand–Risk Ratio (DRR) analyses were performed. The results indicated that growth persisted across moderate and high-risk environments, suggesting increasing Market Resilience where strong demand and digital expansion partially offset adverse market and supply-side risks. Overall, The findings support Resilience-Oriented Market analysis using integrated Statistical and Machine learning approaches.

Keywords: Makhana, Growth Drivers, Risk Analysis, Market Resilience, Random Forest, XGBoost, CAGR

Blockchain-Integrated Agri-Entrepreneurship: A Strategic Framework for the Circular Economy in India

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Abstract

As India embarks on the "Viksit Bharat 2047" vision, the application of frontier technologies in agriculture has emerged as a strategic imperative. The amalgamation of agricultural systems and blockchain presents a transformative route to realize the "Waste-to-Wealth" objective, a key pillar of India's circular economy. Traditional supply chains are characterized by opacity and inefficient resource recovery, whereas blockchain provides the digital infrastructure through immutable traceability and smart contracts to address these structural inefficiencies.This research proposes an operational framework for Agri-entrepreneurship through blockchain. The research seeks to explore how decentralized governance and incentivization could help in waste valorisation and connecting waste generators to recyclers in the Indian agribusiness environment.Using PRISMA protocol, this study analyses the high-impact, peer-reviewed documents published between 2021 and 2026. The synthesis focuses on three thematic clusters: Agri-enterprises as lead adopters of blockchain; blockchain-enabled tracking of by-products; and the impact of digital traceability on Agri-MSME market valuation.Findings indicate that blockchain is foundational in "closing the loop" by verifying the provenance of agricultural residues. Traditionally treated as liabilities, Agri-wastes are being integrated into secondary markets for bio-energy and organic inputs. However, the ecosystem faces a complex SWOT profile; while transparency is enhanced, high technical barriers and digital literacy gaps in rural India remain significant weaknesses.Agri-startups are uniquely positioned to leverage tokenized reward systems to bypass intermediaries and incentivize sustainable practices like stubble management. Integrating "blockchain startups" with the "National Strategy on Blockchain" creates opportunities for converting waste into sustainable raw materials capable of fetching premium prices internationally.This study provides a roadmap for scaling blockchain-drivenAgri-enterprises, emphasizing that digital maturity is a prerequisite for a resilient circular economy. Overcoming regulatory uncertainty and interoperability challenges is essential to realizing a truly sustainable agricultural future for India.

Keywords: Agri-entrepreneurship, Blockchain, Circular Economy, Waste-to-Wealth, Viksit Bharat 2047, Agri-MSMEs.

Hydroponic Lettuce: Future of High-Value Horticulture

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Abstract

India now offers a lot of chances to produce high-value horticulture crops due to the growing demand for fresh, nutrient-dense, and pesticide-free veggies. Due to its nutritional worth and health benefits, lettuce (*Lactuca sativa* L.), a significant exotic leafy vegetable, is becoming more and more popular among urban customers, hotels, supermarkets, and the food sector. However, there are a number of issues with traditional soil-based lettuce farming, including seasonal restrictions, high water requirements, soil-borne illnesses, and uneven quality.An effective and sustainable substitute for producing high-quality lettuce all year round is hydroponic farming. Plants are grown in nutrient-rich water under carefully regulated environmental conditions using hydroponics, a soilless growth method. Lettuce's short growth cycle, compact root system, and strong market demand make it an excellent choice for hydroponic systems. The Nutrient Film Technique (NFT) is a popular hydroponic method for growing lettuce because it provides plant roots with an effective supply of nutrients and oxygen.The commercial potential of hydroponically grown lettuce has increased in Bihar due to growing organized retail marketplaces, growing demand from the hospitality industry, and growing awareness of healthier diets. Hydroponic infrastructure requires a relatively large initial investment, but through premium pricing and continual production, the technique yields higher economic returns. In Bihar, hydroponic lettuce production has the potential to significantly contribute to sustainable agriculture, resource efficiency, and revenue generation for farmers and agri-entrepreneurs. Strong market connections, research assistance, and technical training are necessary for this technology's broader acceptance.

***Keywords*:**Hydroponics, Lettuce (*Lactuca sativa L.*), Soilless cultivation, High-value horticulture, Nutrient Film Technique (NFT), Sustainable agriculture.

Development and Quality Characterization of Probiotic Bael Soy-Yoghurt

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ABSTRACT

Bael (*Aegle marmelos*) is an important indigenous fruit crops of India, known for it's medicinal value, drought tolerance as well as it's nutraceutical applications. It is an undervalued crop, with a high processing potential. Bihar and Jharkhand are one of the leading producers of Bael in India. Major Bael growing districts in Bihar includes Bhagalpur, Gaya, Nalanda, Patna, Muzaffarpur and Banka. Bael is a rich source of riboflavin, calcium, iron, carotene, Vitamin C and antioxidant that gaining importance in food industries and it may infuse in probiotic drink to enrich the nutraceutical properties. In this study, soy milk, bael (5-15%) and agar-agar (0.1-03%) has been optimized for the development of bael based soy-yoghurt. The results indicated that the optimized formulation containing 10% bael pulp and 1% agar-agar was highly acceptable. Physicochemical, sensory and functional properties have been analysed of optimized soy-yoghurt. This study may be beneficial for health-conscious consumers and manufacturers interested in developing lactose-free yoghurt alternatives.

Keywords: Plant -based yoghurt, Lactose-free, Bael, Physicochemical, sensory and functional properties.

In Vitro Efficacy of Fungicides and Botanicals Against *Sclerotinia sclerotiorum*: A Comparative Evaluation

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Sclerotinia sclerotiorum is a devastating polyphagous fungal pathogen causing stem rot disease in rapeseed-mustard with annual crop losses reaching up to 70% under conducive conditions. Management of this disease requires integrated approaches combining chemical fungicides and botanical extracts. This study evaluated the in vitro efficacy of novel fungicides and plant-based botanicals against *S. sclerotiorum* isolates using the poisoned food technique. Twelve fungicide treatments and eight botanical extracts were tested against the pathogen to determine their inhibitory potential on mycelial growth. Colony diameter was recorded at 3, 5, and 7 days after inoculation (DAI), and percent inhibition of mycelial growth was calculated. Among fungicides tested, carbendazim, chlorothalonil, and thiophanate-methyl exhibited superior efficacy with mean inhibition rates exceeding 80% by 7 DAI, while newer fungicides demonstrated comparable or superior activity. Botanical extracts from *Allium sativum, Zingiber officinale*, and *Ocimum basilicum* demonstrated significant antifungal properties with inhibition rates ranging from 60-75% at 7 DAI. Statistical analysis revealed significant differences ($P \leq 0.05$) among treatments, with fungicides showing faster inhibition kinetics compared to botanicals. The combined approach of integrating both chemical fungicides for quick control and botanicals as eco-friendly alternatives offers promising prospects for sustainable management of Sclerotinia stem rot in rapeseed-mustard cultivation. These findings provide a foundation for developing integrated disease management strategies that balance efficacy with environmental sustainability.

Keywords: *Sclerotinia sclerotiorum*, Fungicides, Botanical extracts, In vitro efficacy, Mycelial growth inhibition, Rapeseed-mustard, Stem rot management, Integrated disease management

Sri Aurobindo's Integral Vision for Nation-Building: A Synthesis of Spirituality, Rural Development, Agricultural Sustainability and Women's Empowerment

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ABSTRACT

Sri Aurobindo's philosophy represents a distinctive synthesis of spirituality and material progress, offering an enduring framework for national reconstruction rooted in Integral Yoga. This report critically examines his contributions to Indian nationalism, agricultural development, rural reconstruction, and women's empowerment, demonstrating how his philosophical vision extends beyond metaphysical discourse to practical socio-economic transformation. Rather than viewing spiritual realization as separate from worldly life, Sri Aurobindo proposed that individual and collective evolution should culminate in the transformation of society through ethical action, self-reliance, and human development. The analysis highlights Sri Aurobindo's advocacy of Purna Swaraj, Swadeshi, and decentralized village governance as essential foundations for economic sovereignty and sustainable nation-building. His vision of self-sufficient villages emphasized cooperative institutions, integrated education, sustainable agriculture, irrigation development, and community participation as mechanisms for enhancing rural resilience and food security. The report further explores how his literary works, particularly *Savitri*, and his philosophy of Integral Yoga redefined women's empowerment by recognizing women as equal agents of spiritual, social, and national transformation. Practical implementations of these ideals are examined through the Sri Aurobindo Ashram and Auroville, where organic farming, regenerative agriculture, renewable energy, circular resource management, and community-based farming demonstrate the continued relevance of his principles for contemporary sustainable development. These initiatives illustrate the successful integration of ecological stewardship with economic productivity and social well-being. Lastly, concludes that Sri Aurobindo's integrated philosophy provides a holistic model that bridges cultural heritage with modern development challenges. His vision remains highly relevant for addressing contemporary concerns related to sustainable agriculture, gender equality, rural development, environmental conservation, and inclusive national progress. By harmonizing spiritual values with practical governance and economic self-reliance, Sri Aurobindo offers a timeless framework for achieving equitable, resilient, and sustainable human development in the twenty-first century.

Keywords: Sri Aurobindo, Integral Yoga, Sustainable Rural Development, Women's Empowerment, Spiritual Nationalism

Argulus parasitism in aquaculture under warming water regimes: implications for climate-resilient pond management

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Abstract

Argulus is an ectoparasite causing substantial economic loss by triggering serious disease outbreaks in fish farms worldwide. Interaction between host, parasite and the environment especially change in temperature determines the severeness of the disease. The shift in temperature is a serious concern in aquaculture and mechanism of parasitism is poorly understood on host and parasite. The most obvious outcomes of changing thermal regime is a shift in the spatiotemporal distribution of argulus due to their fastened life- cycle, increasing host susceptibility to secondary infections leading to mortality. High infestations of Argulus typically result in skin ulcers, disruptions in osmoregulation, physiological stress, and weakened immune responses, causing high rates of illness and reduced growth in carps as well as other species.As a result, short generation period will likely be experienced by parasites making their life history traits more complicated. The intensity and frequency of temperature events are expected to rise in the future influencing parasitism and damage to the farmed fishes. With temperature shifts intensifying parasite pressure, aquaculture in regions like India must prioritize eco-friendly, integrated approaches.

Keywords: Argulus, Spatiotemporal, Parasitism, Secondary infections.

Startup and Entrepreneurship in Circular Economy: Bridging The Gap Between Farmers and Markets

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In India, a majority of small and marginal farmers continue to cultivate staple crops such as wheat, rice, and potatoes, largely neglecting high-value cash crops like cotton, jute, and groundnut. This trend persists due to limited market awareness, absence of reliable price information, and exploitation by middlemen who procure raw produce at minimal cost and sell processed goods at significantly higher prices. As a result, farmers fail to receive even the minimum support price for their produce, perpetuating a cycle of low income and economic dependency.

This paper proposes a circular economy-based entrepreneurial model to address these systemic challenges. The model envisions trained agricultural extension entrepreneurs who build farmer trust, educate them about market chains, and introduce integrated farming approaches including IPM, INM, IFS, and IDM to enhance sustainability and productivity. Initially, the entrepreneur absorbs short-term losses by offering farmers fair prices for cash crops, then undertakes in-house processing, value addition, and branded packaging — creating long-term profit-sharing opportunities for both parties.

Furthermore, cash crops offer immense entrepreneurial potential: cotton can support textile and handloom startups; jute can be transformed into eco-friendly bags, handicrafts, and packaging materials — aligning perfectly with circular economy principles of waste reduction and resource efficiency. Groundnut processing can generate edible oil, protein meal, and confectionery products, creating employment at the grassroots level.

The strength of this model lies not in capital-intensive technology, but in communication, ground-level trust, and farmer-centric problem solving — making it a replicable and scalable rural startup framework.

Advancement in crop protection through genomics-assisted aphid resistance in wheat

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Abstract

Climate-responsive aphid infestation is a major constraint to wheat productivity and nutritional security, necessitating advancement in crop protection through genomics-assisted resistance breeding. The present study evaluated 400 wheat genotypes against *Sitobion avenae*, *Rhopalosiphum padi*, and *Schizaphis graminum* under field and controlled growth chamber conditions. Under field conditions during Rabi 2023-24 and 2024-25, only three genotypes were moderately resistant, while 175 and 222 genotypes were susceptible and highly susceptible, respectively. In contrast, controlled conditions revealed greater resistance expression, with 315 genotypes resistant to *S. avenae*, 180 to *R. padi*, and 302 to *S. graminum*. Resistant genotypes recorded nearly five-fold lower aphid incidence than susceptible genotypes. Morpho-physiological analysis revealed significant negative correlations of aphid incidence with total tillers (r = -0.11) and chlorophyll content (r = -0.09), indicating the contribution of plant vigour traits towards aphid resistance. Genome-wide association analysis using 18,239 high-quality SNP markers identified 5 loci associated with *S. avenae* resistance and 19 loci linked to *R. padi* resistance across environments. Major-effect markers including S5B_485787430, S5B_505795032, SUN_30083888, S2A_763798732, S3A_705126974, and S4D_8600690 showed highly significant associations with reduced aphid incidence. Candidate gene analysis identified defense- and stress-responsive genes such as TraesCS3B02G455300, TraesCS5B02G320300, GA2ox-D4, and TraesCS4A02G076100 involved in hormone metabolism and plant defense pathways.Biochemical characterization revealed significantly higher sucrose, starch, tannin, and chlorophyll contents in moderately resistant genotypes compared to susceptible groups. Aphid incidence showed strong negative correlations with sucrose (r = -0.85), starch (r = -0.77), amylopectin (r = -0.84), and chlorophyll content (r = -0.36), highlighting their role in resistance. Molecular analysis using SSR markers revealed considerable genetic diversity among wheat genotypes. Specific alleles, including the 250 bp allele of Xwmc179 and 358/384 bp alleles of Xwmc553, showed strong association with the aphid resistance gene *RA-1*.

Keywords: Wheat, Aphid resistance, SNP markers, Biochemical traits, Marker-assisted selection

Empowering Women farmers

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Abstract

Women constitute an essential part of the agricultural workforce and contribute extensively to farming operations such as crop cultivation, animal husbandry, seed preservation, post-harvest management and maintaining household nutrition. Even with their active participation, many women engaged in agriculture continue to face several barriers, including inadequate access to land rights, institutional credit, advanced technologies, training opportunities, market facilities, and participation in decision-making processes. Empowering women farmers is therefore crucial for strengthening sustainable agriculture, enhancing rural incomes, and improving food and nutritional security. The empowerment of women in agriculture can be promoted through education, technical training, access to quality seeds and inputs, financial assistance, and involvement in self-help groups and farmer organizations. Support from agricultural extension services and awareness regarding government welfare schemes can further help women adopt improved farming practices and modern technologies. Digital agriculture, entrepreneurship opportunities, and leadership development programs can also increase their confidence, productivity, and economic self-reliance. Enhancing the status and participation of women farmers not only contributes to higher agricultural output but also supports social equity, poverty alleviation, and overall rural progress. Hence, coordinated efforts from governments, educational institutions, non-governmental organizations, and local communities are necessary to provide equal opportunities and create a supportive environment for women farmers, enabling them to actively participate in agricultural and national development.

Keywords : Female empowerment, Self-Help Groups (SHGs), Agricultural Extension Services, Financial Inclusion, Sustainable agriculture, Socioeconomic development, Gender-sensitive policies, Government Schemes for Farmers.

Carbon‑Negative Aquaponics: Integrating Algae Biofilters with Fish Farming

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Abstract

Climate‑resilient food production demands innovative systems that not only sustain yields but also mitigate carbon emission. This model introduces a novel Carbon‑Negative Aquaponics that integrates algae biofilters into conventionalfish‑vegetable aquaponic systemsto achieve carbon sequestrationand circular nutrient recycling. In this model, fish waste containing ammonia and carbon dioxide is channeled into algae chambers, where microalgae utilize these compounds for rapid growth and water purification. The treated water then nourishes hydroponic crops, completing a closed‑loop, zero‑waste cycle.Advanced AI‑based sensors continuously track water parameters such as temperature, pH, and nutrient concentration, allowing automated adjustments for optimal algae performance and system stability. This intelligent integration transforms aquaponics from a carbon‑neutral approach into a carbon‑negative production system, generating three valuable outputs—fish, vegetables, and algal biomass. The harvested algae serve as raw material for biofuel, livestock feed, and nutraceuticals, promoting a sustainable bio‑economy.The proposed model offers a pathway toward climate‑positive aquaculture, significantly lowering greenhouse gas emissions while improving food security and supporting rural livelihoods. Its scalability across rural, urban, and industrial contexts positions it as a futuristic solution for eco‑efficient and carbon‑smart farming, aligning with India’s vision for sustainable agricultural transformation.

Keywords: Carbon‑Negative Aquaponics, Algae Biofilters, AI Optimization, Circular Bioeconomy, Climate‑Resilient Farming

Role of Farmer Producer Organizations (FPOs) in Enhancing Agribusiness Sustainability

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Abstract

Agriculture is an integral venture of farmer's livelihood as approx. than 50 per cent of Indian populations depends upon agriculture and allied activities. Farmers face various challenges such as inappropriate market linkage, high cost of seeds, fertilizers, pesticides and farm implements, unavailability of quality seeds and planting materials, less availability of institutional credit for investment in agriculture sector and unawareness about new agri-technologies. Though government dedicating its efforts to enhance the farmers' income by addressing these challenges in equitable manner. In this context farmer producer organizations (FPOs) are the most meaningful initiative of government to unite farmers for producing and marketing of agriproducts. Farmer Producer Organizations (FPOs) are a key strategy for strengthening agribusiness, particularly for small and marginal farmers. By collectivizing farmers, FPOs help and overcome challenges related to market access, leverage input procurement, financing, and value addition. FPOs contribute to strengthening agribusiness through enhancing Market Access, FPOs enable small farmers to aggregate their produce, reducing dependence on middlemen, Better Bargaining Power for Inputs, bulk purchasing of seeds, fertilizers, and machinery reduces input costs. ensures timely availability of quality inputs at fair prices. Governments provide grants, subsidies, and tax benefits to FPOs under initiatives like the 10,000 FPOs Scheme in India, strengthening Rural Economy. The members of FPOs are farmers with small holdings who organize themselves with the set objective of improving their farm income through high quality production, engaging in preparation of value-added products and sale the products via innovative marketing channels. Still most the farmers & FPOs in India are not able to utilize existing innovative agri-technologies and marketing practices. Therefore, strengthening the FPOs are key way of ensuring livelihood security of farmers with intensifying agribusiness. FPOs are transforming the agribusiness by empowering farmers to become entrepreneurs, driving rural development, and ensuring food security for the nation. By investing in FPOs, we are investing in a more resilient, sustainable, & prosperous future for agriculture globally.

Key words: *Agribusiness, Agri-technologies, FPOs, Farmers, Marketing and Farming*

YOUR FARM: AN AGRI-TOURISM VENTURE DRIVEN BY INTEGRATED FARMING SYSTEMSFOR A CIRCULAR ECONOMY

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"YOUR FARM" is an innovative startup inspired by the ideas of Integrated Farming Systems (IFS), agritourism, and the circular economy. Our goal is to build a sustainable and self-reliant ecosystem that brings together crop production, livestock, fisheries, horticulture, agroforestry, and small rural industries—all working in harmony. In this system, waste from one area becomes a resource for another, making the most of every input and reducing environmental impact. We blend cutting-edge agricultural technologies, like drones for fieldwork, with traditional farming practices and local cultural activities. This approach not only boosts productivity and profits but also helps preserve rural heritage. Through agritourism, visitors can enjoy authentic rural experiences: staying on the farm, relaxing in treehouses or by the pond, and trying hands-on activities such as traditional food processing, pottery, garland making, preparing dung cakes, or weaving straw baskets. These activities open up new employment and income opportunities for rural communities. Sustainability is at the heart of "YOUR FARM." Practices like recycling sewage, nutrient cycling, and managing organic waste reduce the need for outside resources and keep the system balanced. While we recognise there are challengeslike the need for significant initial investment, longer setup times, and small land sizeswe believe the adaptable IFS model can be expanded to suit different climates and regions. In short, "YOUR FARM" offers a forward-thinking way to combine agriculture, tourism, and the circular economy to support environmental conservation, rural development, and economic growth.

Keywords: Agritourism, Integrated Farming System, Circular Economy, Rural Entrepreneurship, Sustainability.

Harnessing Rhizospheric and Nodule Associated Microbial consortia for Climate-Resilient Lentil Farming

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Abstract

Climate-resilient agriculture requires sustainable approaches to enhance crop productivity, nutritional security, and soil health under changing climatic conditions. The present study aimed to isolate and evaluate rhizospheric and nodule-associated zinc-solubilizing bacteria (ZnSB) from lentil (*Lens culinaris* L.) for developing effective microbial consortia to improve productivity and biofortification. A total of 157 bacterial isolates were obtained from rhizospheric soil and root nodules collected from RPCAU research farms at Pusa and Dholi. Among them, 127 rhizospheric and 30 nodule isolates were screened for zinc solubilization using ZnO and $ZnCO_3$ as zinc sources. ZnO proved to be the most efficient substrate, with zinc-solubilizing efficiency ranging from 25.00–416.70 in rhizospheric isolates and 57.10–357.10 in nodule isolates.The most efficient isolates, Rh-ZnSB 38, Rh-ZnSB 60, Rh-ZnSB 90, and Nd-ZnSB 1, exhibited multiple plant growth-promoting traits, including phosphate and potassium solubilization, siderophore production, IAA and GA synthesis, and ammonia production. These compatible isolates were used to develop a microbial consortium. Seed germination studies showed that combined inoculation of Nd-ZnSB 1 with the rhizospheric consortium resulted in 100% germination and maximum seed vigor index. Pot experiments demonstrated significant improvements in plant growth, nodulation, yield attributes, and grain micronutrient content under consortium treatment (T_7). Grain zinc and iron contents increased up to 46.80 and 102.30 mg kg^{-1}, respectively. Soil fertility parameters, including available N, P, K, organic carbon, and DTPA-extractable Zn and Fe, were also enhanced. The findings suggest that ZnSB consortia can serve as climate-resilient bioinoculants for sustainable lentil production and nutritional security.

Keywords: Climate-resilient agriculture, Zinc-solubilizing bacteria (ZnSB), Microbial consortium, Biofortification, Lentil

Influence of Weather Parameters on Population Dynamics of *Helicoverpa armigera* in Medium-Duration Pigeonpea under Eastern Plateau and Hill Region Conditions of India

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Abstract

A field investigation was conducted during *Kharif* 2023-24 and 2024-25 to elucidate the influence of abiotic weather parameters on the population dynamics of the gram pod borer, *Helicoverpa armigera*, infesting medium-duration pigeonpea in the Eastern Plateau and Hill region of India. The experiment was carried out at the research farm of Birsa Agricultural University, Ranchi, using the susceptible pigeonpea genotype BAUPP 22-12 under untreated field conditions. Weekly observations on larval incidence were recorded from crop establishment until physiological maturity and correlated with prevailing meteorological parameters, including maximum temperature, relative humidity, rainfall, and evaporation.The seasonal incidence pattern of *H. armigera* was found to be consistent across both experimental years. Larval activity commenced during the 36th-37th Standard Meteorological Week (SMW) and persisted up to the 2nd-3rd SMW, with population densities ranging from 0.07 to 3.53 larvae per plant. The highest infestation level was recorded during the 45th SMW in both years, coinciding with the flowering and pod formation stages of the crop. Correlation analysis based on pooled data revealed that larval population exhibited a significant positive association with morning relative humidity (7:00 AM) ($r = 0.373$, $p < 0.05$) and mean relative humidity ($r = 0.408$, $p < 0.05$), indicating the favourable role of atmospheric moisture in pest proliferation. In contrast, rainfall showed a non-significant negative association with pest abundance.Stepwise multiple regression analysis identified weather variables as significant determinants of *H. armigera* incidence, and the developed predictive model explained 35% of the observed variability in larval population dynamics. Model validation through observed versus predicted population values demonstrated acceptable predictive reliability. The findings indicate that relative humidity is a major ecological driver regulating *H. armigera* population build-up in pigeonpea and may be effectively utilized for developing weather-based pest forecasting and integrated pest management strategies in the region.

Keywords: *Helicoverpa armigera*, Population dynamics, Integrated pest management (IPM), Eastern Plateau and Hill region, Pest forecasting.

Hydroponics: A Climate-Resilient Agricultural Innovation for Sustainable Income Generation and Food Security

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Abstract

Hydroponics is an advanced soilless cultivation technique in which plants are grown using nutrient-rich water solutions under controlled environmental conditions. As climate change increasingly threatens conventional agriculture through erratic rainfall, soil degradation, and water scarcity, hydroponic farming emerges as a robust climate-resilient alternative capable of ensuring year-round food production independent of weather variability. This modern farming system enables efficient utilization of water, nutrients, and space, consuming up to 80–90% less water compared to traditional soil-based agriculture, making it highly suitable for regions facing poor soil fertility or limited water availability. High-value crops including lettuce, tomato, cucumber, strawberry, spinach, and various herbs can be cultivated with significantly faster growth rates and superior yields, directly enhancing market value and farmer profitability. Small-scale hydroponic units can be established on rooftops, balconies, and polyhouses, while large-scale commercial systems open avenues for agribusiness development and export opportunities. The technology substantially reduces weed pressure, soil-borne diseases, and pesticide dependency, thereby improving food quality and promoting environmental sustainability. From an economic perspective, hydroponic farming creates diverse employment opportunities for farmers, entrepreneurs, and urban growers in both rural and urban communities. With appropriate training, infrastructure support, and market linkage, this innovation holds strong potential for income diversification and rural livelihood enhancement. Integration of digital monitoring technologies further optimizes resource management and crop performance under changing climatic conditions. In conclusion, hydroponic farming represents a sustainable, profitable, and climate- adaptive agricultural innovation that significantly contributes to food security, efficient resource utilization, and long-term income generation, aligning with national priorities of agricultural modernization and entrepreneurship development.

Keywords: Hydroponics, Climate-resilient agriculture, Soilless cultivation, Food security, Sustainable farming

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राम निरीक्षण आत्माराम महाविद्यालय, समस्तीपुर शहर का एक उत्कृष्ट एवं आदर्श महाविद्यालय है। जिसकी स्थापना सन् 1968 ई0 में हुई थी। महाविद्यालय में 16 विषयों में कला व विज्ञान संकाय में स्नातक (प्रतिष्ठा) स्तर तक एवं 2 विषयों हिन्दी एवं राजनीति विज्ञान में स्नातकोत्तर स्तर तक सह शिक्षा की उत्तम व्यवस्था है। महाविद्यालय में समृद्ध प्रयोगशालायें, ई–पुस्तकालय, कम्प्यूटर लैब, मुक लैब, स्मार्ट वर्ग कक्ष, एन. एस. एस. इकाई एवं विभिन्न प्रकार के खेल (इनडोर एवं आउटडोर) की सारी सुविधायें उपलब्ध है। महाविद्यालय की चारदिवारी, मुख्य द्वार एवं पर्यावरण मैत्री से मंडित व्यापक खेल मैदान भी आकर्षण का मुख्य केन्द्र है। वर्तमान प्रधानाचार्य प्रो0 (डॉ0) दिलीप कुमार के कुशल मार्गदर्शन में महाविद्यालय का चहुमुखी उतरोत्तर विकास हो रहा है। महाविद्यालय परिवार अपने छात्र–छात्राओं के उज्जवल भविष्य के लिए सदैव तत्पर रहता है। महाविद्यालय परिवार First Zonal Convention- Eastern Bharat cum National Conference के अवसर पर अपनी शुभकामनाएं प्रेषित करता है।

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दिनांक .....

महाविद्यालय का संक्षिप्त परिचय

बलिराम भगत महाविद्यालय, समस्तीपुर, ललित नारायण मिथिला विश्वविद्यालय, दरभंगा की अंगीभूत इकाई है। इसकी स्थापना वर्ष 1969 हैं। इस महाविद्यालय की स्थापना का मुख्य उद्देश्य समाज के पिछड़े एवं दलित वर्ग के विद्यार्थियों के लिए किया गया था जिस से इस संवर्ग के बच्चे समाज में अपनी पहचान बना सकें। यह बिहार का प्रतिष्ठित महाविद्यालय है जो उच्च शिक्षा के माध्यम से छात्र-छात्राओं के सर्वांगीण विकास हेतु समर्पित है तथा गुणवत्तापूर्ण शिक्षा अनुशासन नैतिक मूल्य एवं सामाजिक दायित्वों को बढ़ावा देने के लिए जाना जाता है। इस महाविद्यालय में कला, विज्ञान एवं वाणिज्य संकाय में स्नातक एवं स्नातकोत्तर शिक्षा की उत्कृष्ट व्यवस्था है । इसके अतिरिक्त प्राक परीक्षा प्रशिक्षण केंद्र संचालित होता है। यह महाविद्यालय शहर के हृदय स्थल में स्थित होने के कारण छात्र एवं छात्राओं के बीच अत्यंत लोकप्रिय है। इस महाविद्यालय में राष्ट्रीयता की भावना के साथ-साथ सामाजिक सांस्कृतिक और पर्यावरणीय जागृति के लिए राष्ट्रीय सेवा योजना एवं एन.सी.सी. इकाई(बिहार १२ बटालियन) की सक्रिय भागीदारी होती हैं। इस महाविद्यालय के छात्र-छात्राएं अनुकूल शैक्षिक वातावरण में अपनी योग्यता क्षमता परिश्रम और दृढ़ संकल्प के बल पर नित्य नहीं उपलब्धियां हासिल करते हैं। यह उपलब्धियां महाविद्यालय और समाज के लिए गौरव और प्रेरणा है मूलत महाविद्यालय का उद्देश्य अपने छात्र एवं छात्राओं को शिक्षित सशक्त एवं आत्मनिर्भर बनाना है ताकि वे समाज और राष्ट्र के विकास में सक्रिय भूमिका निभा सके।

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हमारी विशेषताएं

1. स्नातक के छात्रों के लिए घर बैठे ऑनलाइन नामांकन की व्यवस्था।
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(ललित नारायण मिथिला विश्वविद्यालय, दरभंगा की अंगीभूत इकाई)

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यहाँ निम्नलिखित विषयों के पढ़ाई की सुविधा है–

विज्ञान संकाय : भौतिकी विज्ञान, रसायन विज्ञान, वनस्पति विज्ञान, जन्तु विज्ञान एवं गणित
कला संकाय : मनोविज्ञान, दर्शनशास्त्र, राजनीतिशास्त्र, अर्थशास्त्र एवं इतिहास
मानविकी विषय : हिन्दी, अंग्रेजी, संस्कृत, उर्दू

विशेषताएँ :

- Computer Lab
- Automated Library
- Conference Hall
- Sports Ground
- Science Lab
- Green Campus
- Sehat Kendra
- Smart Classes
- NCC & NSS Unit
- Wi-Fi- Campus
- Football Stadium
- Purified & Cold Water
- Red Ribbon Club
- CCTVs Equipped Campus
- Ragging Free Campus



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