

Towards Viksit Bharat@2047 Technological Innovations and Policy Options for Eastern Region



ICAR Research Complex for Eastern Region

**ICAR Parisar, P.O. Bihar Veterinary College
Patna-800 014, Bihar**

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Towards Viksit Bharat@2047: Technological Innovations and Policy Options for Eastern Region

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Preface

India is undergoing a period of significant transformation driven by a growing population, evolving lifestyles, rapid urbanization, and the escalating impacts of climate change. These dynamic shifts pose new challenges to the national agricultural research system. While ensuring food security was once the primary concern, the focus has now broadened to encompass the provision of nutrient-rich food for improved public health. Fortunately, scientific advancements and emerging technologies are creating new opportunities to address these evolving challenges effectively. The eastern region of India, endowed with rich natural resources and diverse agro-climatic conditions, holds immense potential to strengthen national food security and enhance rural prosperity. Despite its substantial contributions to agriculture, the region continues to grapple with several constraints, including fragmented landholdings, lack of good quality seeds, climatic hazards like flood, drought and terminal heat stress, low mechanization, inadequate power supply, the lowest per capita income in the country, high human and livestock population density, poor-quality feed, and insufficient infrastructure for storage, processing, and marketing. These factors have hindered the adoption of modern farming practices in the region. Addressing these challenges necessitates a holistic and integrated approach, driven by scientific research, technological innovations, and sustainable resource management practices. The ICAR-Research Complex for Eastern Region (ICAR-RCER), Patna, has been at the forefront of this mission, developing and deploying region-specific technologies to enhance agricultural productivity and resilience. This book highlights some of the institute's outstanding technological and policy interventions, including Integrated Farming System models for small and marginal farmers, sustainable intensification of the rice-wheat system, technological solutions for greening rice fallows, horticulture-based multi-tier land use models for hill and plateau regions, solar energy-based farm machinery, innovative resource conservation technologies for vegetable farming, FPO-led technology dissemination models, Nutri-garden concepts, and value chain development for key crops like Makhana. Additionally, the institute has successfully developed 12 multiple stress-tolerant rice varieties, one chickpea variety, 61 high-yielding, nutrient-rich vegetable varieties, two pulse-type faba bean varieties, one Makhana variety, and six high-yielding fruit varieties. These innovations have gained widespread adoption among farmers, covering significant agricultural areas in the eastern region and beyond. This publication, entitled *"Towards Vikshit Bharat@2047: Technological Innovations and Policy Options for the Eastern Region,"* serves as an extensive knowledge repository, providing valuable insights into climate-resilient crop varieties, cutting-edge production and protection techniques, innovative farm machinery, and sustainable strategies for livestock and fisheries management. It also offers policy recommendations to enhance the dissemination of these technologies to end users. Aligned with India's national priorities, the publication emphasizes the promotion of eco-friendly farming practices, efficient utilization of natural resources, crop diversification, and the reduction of greenhouse gas emissions. Additionally, it supports the developmental vision outlined in Viksit Bharat 2047, contributing to the nation's sustainable agricultural growth and resilience.

We hope that this book will serve as a valuable resource for researchers, policymakers, extension personnel, and farmers, guiding them towards a more sustainable and resilient agricultural future in the eastern region and beyond.

Editors



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अध्यक्ष

Dr. Sanjay Kumar FNA, FNASc, FNAASc, FCISI

Chairman

Date: 10/02/2025

Foreword

Agriculture is the bedrock of India's economy, and the Eastern region, with its abundant natural resources and diverse agro-climatic conditions, possesses immense potential to strengthen national food security and drive rural prosperity. Despite its significant contributions to the nation's agricultural output, the region faces persistent challenges, including fragmented landholdings, declining soil health, climate variability, low productivity and income, and inadequate infrastructure for irrigation, post-harvest management, and market access. Addressing these interconnected issues requires a holistic and integrated approach, grounded in scientific advancements, technological innovations, and sustainable resource management.

The ICAR-Research Complex for Eastern Region (ICAR-RCER), Patna, has been instrumental in this endeavour, developing and deploying cutting-edge technologies tailored to the region's specific needs. I am pleased to highlight several impactful technologies and policy options developed by the institute. These include the development and promotion of Integrated Farming System models for small and marginal farmers; sustainable intensification of the rice-wheat system; technological interventions for utilizing rice fallow areas; horticulture-based multi-tier land use models for hill and plateau regions; solar energy-based farm machinery; innovative resource conservation technologies for vegetable farming; FPO-based technology delivery models; value chain development for key crops like Makhana; and the promotion of climate-resilient agriculture through participatory approaches.

The Institute's contributions also extend to the development of improved crop varieties. Impressively, ICAR-RCER has developed 12 multiple stress-tolerant rice varieties, 1 chickpea variety, 61 high-yielding and nutrient-rich vegetable varieties, and 6 high-yielding fruit varieties. These varieties have gained widespread acceptance among farmers, significantly impacting agricultural production across the Eastern region and beyond. These achievements underscore ICAR-RCER's commitment to advancing agricultural productivity and resilience through innovation and farmer-centric research.

This publication, "Towards Viksit Bharat@2047: Technological Innovations and Policy Options for the Eastern Region," serves as a valuable compendium of knowledge. It offers insights into climate-resilient crop varieties, advanced production and protection techniques, innovative farm machinery, sustainable livestock and fisheries management strategies, and policy options for effective technology dissemination to end-users. Furthermore, this publication aligns with India's national priorities, including promoting eco-friendly farming practices, efficient natural resource utilization, crop diversification, greenhouse gas emission reduction, and achieving the developmental goals outlined in Viksit Bharat 2047.

I commend ICAR-RCER, Patna, for their dedication in compiling this invaluable resource. I am confident that this publication will be an essential guide for farmers, researchers, policymakers, and extension personnel, empowering them to make informed decisions and adopt best practices for sustainable agricultural development in the Eastern region.


(Sanjay Kumar)

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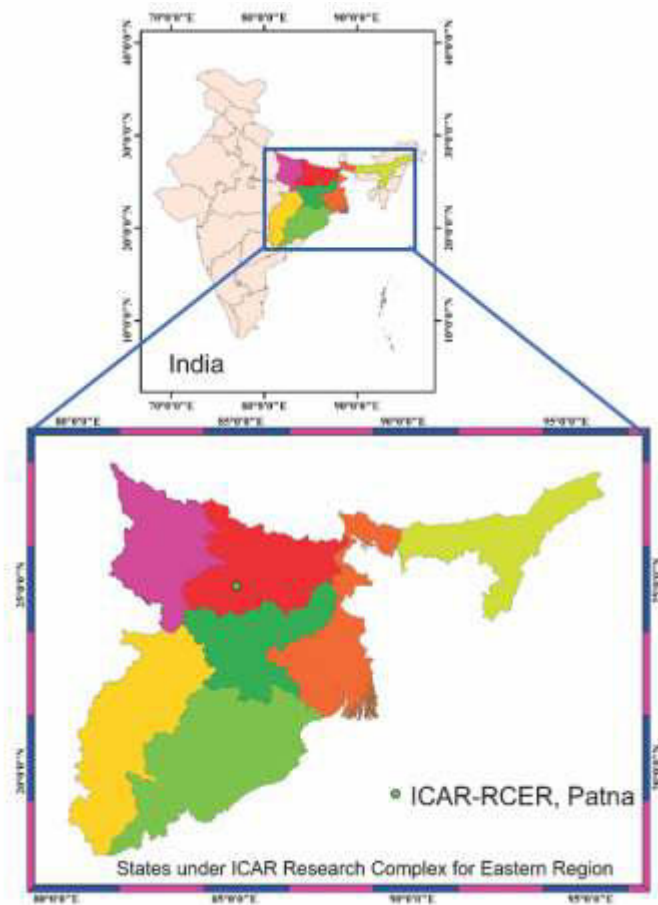
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Introduction

The Eastern region of India is endowed with rich natural resources and diverse agro-climatic conditions, offering immense potential for agriculture, horticulture, livestock rearing, and aquaculture. The region comprises states of Assam, Bihar, Chhattisgarh, Eastern Uttar Pradesh, Jharkhand, Odisha, and West Bengal, is home to approximately 34% of India's population and spans 21.85% of the country's geographical area (Fig. 1).



Location map of ICAR-RCER, Patna

It is endowed with abundant surface and groundwater resources, with rainfall distribution varying across states. As per *Agricultural Statistics at a Glance 2022*, the Eastern region comprises 26.86% (35.06 million hectares) of India's total agricultural land and contributes 27.14% (85.70 million tonnes) to the nation's food grain production. With nearly 82% of the population residing in rural areas and relying on agriculture for their livelihood, the sector remains the backbone of the regional economy. Beyond crop production, the region is also a key contributor to India's livestock and fisheries sectors, accounting for approximately 17.2% of the nation's total milk production and 32.3% of its fish yield. However, agriculture in this region is complex, diverse, and highly risk-prone, with vast rainfed areas facing challenges related to limited

resources, inadequate infrastructure, restricted technology outreach, weak institutional support, and climate-related uncertainties. Horticulture is another important sector providing livelihood to the millions in the region. The agricultural landscape is characterized by small and fragmented landholdings, which significantly hinder the adoption of advanced agricultural technologies. According to the Agricultural Census (2010-11), marginal farms dominate the region, accounting for 91.06% of landholdings in Bihar and 84.95% in Eastern Uttar Pradesh, while small landholdings constitute a considerable proportion in Chhattisgarh (22.23%) and Odisha (19.69%). This fragmented land tenure system imposes significant constraints on mechanization, precision agriculture, and efficient resource management, thereby limiting the scope for technological innovation and productivity improvements.

In addition to land fragmentation, declining soil health and widespread land degradation pose serious threats to agricultural sustainability. Degraded lands, including those affected by coal mining in hilly and plateau regions, and unsustainable farming practices (over exploitation of land and water etc) like rice-wheat system, further exacerbate the challenges of maintaining farm productivity. Climate variability remains a major concern, with the region frequently experiencing extreme weather events such as droughts and floods, which adversely impact crop, livestock, and fishery production. The lack of an extensive and reliable irrigation infrastructure further intensifies the dependency on monsoonal rainfall, increasing the vulnerability of agricultural output to erratic precipitation patterns. Despite receiving approximately 80% of its annual rainfall during the *kharif* season, the region exhibits considerable spatial and temporal variability in precipitation, leading to uncertainties and instability in agricultural yields. Prolonged droughts, particularly during critical crop growth stages, significantly reduce yields, while excessive rainfall events frequently cause waterlogging and flooding, further hindering crop cultivation during the *kharif* season. Bihar for example is clearly divided in two parts, drought prone in southern and floods in northern Bihar, warranting efforts for developing resilient farming practices for transforming rural livelihoods.

The agricultural value chain in Eastern India is also significantly constrained by inadequate infrastructure for post-harvest management, processing, and market linkages, leading to considerable post-harvest losses, particularly in high-value crops such as litchi, mango, and *makhana*. Weak extension mechanisms for technology dissemination further exacerbate these challenges, leaving resource-poor and marginalized farmers with limited access to advanced agricultural practices, mechanization, and essential inputs such as high-quality seeds, fertilizers, and planting materials.

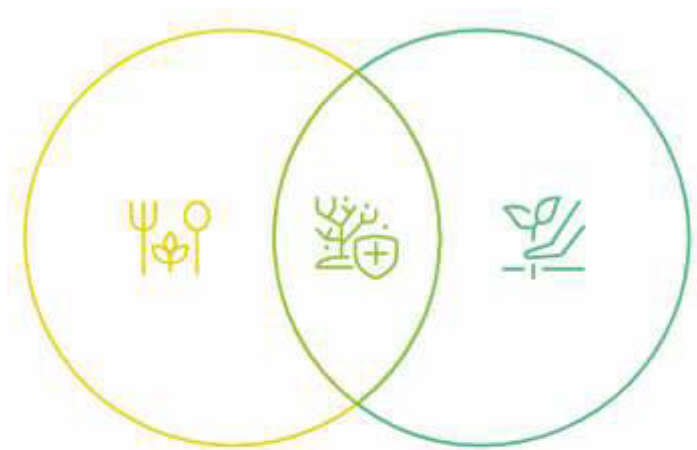
However, the livestock sector, despite a high population density compared to the national average, faces several critical constraints, including poor veterinary health infrastructure, low milk productivity, and inadequate availability of green fodder. A significant proportion of the region's cattle population comprises indigenous and non-descript breeds, underscoring the urgent need for systematic characterization, conservation, and propagation strategies to preserve genetic diversity and enhance productivity. Similarly, the fisheries sector, which holds immense potential due to the region's abundant water resources, remains underutilized due to inefficient supply systems for fish seed, feed, and medicines. The absence of a well-established disease monitoring system and water quality assessment framework further hampers

productivity and sustainability in aquaculture. Despite the availability of approximately 0.4 million hectares of waterlogged land and 8.16 lakh hectares of tanks and ponds, pond-based fish production remains suboptimal, averaging around 3.0 tonnes per hectare per year, well below the region's potential.

Addressing these multifaceted challenges in these regions requires an integrated, holistic and sustainable approach that emphasizes scientific input (water/nutrient/seeds, etc) management, climate-smart agricultural practices, enhanced irrigation infrastructure, and technological innovations in crop, livestock, fisheries sectors and secondary income generating activities. The Eastern region holds immense promise in emerging as the future grain bowl of India, provided a concerted effort is made to bridge technology gaps, improve market infrastructure, and develop resilient agricultural systems. Addressing these challenges is crucial for aligning with India's national priorities, which include reducing greenhouse gas (GHG) emissions, enhancing water and nutrient use efficiencies, increasing the production of oilseeds, millets and pulses, promoting processing and value addition, for achieving the developmental goals outlined in *Viksit Bharat 2047*. ICAR-RCER, Patna, plays a pivotal role in driving sustainable agriculture in the Eastern Region of India through its innovative technology development, validation and dissemination efforts. As a multidisciplinary and multi-commodity institute, it adopts a comprehensive, integrated approach to address diverse agricultural challenges related to water and land resource management, crop production, horticulture, agroforestry, livestock and fisheries management, socio-economic development, policy mechanism for technology delivery and extension services through a program matrix, encouraging collaboration and partnerships with State Agricultural Universities (SAUs), ICAR Institutes, and NGOs. Recognizing the existing gaps in production and productivity across various agricultural enterprises, as well as the potential for enhanced productivity in farming, the ICAR-Research Complex for Eastern Region (ICAR-RCER) has documented the *technologies and policy options generated over the years into a publication* to commemorate its Silver Jubilee year celebration. This comprehensive document serves as a repository of knowledge, offering valuable insights and policy recommendations to empower farmers in the eastern regions of India. This publication also presents a cutting-edge technology basket, featuring climate-resilient varieties of rice, chickpea, vegetables, and fruits, along with advanced production and protection techniques and state-of-the-art farm machineries. Technologies like sustainable intensification of rice –wheat system, greening rice fallow areas, climate resilient rice and vegetable varieties are suitable for entire Eastern Region. Whereas, technologies like agroforestry approach for rehabilitation of coalmine affected areas and horti-based multitier land use models are mostly suitable for coal mine affected areas and hill and plateau region, respectively. The innovative extension cum policy options like PRAYAS (Participatory Research Application for Year-round income and agricultural Sustainability) and ZHZTG (Zero-hunger Zero technology gap village) village are applicable to entire eastern India dominated by small and marginal farmers and weaker sections.

Chapter-1 Technologies

Crop Production and Protection



Sustainable Intensification of Rice-Fallow System of Eastern India

Period of development: 2016 - 2023

Developers :

Rakesh Kumar, JS Mishra, BK Jha, SK Naik, SS Mali, S Mondal, AK Biswas, Rachana Dubey, Sanjeev Kumar, Anup Das, BP Bhatt, KK Rao, SK Singh, Santosh Kumar, JS Choudhary

Background:

Rice-fallow, a rainfed mono-crop production system practiced over 22.3 M ha in South Asia, is gaining greater attention in the recent times for cropping intensification. Main challenges for sustainable intensification of rice-fallow systems are lack of irrigation facility, preponderance of long-duration rice varieties which delay the planting of succeeding winter crops, low residual soil moisture and poor-fiscal status of farmers. Rice-fallow areas of eastern India have the potential for crop intensification by inclusion of a second crop after rice through strategic crop management. Choices of the suitable winter crops are decisive, largely depend on adaptive nature of the crops to biotic and abiotic stresses. Grain pulses (e.g., lathyrus, chickpea, lentil) and oilseeds (safflower, mustard, linseed) have been identified and proposed as potential post-rainy crops for improving the productivity of rice-fallow production system in eastern India. Greening rice fallow areas with appropriate technological interventions, reducing C-footprints and improving energy use efficiency in rice-fallows of eastern India is also a great challenge.

Description of the technology:

Experiment was conducted for 05 consecutive years (2016-2020) with an aim to design most carbon-cum-energy efficient, cleaner/safer, and eco-friendly production systems for rice-fallows in eastern India. Split-plot experiment had crop establishment-cum-residue management treatments in main-plots and post-rainy/winter season crops in sub-plots. Production systems selected for analysis included 03-crop establishment methods [(1) zero-till-direct-seeded rice (ZTDSR), (2) conventional-till direct-seeded rice (CTDSR), and (3) transplanted puddled rice (TPR)], and two residue management practices [(1) with residue, (ii) without residue) in combination with five potential winter season crops i.e. Chickpea, lentil, safflower, linseed, and mustard. Short/medium duration rice varieties (115-120 days: Naveen/Swarna Shreya/Lalit) in *kharif* followed by *rabi* crops i.e., chickpea, lentil, and safflower have been identified as a potential cropping system. Crop productivity of ZT/CTDSR was less (25-30%) than TPR during *kharif* but yield of winter crops were markedly higher (16-30%) in ZT/CTDSR, thereby improved system productivity. ZTDSR increased the crop yields of chickpea by 31%, lentil by 34%, safflower by 50%, linseed by 19%, mustard by 15% as compared to TPR production system. Increase of 4.17–5.80, 0.27–4.07, 1.91–3.32, 0.85–1.83 and 2.04–3.16 Mg REY ha⁻¹ noted with inclusion of chickpea, lentil, safflower, linseed and mustard in system mode. Rice-chickpea, rice-lentil and rice-safflower rotations led to higher economic returns (14.3%), reduced energy use (23.3%) and lower emission of GHGs (20-25%). Soil Crack volume was markedly higher (2.6-3.3 times) in TPR production system. More diversity of earthworms was noted with CA and *E. Fetida* was the most dominating *sp.*

Commercial potential:

The technology can be offered through consultancy services, licensed, or outsourced to the State Agricultural Department, Private Sector & Agri-Entrepreneurs, Development agencies, RKVY, NGOs and farmers' groups.



Experimental field of conservation agricultural practices under rice fallow system

Impact:

Short/medium duration rice varieties (115-120 days: Naveen/Swarna Shreya/Lalit) in kharif followed by *rabi* crops i.e., chickpea, lentil, and safflower have been identified as a potential cropping system. ZTDSR increased the crop yields of chickpea by 31%, lentil by 34%, safflower by 50%, linseed by 19%, mustard by 15% as compared to TPR production system.

Agro-eco region suitability:

Rice Fallow areas of Eastern Indian States

Reference:

Kumar Rakesh, Mishra JS, Mali SS, Mondal S, Meena RS, Lal R, Jha BK, Naik SK, Biswas AK, Hans H, Sundaram PK, Choudhary AK, Monobrullah M, Kumar S, Kumar S, Raman RK, Bhatt BP, Kumar U. 2022a. Comprehensive environmental impact assessment for designing carbon-cum-energy efficient, cleaner, and eco-friendly production system for rice-fallow agroecosystems of South Asia. *Journal of Cleaner Production* 331:129973. <https://doi.org/10.1016/j.jclepro.2021.129973>

Impact:

The success of RCTs in Bihar led to a ₹ 23.06 crore NABARD-funded project and a ₹ 60 crore Climate Resilient Agriculture Program (2019–24) by the Bihar government, covering all 38 districts. ICAR-RCER Patna developed 10 Climate-Smart Villages in Gaya and Buxar, implementing RCT-based cropping on more than 10,000 ha.

Agro-ecoregions suitability:

Irrigated rice-wheat ecosystem of Bihar, Uttar Pradesh, Jharkhand, Chhattisgarh, West Bengal, Odisha

Reference:

Kumar Rakesh, Sarkar B, Bhatt BP, Mali SS, Mondal S Mishra JS, Jat RK, Meena RS, Anurag AP, Raman RK. 2021. Comparative assessment of energy flow, carbon auditing and eco-efficiency of diverse tillage systems for cleaner and sustainable crop production in eastern India. *Journal of Cleaner Production* 293:126162. <https://doi.org/10.1016/j.jclepro.2021.126162>

Improved Agro-techniques for Enhancing the Productivity of Millets in Eastern India

Period of development: 2020 - 2024

Developers:

Rakesh Kumar, JS Mishra, BP Bhatt, S Mondal

Background:

Growing of nutri-cereals/millets is an alternative approach for realizing & sustaining the crop productivity. Millets are highly nutritious, resilient to harsh growing conditions and require minimal input, thus, could play a vital role for food and nutritional security in climate change scenario. Diversification of the existing production system through inclusion of nutri-cereals/millets help to improve socio-economic situation. Thus, there is an urgent need to standardize agro-techniques of nutri-cereals for improving the system productivity in eastern India & accelerates its present form from of cultivation i.e. subsistence farming to income generation-oriented farming.

Description of the technology:

A long-term field experiment was conducted during *kharif* 2020 at ICAR Patna with an objective to standardize agro-techniques of nutri-cereals for enhancing system productivity. During 1st/2nd year, 7-nutri-cereals including [(Jowar: CSV 15) & Bajra: Proagro 9001)] & 5-minor nutri-cereals [(Ragi: RAU 8), Barnyard millet: VL 207), Foxtail millet: Rajendra Kauni), Proso-millet: TNAU 202) and Kodo-millet: JK 41)] were grown in 3-different planting window (starting with onset of monsoon and later at 10-days intervals). Among tested cultivars of Bajra, maximum grain yield was recorded with Proagro 9001 (2.98 t/ha). Thus, bajra hybrid Proagro 9001 may be promoted for commercial cultivation at wider area of rainfed production system. Similarly, among the tested cultivars of Ragi, the maximum grain yield was recorded by RAU 8 (2.10 t/ha). Thus, ragi cv. RAU 8 may be promoted at wider scale in rainfed system with improved production technologies. Among the cultivars, maximum grain yield was recorded by Barnyard cv. DHMB 93-3 (1.70 t/ha). Thus, barnyard cv. DHMB 93-3 may be grown at wider scale along with 100% fertility levels to achieve better the crop yields under rainfed production system. Application of atrazine@0.5 kg/ha (PE) *fb* 1 HW (30 DAS) had significantly higher yields of Bajra (3.08 t/ha, Ragi (2.29 t/ha) and Sawa (1.61 t/ha) but at par with 2-hand weeding (25 & 45 DAS). Amongst nutrient management, application of 100% RDN was significantly higher yield of Bajra (2.83 t/ha), Ragi (2.25 t/ha) & Sawa (1.54 t/ha) at par with 75% RDN (IN) & 25% RDN (FYM).

Commercial potential:

The technology can be offered through consultancy services or outsourced to the State Agricultural Department, Development agencies like Millets Mission, RKVY, NGOs, and farmers' groups.



Field view of different millets production

Impact:

Under Bihar's Climate Resilient Agriculture (CRA) Program, millet-based systems were promoted across 38 districts with a ₹ 60 crore budget (2019–24). ICAR-RCER Patna developed 10 Climate-Resilient Villages in Gaya and Buxar, covering more than 1,000 ha in drought-prone areas.

Agro-ecoregions suitability:

Rainfed and water scared Areas

Reference:

Kumar Rakesh, Makarana G, Mishra JS, Bhatt BP. 2022. Response of sorghum (*Sorghum bicolor*) cultivars to nitrogen in non-traditional areas of Bihar. *Indian Journal of Agricultural Sciences* 92(9):1076–1079. <https://doi.org/10.56093/ijas.v92i8.109875>

Innovative Millet-Based Climate Resilient Cropping System for Eastern India

Period of development: 2016 - 2020

Developers:

Rakesh Kumar, JS Mishra, RS Pan, BP Bhatt, S Mondal, K Saurabh, R Shinde

Background:

Change in climate impose for identification of an eco-friendly production system that is more productive-cum-energy efficient & environmentally safer. Four-year study was conducted (2016-2019) to diversify dominant rice-wheat system through climate resilient cropping in eastern India. Ten diverse cropping system comprised of transplanted puddle rice-wheat-mung, conventional till-direct seeded rice (CTDSR)-wheat-mung, soybean-maize, CTDSR-mustard-urd, foxtail millet-lentil-fallow, pearl millet-chickpea-fallow, finger millet-toria-fallow, sorghum (grain)-chickpea -fallow, maize cob-pigeon pea & sorghum (fodder)-mustard-urd.

Description of the technology:

Ten millet based diverse cropping systems were evaluated for their adoption in eastern India. Millet-based systems reduced input cost (43-69%) and sometimes doubled the farmers' income. Most productive cropping system in terms of system rice equivalent yield (SREY) was noted with maize cob-pigeonpea (ZT) (22.3 t/ha) followed by sorghum fodder-mustard (ZT)-urd bean (ZT) system (18.5 t/ha). In terms of economics, most profitable cropping system was maize cob-pigeon pea (Rs.255272/ha) followed by sorghum fodder-mustard-urd bean system (Rs.178059/ha). Millet-based system helps in reducing C-input (172%) and improves energy ratio (61%) as compared to cereal-based production system. Inclusion of millets in the existing production system improved energy productivity, productivity, economic efficiency on diverse agro-ecological zone of eastern India.

Commercial potential:

The technology can be offered through consultancy services or outsourced to the State Agricultural Department, Development agencies like Millets Mission, RKVY, NGOs, and farmers' groups.

Impact:

Under CRA Program (GoB), ICAR RCER Patna has developed 10-Climate Smart Village (CSV) in Gaya (05) and Buxar (05) and covered more than 500 ha area with millet-based production system during last three years in drought prone district of Bihar. Thus, inclusion of millets in existing production system (rice-wheat) improved energy productivity and system productivity in diverse agro-ecological zone of eastern India.



Millet-Based Climate Resilient Cropping System strategies



Millet-Based Climate Resilient Cropping System

Agro-ecoregions suitability:

Rainfed ecosystem of Eastern states

Reference:

Kumar Rakesh, Mishra JS, Mondal S, Meena RS, Sundaram PK, Bhatt BP, Pan RS, Lal R, Saurabh K, Chandra N, Samal SK, Hans H, Raman RK. 2021. Designing an ecofriendly and carbon-cum-energy efficient production system for the diverse agroecosystem of South Asia. Energy 214:118860. <https://doi.org/10.1016/j.energy.2020.118860>

Interspecific Grafting in Solanaceous Vegetables for Bacterial Wilt Management

Period of development: 2019 - 2024

Developers:

P Bhavana, AK Singh, S Maurya, AK Jha, JS Choudhary

Background:

Bacterial wilt, caused by *Ralstonia solanacearum* (Yabuuchi), poses a severe threat to tomato cultivation, leading to significant yield losses, particularly during the rainy season. This soil-borne disease results in yield reductions ranging from 11.7% to 96.7%. Chemical control methods and breeding for resistance often provide neither sustainable nor immediate solutions. An effective and immediate alternative involves grafting resistant varieties - whether newly developed or existing - onto high-yielding but susceptible cultivars, offering a viable solution to mitigate the impact of bacterial wilt.

Description of the technology:

Bacterial wilt-resistant germplasm of brinjal *viz.*, HAB-901, HAB-921, HAB-928, and HAB-930 are identified to be used as rootstock for grafting onto the tomato hybrid *Swarna Baibhav*, which is otherwise susceptible to wilt. The seeds of both the scion (tomato) and rootstock (brinjal) are sown in a peat moss mixture during the last week of June. Grafting is carried out once the seedlings reached the four to five-leaf stage using two methods: tube grafting and wedge grafting. In tube grafting, both the scion and rootstock stems are cut at 30° angles. The diameter of the rootstock is matched to that of the scion. A latex tube, also cut at a 30° angle, is slid over the scion, ensuring both cut angles were aligned. The scion, fitted with the latex tube, is then slid onto the rootstock seedling, and the cut surfaces were gently pressed together to ensure full contact. The tube remained on the seedling until it naturally hardened, split, and fell away.

In wedge grafting, both the rootstock and scion are cut into a “V” shape allowing each to fit into the other. The graft union is secured using a plastic clip. After grafting, the seedlings are immediately placed in a shaded chamber for 4-5 days, then moved to a screen house for another five days. They are gradually exposed to sunlight for hardening over the course of the following five days.

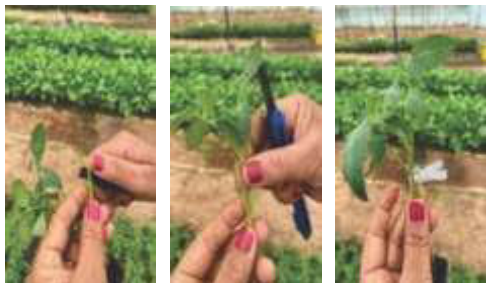
Commercial potential:

The technology has strong commercialization potential through private nurseries, FPOs, and start-ups. Three MoUs were signed with Maitri Enterprises, Ichak Green Agro Producer Company Ltd and the Agri Entrepreneur Growth Foundation for commercialization (Rs 30,000/-). In the last three years, 75,000 grafted plants were sold to farmers in Jharkhand, Odisha, West Bengal, and Bihar, generating Rs 8,00,000/-.

Impact:

The grafting technology significantly enhanced disease resistance in tomato plants. Grafting onto resistant rootstocks resulted in 90-95% survival rates. The average yield of

grafted tomato is 127.7 t/ha, which is 2.17 times higher than non-grafted plants. Additionally, grafting provided net returns of¹ 14,39,000/ha, with a B:C ratio of 1:2.29.



Different stages of wedge grafting in tomato



Grafted tomato on bacterial wilt resistant rootstock of brinjal

Agro-ecoregions suitability:

Eastern Plateau and Hill Region (EPHR) during the rainy season.

References:

Bhavana P, Singh AK. 2017. Effect of grafting in tomato to control bacterial wilt (*Ralstonia solanacearum* Yubuuchi). *Vegetable Science* 44(2): 110-113.

Package of Practices for Upland Field Water Spinach (*Ipomoea aquatica* Forsk) Production in Bihar

Period of development: 2020 - 2024

Developers:

Kumari Shubha, A Mukherjee, AK Choudhary, Sanjeev Kumar, Anup Das

Background:

Water spinach is traditionally grown in waterlogged areas of Bihar, but this method presents several challenges. Managing plant protection measures and harvesting in such conditions is labor-intensive and difficult. Additionally, waterlogged fields are prone to contamination by pollutants, which can pose serious health risks to consumers. To overcome these challenges, an attempt was made to cultivate water spinach under upland field conditions in Bihar. The results were highly promising, demonstrating that the crop can be successfully grown without requiring waterlogged conditions. This approach simplifies the cultivation process, reduces health risks associated with water pollution, and minimizes the need for labor-intensive practices.

Description of the technology :

Shifting to upland field cultivation provides a cleaner, safer, and more sustainable alternative, enabling year-round production with multiple harvests. This method minimizes reliance on submerged conditions, reduces contamination risks, and simplifies crop management. Balanced nutrient application is essential for optimal growth. Before transplanting, 40 t/ha of manure should be incorporated into the soil, followed by a basal dose of NPK (60:40:40 kg/ha). To support continuous growth, nitrogen is applied in three top dressings at 10-day intervals (30, 15 and 15 kg/ha). In multiple-cutting systems, additional nitrogen application after each harvest promotes vigorous regrowth, but excessive nitrogen should be avoided to prevent nitrate accumulation in leaves. Water spinach should be harvested before flowering, typically 50–60 days after sowing or 35–45 days after transplanting. Shoots are cut 5 cm above the ground to allow regrowth from the nodes, ensuring multiple harvests. This method enables at least 2-3 cuttings, yielding 32–35 t/ha of fresh greens. Proper post-harvest handling is crucial for maintaining freshness. For local markets, water spinach is commonly sold in 500 g bunches at ₹ 40/kg, while for long-distance transport and supermarket supply, bundles are packed in bamboo crates with layers of crushed ice to extend shelf life. By adopting upland cultivation, farmers can achieve higher productivity, improved food safety, and increased profitability, making water spinach farming a more viable and sustainable option.

Commercial potential:

The technology can be offered as a package of practices (PoPs) through consultancy services for upland growers, State Agricultural Departments, development agencies, FPOs, NGOs, and extension service providers.

Impact:

Technology has revolutionized water spinach farming, making it more productive, profitable, and sustainable. The shift to upland cultivation ensures higher yields (32–35 t/ha), cleaner produce, and year-round harvests.

Agro-eco region suitability:

Small and Marginal water spinach upland grower of Bihar and adjoining states.



Growth and Phenological Stages of Water Spinach Under Seasonal Variations in upland ecology

Reference:

Newsletter, ICAR Research Complex for Eastern Region, Patna Jan Aug (2023).

Rice-Legume System for Enhancing Productivity of Rainfed Uplands

Period of development: 2018 - 2020

Developer:

RS Pan

Background:

Low productivity in rainfed uplands is primarily caused by limited irrigation, erratic rainfall, poor soil fertility, and climatic variability. In such conditions, crop diversification becomes essential for building climate resilience. By cultivating a variety of crops suited to diverse climatic conditions, farmers can reduce risks associated with crop failure and improve overall productivity. Diversified farming not only enhances soil health and fertility but also helps to mitigate the impacts of unpredictable weather patterns, ensuring more stable incomes and greater food security in the face of changing climates.

Description of the technology:

This technology integrates legumes, specifically vegetable soybean, into rice-based cropping systems to create a sustainable farming model aimed at improving soil health, enhancing productivity, and boosting farmers' income in water-scarce and marginal soils. By incorporating soybean into traditional rice fields, it not only diversifies the cropping system but also promotes nitrogen fixation, which naturally enriches the soil and reduces dependency on chemical fertilizers. This innovative approach enhances the overall productivity of rainfed uplands, where conventional farming practices often face challenges due to limited water resources and poor soil quality. One of the key benefits of this system is the flexibility it offers in planting patterns. For instance, planting 6 rows of rice alongside 6 rows of soybean achieves a rice-equivalent yield of 6.09 t/ha, providing a viable solution for farmers to optimize their land use. When compared to traditional monoculture farming, sole soybean yields can reach up to 9.96 t/ha, while sole rice yields are lower at 4.10 t/ha. The technology also offers variations in treatment to refine planting patterns, enabling farmers to choose the most efficient configurations for maximizing both crop yield and soil health. This integrated approach holds great promise for improving sustainable agricultural practices in resource-limited



Rice-legume system for enhancing productivity of rainfed uplands

Commercial potential:

The technology has large scale adoption and commercial potential through FPOs and inclusion in government programs on building climate resilience.

Agro-ecoregions suitability:

Suitable for the rainfed uplands of Eastern Plateau and Hill Region of India.

Impact:

Significant improvement in rice-equivalent yields from 2-3 t/ha to 9.96 t/ha. System fosters long-term soil health by promoting natural nitrogen fixation, enhancing soil fertility, and reducing the need for chemical inputs.

Rejuvenation of Unproductive Mango Plants

Period of development: 2005 - 2010

Developers:

Bikash Das, Vishal Nath, Mathura Rai

Background:

Mango orchards in the eastern region are dominated by aged and unproductive trees, leading to significantly low fruit yield. Over time, these trees experience a decline in vigour, reduced flowering, and poor fruiting due to factors such as overcrowding, nutrient depletion, and lack of proper canopy management. This stagnation in productivity affects the profitability of mango growers and restricts the potential of mango cultivation in the region. Rejuvenation techniques are essential to restore the health and productivity of these orchards, ensuring better yield and improved quality of mangoes.

Description of the technology:

Rejuvenation of unproductive mango plants is a systematic technique aimed at restoring the productivity of old and senile orchards, which are otherwise characterized by long, unfruitful branches, overcrowded canopies, and poor sunlight penetration. These structural issues lead to intense competition among branches for light, restricting fruiting to the outer periphery and significantly reducing overall yield. Farmers often consider removing such trees and replanting new orchards, but this approach delays fruit production by 6 to 7 years. In contrast, the rejuvenation technique provides a faster and more cost-effective alternative, enabling trees to bear fruit within three years while achieving optimum productivity in about six years. This method ensures a substantial reduction in the unproductive phase of mango orchards, offering both economic and agronomic advantages to farmers.

The rejuvenation process involves a well-defined set of steps to systematically revitalize old trees. It begins with the selection and sharp pruning of tertiary limbs during December, followed by the removal of pruned wood from the orchard. To protect the cut ends from infection, appropriate pasting is applied, and the trunk is painted to prevent latex oozing. A ring is prepared around the trunk for efficient watering and fertilizer application, ensuring adequate nutrient uptake. As new sprouts emerge, only 10-12 well-positioned ones are selected, while the rest are removed periodically. Over time, these sprouts are managed to develop a well-balanced canopy, with 4-5 shoots per branch maintained in later years. In cases where trees produce inferior fruit, grafting with scions of improved cultivars is recommended to enhance fruit quality. Additional care includes trunk borer management, application of fertilizers at the rate of 800:300:1000 g NPK along with 50 kg of FYM per plant, and intercropping during the rejuvenation period to maximize land utilization. By following these steps, the restored trees begin fruiting within three years, with optimal productivity achieved in six years, a significant improvement over the 15-year timeline required for newly planted mango orchards. A total of Rs. 2000/- per plant will be required in a period of three years for rejuvenation of plants by adoption of this technology.



Rejuvenation
pruning



Profuse
sprouting



Maintenance of
shoot



Build up of plant
canopy



Heavy bearing after
3 years

Stages in rejuvenation of old mango Orchards

Commercial potential:

The technology has wide scale commercialization potential through National Horticultural Boards, NABARD and NGOs working on the aspects of mango production.

Impact:

Significantly enhances orchard productivity, reducing the time to fruiting from 6-7 years (in case of replanting) to just three years. Improves yield, fruit quality, and orchard longevity while minimizing input costs for farmers. Ensures better resource utilization through intercropping.

Agro-ecoregions suitability :

The technology can be adopted for rejuvenation of old and unproductive mango plants throughout Eastern India

Transforming Rice Straw into Eco-Friendly Growing Medium for Microgreens

Period of Development: 2022 -2023

Developers:

Kirti Saurabh, Himadri Shekhar Roy, Kumari Shubha, Prem K Sundaram, Ved Prakash, TK Koley, Anirban Mukherjee, Bikash Sarkar, AK Singh, Anup Das, Ashutosh Upadhyaya, Pawan Jeet, Sanjeev Kumar and Ravi Ranjan Singh

Background:

Rice straw burning is a major environmental issue in India, contributing significantly to air pollution and greenhouse gas emissions. Traditional disposal methods for rice straw are unsustainable, leading to severe ecological consequences. This study explores an innovative approach to repurpose rice straw as a sustainable growing medium for microgreens, addressing both agricultural waste management and substrate sustainability. Converting rice straw into a viable alternative to conventional substrates like cocopeat and vermiculite not only reduces environmental pollution but also offers an affordable and effective solution for microgreen cultivation.

Description of the technology:

This study focuses on repurposing rice straw as a sustainable growing medium for microgreens through an optimized NaOH pretreatment process. Rice straw was collected, air-dried, and chopped into 2–4 cm pieces before being treated with varying concentrations of NaOH (1%-7%) for different durations (10–30 minutes). The optimal treatment—1% NaOH for 30 minutes followed by dilute acid and distilled water wash—produced a soft, pH-neutralized pulp, which was then dried at 65°C for two days to prepare it for use. Pretreatment significantly improved the straw's physical and chemical properties, reducing ash content from 20.05% to 7.10%-11.10% and enhancing water holding capacity (673%), making it competitive with cocopeat (891%) and superior to vermiculite (389%). Microgreens of Amaranthus, cabbage, and cauliflower grown on treated rice straw exhibited healthy growth, with cabbage achieving the highest plant length (6.2 cm) and fresh weight (59.83 mg/plant). While vermiculite provided higher micronutrient availability, rice straw provided better plant growth and biomass production. With further nutrient fortification, pretreated rice straw has the potential to serve as an eco-friendly, cost-effective alternative to conventional substrates, promoting sustainable microgreen cultivation while reducing environmental pollution.



Process and Materials for Transforming Rice Straw into an Eco-Friendly Growing Medium for Microgreens

Commercial potential:

The technology can be licensed or outsourced to horticulture and agribusiness development agencies, sustainable agriculture NGOs, hydroponic and vertical farming entrepreneurs, and researchers in soil-less cultivation and organic farming.

Impact:

A cost-effective, biodegradable alternative to traditional growing media, this innovation enhances sustainability and affordability in commercial microgreen cultivation across the Eastern region of India.

Agro-ecoregions suitability:

Middle & Lower Gangetic Plains; Eastern Plateau & Hills; Assam & Northeastern Hills

Eco-Friendly Plantable Seedling Pot or Decorative Pot from Agricultural Residue

Period of development:2023 - 2024

Developers:

Kirti Saurabh, Bikash Sarkar, PK Sundaram, Kumari Shubha, RK Singh, Anup Das, TK Koley, Pawan Jeet, AK Singh, Ashutosh Upadhyaya

Background:

The widespread use of non-biodegradable plastic pots in horticulture contributes significantly to environmental pollution, as they are difficult to recycle and accumulate in landfills, contaminating soil and water with microplastics. Furthermore, plastic pots hinder root aeration, causing root damage during transplantation and increasing plant disease susceptibility. Additionally, burning rice straw, a major agricultural residue, releases harmful greenhouse gases and pollutes the environment. To address these issues, an eco-friendly biodegradable plantable pot made from rice straw and natural binders has been developed, offering a sustainable solution that reduces plastic waste, enhances plant growth, and repurposes agricultural by-products.

Description of the technology:

The eco-friendly biodegradable plantable pot is made from a blend of 11-23 wt% rice straw, 3-7 wt% natural binders like guar gum, and 74-82 wt% water. This innovative pot offers several advantages: it decomposes naturally within 3-5 months, enriching the soil; its porous structure promotes root growth and reduces transplantation shock; it balances water absorption and drainage, providing a favourable microclimate for plant growth; it helps reduce agricultural waste by utilizing rice straw, thus preventing stubble burning and air pollution; and it is cost-effective, making it suitable for large-scale commercial use. The manufacturing process involves grinding rice straw, mixing it with binders and water, moulding it, and drying it to achieve the necessary strength and durability. Additionally, these pots can serve as decorative items for extended periods.



Eco-friendly plantable seedling pot or decorative pot from agricultural residue

Commercial Potential:

The technology can be licensed/ outsourced to development agencies, Agricultural entrepreneurs, Nurseries and Agro-based Industries & Entrepreneurs.

Impact:

The development of eco-friendly plantable seedling pots and decorative pots, Biodegradable alternatives have a transformative impact on sustainable agriculture, waste management, and green entrepreneurship.

Agro-ecoregions Suitability:

Pan India

Conceptual Model for Integrated Organic Farming in an Acre Farm Plot

Period of development: 2010 - 2012

Developer:

Ashutosh Upadhyaya

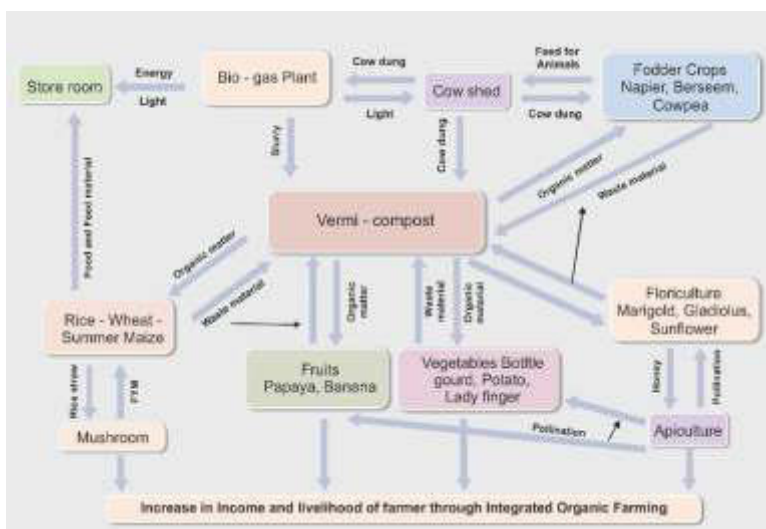
Background:

In order to maintain soil health, reduce environmental and water pollution, and increase income and livelihood of poor farmer of our country on sustainable basis, an acre integrated organic farming model can be proposed. In one-acre land, various components like Livestock, Bio-gas plant, Vermi-compost, Cereal crops, Fodder crops, Fruit crops, Vegetables, Floriculture, Mushroom, Apiculture, and Azolla etc. can be allocated in such a way that by product of one component is input to other component and there is perfect integration of all the proposed components.

Description of the technology:

In the proposed one-acre integrated organic farming model it may be observed that two cows producing 18.25 T cowdung and 5110 L urine annually along with crop residue and organic waste from farm is sufficient to prepare 9.75 T vermi-compost required to meet the demand of cereals, fodder, fruits, vegetables and flowers planted. In addition to this apiculture and mushroom cultivation are promising enterprises to improve income and livelihood of farmers through integrated organic farming. It may also be observed that by adoption of integrated organic farming not only sustainable yield with high nutritional value is achieved but also soil, livestock and human health is improved, resources are reused and recycled and ultimately wastage will be minimized.

The concept and methodology of conceptual model is based on following flow chart



Framework of Conceptual Model for Integrated Organic Farming in an Acre farm plot

The Conceptual Model for Integrated Organic Farming (IOF) has a good potential for higher yield and productivity by efficiently utilizing resources, as the by-products of one component serve as inputs for another, minimizing wastage and enhancing overall system efficiency. The synergistic nature of this model leads to significant savings in water, labor, time, and energy, ensuring their optimal utilization. Additionally, it has capacity to promote soil conservation and enhances long-term soil fertility, making it a sustainable approach for farmers. Its efficiency is remarkable, as minimal losses occur due to resource integration, making it a cost-effective solution. Moreover, the system's effectiveness and productivity contribute to a higher Benefit-Cost (B:C) ratio, ensuring economic sustainability while maintaining soil health for future generations.

Model components	Area (m ²)	Input/Vermi-compost required (T/year)	Other outputs produced /year	Output produced (kg) from allocated area
Livestock (2 cows)	100	Dry fodder - 2.2 T Green fodder- 14.6 T Concentrate - 4.4 T	Cow dung - 18.25 T Cow urine - 5110 L Cow milk - 4350 L	-
Bio-gas plant	50	Cow dung -18.25 T	Bio-gas slurry-10 T	-
Vermi-compost	50	Bio-gas slurry-10 T Crop residue - 10 T Earth worms 75000	Vermi-compost- 9.75 T	-
Cereal crops (Rice- Wheat-Summer Maize)	1250	Vermi-compost - 2.5 T	Rice straw-750 kg Wheat straw-575 kg Maize fodder- 875 kg Dry fodder - 2.2 T	Rice-500 kg Wheat-375 kg Maize-562 kg Total grains -1.44 T
Fodder crops (Napier grass- Berseem-Cowpea)	1000	Vermi-compost - 1 T	-	Napier grass-10 T Berseem - 3.5 T Cowpea - 1.5 T Total - 15 T
Fruit crops (Papaya, Banana)	500	Vermi-compost-2.275 T	-	Papaya - 4875 kg Banana - 975 kg
Vegetables (Bottle gourd- Potato- Lady finger)	750	Vermi-compost- 3.375 T	-	Bottle gourd-550kg Potato - 1180 kg Lady finger-800 kg
Floriculture (Marigold, Gladiolus)	100	Vermi-compost - 600 kg	-	Sufficient for apiculture
Mushroom	75	Paddy waste - 750 Kg		Mushroom - 750 kg
Azolla	25	Tank	Supplements 3.5% N	5-15% increase in yield of Rice

Details of Input and output components in One Acre Integrated Farming model

Agro-ecoregions Suitability:

Irrigated Ecosystem of Eastern India

References:

Upadhyaya A. 2018. Waste management for sustainable development-An Integrated Organic Farming Model. Proceedings of National Seminar on Waste Management for Sustainable Development. Organized by The Institution of Engineers (India) Bihar State Centre, Patna on June 03, 2018, pp. 1-10.

Air Pollution Tolerance Index and Anticipated Performance Index in Trees and Crops Across the Eastern Gangetic Plains of India

Period of development: 2021 - 2022

Developers:

Rachana Dubey and AK Choudhary

Background:

India ranks as the third most polluted country globally, with the highest annual average PM 2.5 exposure, severely impacting crops and trees. Particulate matter accumulates on leaves, reducing photosynthesis, causing leaf injury, stomatal damage, early senescence, and lower membrane permeability. Air pollution also affects chlorophyll content, relative water content (RWC), ascorbic acid, and pH, though findings remain inconclusive. Major pollution sources include vehicle emissions, industrial discharge, construction, waste burning, and agricultural residue burning. Trees and crops act as biofilters by absorbing pollutants. The Air Pollution Tolerance Index (APTI) and Anticipated Performance Index (API) help identify species tolerant to air pollution, aiding in the selection of crops and trees that minimize yield loss and reduce pollution. This study assesses the tolerance and performance of tree and crop species during winter in Patna district, Bihar, using APTI/API methods.

Description of the technology:

The developed Air pollution tolerance index value showed that *Ficus religiosa* (20.99 ± 0.22), *Zea mays* (9.81 ± 0.14), *Carthamus tinctorius* (10.19 ± 0.05) and *Cajanus cajan* (12.53 ± 0.29) were more tolerant compared to the other crops. Anticipated performance index value showed that trees like *F. religiosa*, *Azadirachta indica* and *Mangifera indica* and crops like *Cajanus cajan*, *Zea mays* and *Triticum aestivum* were most suitable under air pollution condition.

Impact:

APTI and API values serve as selection tools, where we can choose higher value tree and crop species as bio-accumulators and lower value species as sensitive ones. This study is a step towards assessing air pollution tolerance in eastern plains, which will help in better urban planning and management.

Gradation of crop/tree species based on APTI and other biological and social characteristics for API development

Plant spp.	AP TI	Morphological			Laminar structure			Eco nom ic use	Total	Score (%)	API grade	Categor y
		Pla nt heig ht	cano py type	pl an t type	size	text ure	hard ness					
Trees												
<i>Mangifera indica</i>	+++ ++	++	++	++	+	-	+	++	15	93.75	7	Best

<i>Azadiracht a indica</i>	+++ ++	++	++	++	+	-	+	++	15	93.75	7	Best
<i>Ficus religiosa</i>	+++ ++	+++	++	++	+	-	-	++	15	93.75	7	Best
Crops												
<i>Triticum aestivum</i>	++	++	+	+	++	+	-	++	12	75	5	very Good
<i>Zea mays</i>	+++	+++	+	+	++	+	-	+++	14	87.5	6	Excellent
<i>Cajanus cajan</i>	+++ ++	++	+	++	++	+	-	++	15	93.75	7	Best
<i>Carthamu s tintorius</i>	+++ +	++	+	+	++	++	+	+++	15	93.75	7	Best

Agro-ecoregions suitability:

Eastern Region of India

Reference:

Dubey Rachana, Choudhary Arbind Kumar, Singh Shreetu, Ajay Anurag, Kumar Santosh, Kumar Rakesh, Mondal Surajit, Singh.Vivek Kumar. 2023. Assessing the impact of air pollution of trees and crops in Eastern Gangetic plains of India. *Current Science*, 124 (8): 956.

Selecting Wheat Cultivars for Heat and Drought Stress Adaptation in the Middle Gangetic Plains

Period of development: 2019 - 2023

Developers:

Rachana Dubey, Santosh Kumar, Ved Prakash, SK Dwivedi, Md Monobrullah

Background:

The Eastern Indo-Gangetic Plains face rising temperatures, frequent droughts, and heat waves, threatening wheat production. Erratic rainfall and elevated temperatures, especially during grain filling, reduce yields. Water scarcity in irrigated systems is worsening, while heat stress increases plant water demand. Future wheat varieties must integrate heat tolerance and water-use efficiency to sustain yields, as moisture deficiency further intensifies heat stress, making rainfed and restricted irrigation systems highly vulnerable. Therefore, heat tolerances and water use efficiency must be combined in all future wheat varieties to optimize the yield potential under heat stress.

Description of the technology:

Wheat was sown under timely (Nov 20) and late (Dec 20) conditions with irrigation stress at the vegetative and reproductive stages. Late sowing reduced yield attributes and yield by 12–22% compared to timely sowing, while combined heat and drought stress led to a 20–29% grain yield decline. Physiological traits such as RWC (27.9%), chlorophyll content (15.3%), and MSI (16.65%) decreased under late sowing, whereas lipid peroxidation (74.97%) and proline content (312.63%) increased. The top five promising genotypes Raj 3765, HD 2967, HD 3093, DBW 187, and DBW 14 performed well under late sowing in the Middle Indo-Gangetic Plains. Grain yield showed a positive correlation with mobilization efficiency, RWC, and chlorophyll content under late-sown conditions.

Commercial potential:

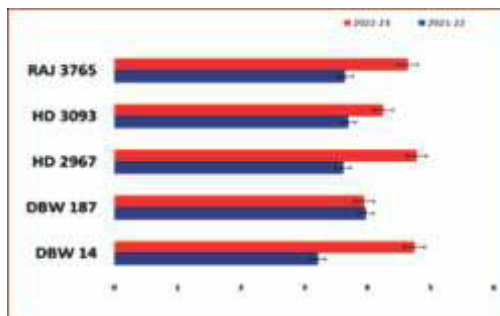
The top five promising genotypes identified for the Middle Indo-Gangetic Plains have demonstrated superior performance under heat and drought stress conditions, making them a valuable option for farmers practicing late sowing. Their ability to withstand combined heat and drought stress can help mitigate yield losses and ensure more stable wheat production in the region. Furthermore, these varieties hold significant potential as donor lines for breeding programs aimed at developing future climate-resilient wheat cultivars. By incorporating their genetic traits, breeders can enhance heat and drought tolerance in new varieties, ensuring long-term sustainability and food security for the Middle Indo-Gangetic Plains.

Impact:

By incorporating the genetic traits of identified varieties, breeders can enhance heat and drought tolerance in new varieties, ensuring long-term sustainability and food security for the Middle Indo-Gangetic Plains



Field view of Wheat crops under timely and late sown condition



Promising varieties performing under heat stress conditions

Agro-ecoregions suitability:

Middle Indo Gangetic Plains

Reference:

Institute Annual report 2023 and 2024

Optimizing soil C under different cover crops and irrigation systems

Period of development: 2019 - 2023

Developer:

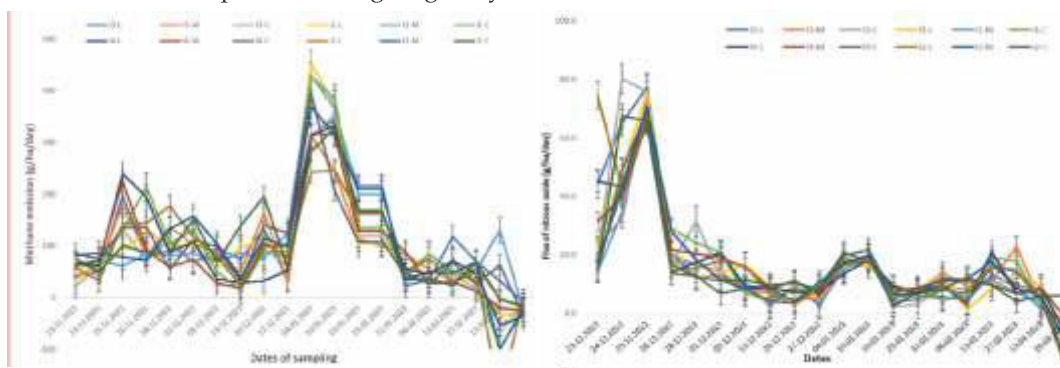
Rachana Dubey

Background:

India faces the dual challenge of increasing agricultural production while reducing greenhouse gas emissions. Major constraint in utilizing rice fallows is limited moisture availability and low organic carbon content. Increasing cropping intensity in these areas is possible through the cultivation of water-efficient, short-season oilseeds and pulses using micro-irrigation systems. These crops not only have high market demand but also contribute to soil health by recycling crop biomass. However, in South Asia, crop residues are often either removed or burned for fodder and fuel, leading to continuous SOC depletion negatively impacting soil productivity and environmental quality. Optimizing biomass incorporation is essential for maintaining SOC levels, improving land and water productivity, and reducing greenhouse gas emissions.

Description of the technology:

Irrigation systems play a crucial role in managing cool season crops during Rabi season. A field experiment was conducted during Rabi 2021-22 comprising three crops, viz., lentil (cv HUL 57), chickpea (cv Pusa 256) and Indian mustard (cv RH 749), under three irrigation systems (drip, sprinkler and surface irrigation) and control to evaluate their global warming potential. Greenhouse gas emission was sampled through close chamber technique and measured in gas chromatograph. On a 100-year time scale, global warming potential (kg CO₂/ha) GWP of Surface irrigation was 29-33% and 33-55% more compared to Sprinkler and drip irrigation, respectively whereas highest yield was recorded with the drip irrigation system. Under different biomass recycling ratios, the highest GWP was in T5 (100% biomass incorporation) which was statistically significant over other ratios. C flow ranged from -2.4 to -3.2 tC/ha/year indicating that T4 can be the best option where 75% biomass incorporation can give good yield with less GHG emission.



Methane emission during rabi season of 2022-23. Where I1: Surface irrigation; I2: Sprinkler; I3: Control; I4: Drip irrigation

Nitrous oxide flux during rabi season of 2022-23



Field View During rabi season



Field View During kharif season

Impact:

This technology provides precise quantification of the type and amount of crop residue that should be incorporated to minimize greenhouse gas emissions while maximizing carbon sequestration. It has also demonstrated that using micro-irrigation with limited water can achieve high yields.

Agro-ecoregions suitability:

Eastern Region of India

Reference:

Institute Annual report 2024 and Newsletter (Jan-August 2023)

Technologies

Farming System and Land Use Models



Integrated Farming Systems for Different Ecologies of Eastern India

Period of development: 2011 - 2022

Developers:

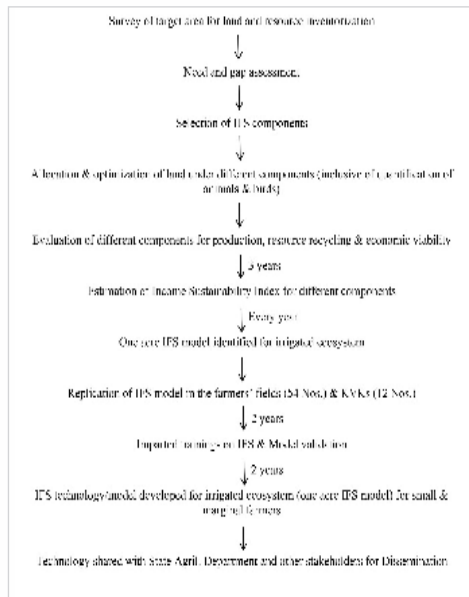
Sanjeev Kumar, Amitava Dey, Ujjwal Kumar, N Chandra, BP Bhatt, Abhay Kumar, Bikas Das, AK Singh, RS Pan, Lokendra Kumar, Md Monobrullah

Background:

Due to declining per capita availability (about 0.4ha) of land in the Eastern India, there is hardly any scope for horizontal expansion of land for food production. Only vertical expansion is possible by integrating appropriate farming components that require lesser space and time to ensure periodic income to the farmer by offering enough scope to nutrient recycling within the system to economize and sustain the system and minimizes the dependence on chemical fertilizers for crop production to earn more profit and offering more man-days generation over traditional cropping systems.

Description of the technology:

Detailed methodology of the IFS is presented here. The developed integrated farming system models fulfils the multiple objectives of making farmers self-sufficient by ensuring the family members a balance diet improving the standard of living through maximizing the total net returns and provide more employment, minimizing the risk and uncertainties and keeping harmony with environment. Different area specific IFS models were developed for waste land, irrigated ecology, flood prone ecology, hill and plateau region etc. The developed IFS models have enhanced the farm income by 112-256 percent, net income by three to four times over conventional cropping system (rice-wheat) along with ample employment 155-212 percent. Due to IFS interventions, the cost of production reduced by 28- 36 percent due to efficient resource recycling within the system.



Detailed methodology of the IFS

Commercial potential:

The technology can be commercialized for potential agribusiness, State Agricultural Department. The interested entrepreneurs can take up these IFS technologies which can provide an economic returns upto Rs. 1.0 lac/acre. The institute can commercialize this technology at a tentative cost of Rs. 10000/farmer.

Impact:

The developed IFS models have been accepted by Govt. of Bihar and the developed IFS models are being replicated in 1068 farmers field in 534 blocks of Bihar. More than 300 farmers have adopted the models suitable for their location due to which their livelihood

enhanced with an increased income by 87-352 percent. Till date 52 acres of waste and unutilized lands had been made productive through IFS approach. Food and nutritional security of small and marginal farmers have been strengthened.



Half acre IFS model (Crops + Livestock + Fish + Duck): 2000m²



One acre IFS model (F. Crops + Hort.+ goat + Poultry + mushroom): 4000m²



Two-acre IFS model (F. Crops + Hort.+ Cows + Fish/duck): 8000m²

IFS models established in different Irrigated Ecologies of Eastern India

Agro-eco region suitability:

Irrigated Ecologies of Eastern India

Reference:

Kumar Sanjeev, Shivani, Dey A, Kumar U, Kumar, Mondal S, Kumar A, Manibhushan. 2022. Location-specific integrated farming system models for resource recycling and livelihood security for smallholders. *Frontiers in Agronomy* 4:938331, doi: 10.3389/fagro.2022.93833.

Multitier Cropping System for Rainfed Uplands of Eastern India

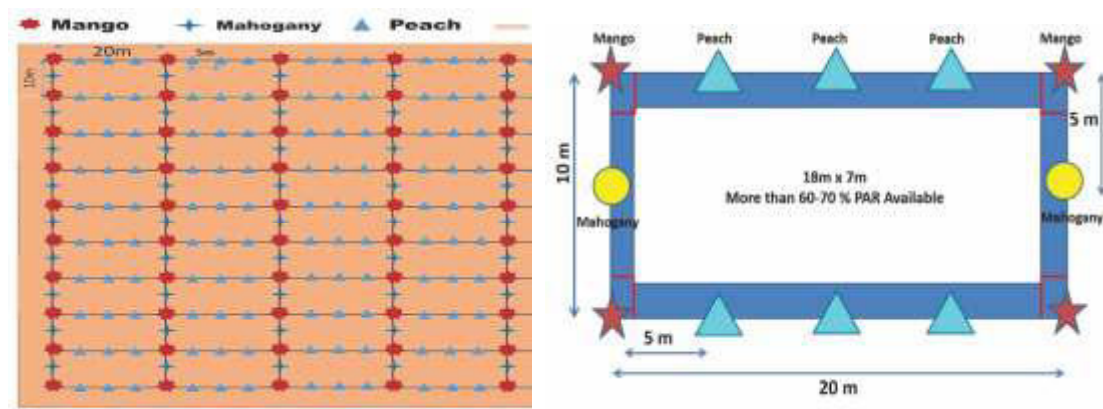
Period of development: 2014 - 2022

Developers:

MK Dhakar, Bikash Das, Reshma Shinde

Background:

In the previously developed multitier models, initially light demanding intercrops are planted but later due to shading effect of perennials, shade tolerant intercrops are recommended. So, it is currently unclear how to achieve optimal yields for light demanding intercrops in these systems on a continuous basis. Cereals-Fruit-Timber-tree based multitier system can produce benefits to farmers by using resources that would not be exploited in monoculture systems and will provide an excellent case study for the potential of cereals-fruit-timber-tree based systems to address the needs of resource limited farmers in marginal upland areas. The current model which integrated fruit and timber tree with rice and finger millet is giving relative income advantages over the monoculture alternatives.



Layout of 1ha plot (Total number of plants in 1 ha= 215 nos.)

Description of the technology:

The developed technology includes Mahogany as top story component, Mango (var. Amrapali) as middle story component, sub tropical peach as filler crops (or region specific) and light demanding intercrops (region specific) (Figure 1). More than 60% area is receiving sufficient light for growing cereals such as finger millet and rice under Mango + Mahogany + Peach system. The filler crop peach attained its maximum canopy after 4 years and producing 45-50kg fruits per plant. The middle story crop (mango) gave fruit yield of 30-35kg/plant under the system. Based on the economics, multitier cropping system Mango + Mahogany + Peach + Rice and Mango + Mahogany + Peach + Finger millet system gave net income of Rs. 120000/- and 150000 respectively from one-hectare area under rainfed condition.

Commercial potential:

Based on the economics, multitier cropping system Mango + Mahogany + Peach + Rice and Mango + Mahogany + Peach + Finger millet system gave net income of Rs. 120000/- and 150000 respectively from one-hectare area under rainfed condition. Model I and II having soil organic carbon stock of 55-60 Mg ha⁻¹ which is only 45 Mg ha⁻¹ in case of mono-cropping of paddy. The multitier cropping system is demonstrated to more than 1000 farmers. The multitier system in upland is adopted by 50 farmers in Jharkhand.

Impact:

This technology is proposed to include under Birsa Harit Gram Yojna of Department of Rural Development, Government of Jharkhand.

MoUs with different NGOs for scaling-up of the multitier model.

S.N.	NGO/Institutions	State
1.	PRADAN - Professional Assistance for Development Action	Jharkhand
2.	TRI: Transform Rural India	Jharkhand
3.	Bhartiya Lok Kalyan Sansthan	Jharkhand
4.	Maharashtra Prabodhan Seva Mandal (MPSM)	Maharashtra



Field view of horti based multi-tier model

Agro-ecoregions suitability:

Rainfed Uplands of Eastern India

Reference:

Beauty, K, Dhakar, M.K, Das, B, Naik, SK, Oraon, BC, Shinde R and Bhatt BP. 2024. Effects of Different Fruit-based Multitier Systems on Soil Chemical Properties and Leaf Nutrient Acquisition Under Rainfed Plateau Conditions. *Applied Fruit Science*, 66(5): 2053-2060.

Carbon Stock Quantification Models for Important Fruit Trees of Eastern India

Period of Development: 2018 - 2021

Developers:

SK Naik, BP Bhatt, S Maurya, PK Sarkar, Bikash Das, AK Singh

Background:

Sequestering carbon through tree-based systems is considered as an attractive economic opportunity for carbon trading. Majority of Indian population is dependent on agriculture, so that fruit tree-based systems provide a long-term strategy to increase the amount of carbon along with food crops. Understanding the carbon storage potential of fruit trees, will likely provide additional value to farmers' livelihood in poverty alleviation in carbon market schemes like REDD+. The biomass estimation of individual trees or orchard is important for the valuation of the amount of CO₂ that is sequestered from the atmosphere as well as changes in the carbon stock.

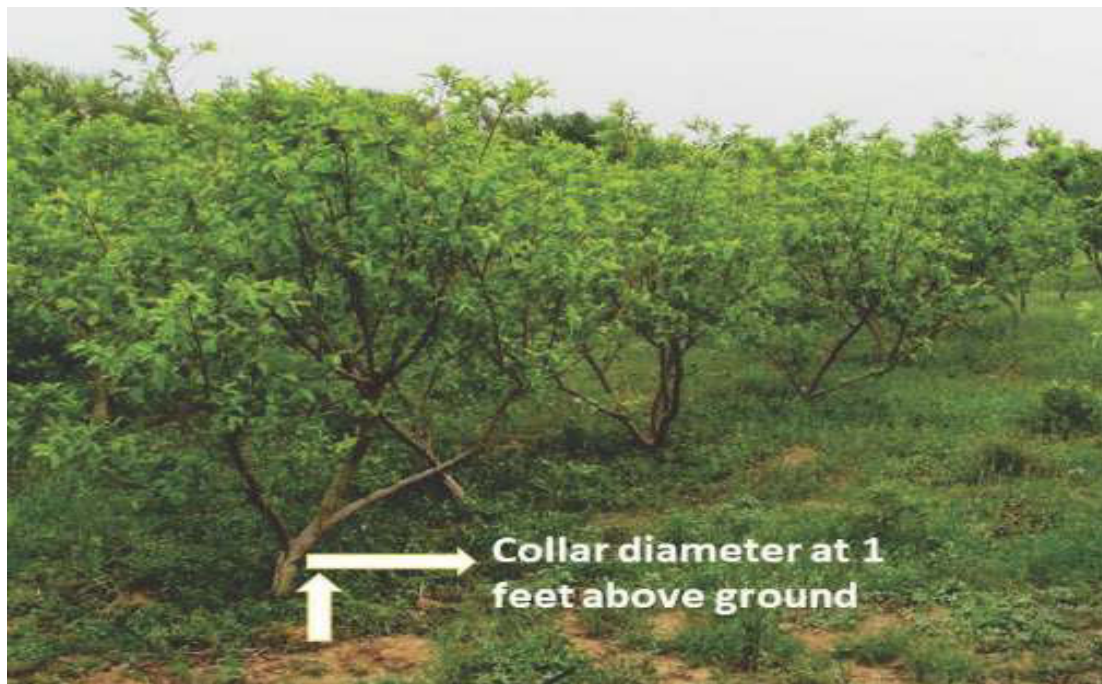
Description of the technology:

Guava orchards under rainfed conditions in a hot and sub-humid climate contribute significantly to atmospheric CO₂ sequestration while mitigating emissions from deforestation. A model was developed to estimate biomass carbon stock in *Psidium guajava* orchards, aiding in understanding carbon dynamics and optimizing orchard management for enhanced sequestration and carbon credit earnings. The study assessed above-ground biomass (AGB) and below-ground biomass (BGB) in a 1 ha orchard with 275 guava trees (2–10 years old) spaced at 6 m × 6 m. Trees were categorized into five age classes (2, 4, 6, 8, and 10 years), with collar diameter measured at 30 cm above ground. Root biomass was excavated from a 1.5 m soil volume per tree, and tree components (roots, bole, branches, leaves) were separated to estimate dry weight using the fresh-to-dry weight ratio. Carbon stocks were determined by multiplying biomass with average carbon content. Component-wise biomass carbon stock (kg/plant) and collar diameter (cm) were analyzed using nine predictive models—linear, allometric, logistic, Gompertz, Richard's, negative exponential, monomolecular, Mitcherlich, and Weibull—to establish functional relationships. Richard's equation was identified as the most suitable model for estimating dry biomass and carbon stock using collar diameter as an independent variable. The validity of the developed models is within the collar diameter range of guava orchards considered during sampling, because they do not include other sources of variation. The present developed model for estimation of biomass carbon stock will help in better understanding of C stocks and dynamics in *P. guajava* orchards and can be used in orchard management activities to enhance C sequestration while earning significant C credits.

Impact:

Understanding the carbon sequestration potential of fruit trees will provide additional benefits to farmers by earning additional income terms of selling carbon credits. The farmers' in the non-forest area having fruit orchard will be benefitted from this model. The

present developed model will be helpful for developing suitable policy to the government for designing state plan in minimizing the GHG emission.



Collar diameter measurement for carbon stock

Commercial potential:

The technology can be Consultancy services provider/ licensed/outsourced to State Agricultural Department, National Horticulture Mission, RKVY, NGOs and stakeholders engaged in efficient nutrient management in Orchards.

Agro-ecoregions suitability:

Hill and plateau regions of Jharkhand

Reference:

Naik SK, Sarkar PK, Das B, Singh AK, Bhatt BP. 2021. Biomass production and carbon stock in *Psidium guajava* orchards under hot and sub-humid climate. *Current Science* (00113891), 120(10): 1627-1635.

Climate Resilient Agriculture Practice in Rice- Fallow Ecosystems of East India Plateau

Period of Development: 2018 - 2022

Developers:

SK Naik, BK Jha, SS Mali, Rakesh Kumar, Surajit Mondal, Rachana Dubey, KK Rao, JS Mishra

Background:

India's Eastern Hill and Plateau eco-region is a less developed region and, therefore, has a great scope for improvement in food production by adoption of scientific agricultural practices. Therefore, an immediate attention is required for identification of suitable management and to devise practical solution for improving soil quality, water profitability and sustainability of rice fallows system. To enhance crop yields and yield stability of succeeding winter crops after rice, CA is presently being emphasized in rice-fallow system. This calls for precise and accurate assessments on energy and carbon budget of diversified CA-based cropping systems in Eastern Hill and Plateau region. This will facilitate designing of better cropping systems and energy and carbon efficient cropping systems in region.

Description of the technology:

The CA-based crop management practices can address the issues of deteriorating soil health, declining system productivity, water availability and greenhouse gas emissions. The present research concludes that climate resilient agriculture practice (conservation agriculture) caused a significant improvement in TSOC both in labile and non-labile carbon fractions that led to an increase in carbon retention efficiency. The practice of conservation agriculture enhanced the very labile C in all of the soil depths and stabilized the SOC as a non-labile recalcitrant fraction in 0-0.30 m soil depth. This has larger implications on the water-stressed Eastern Hill and Plateau region where water availability is a major concern. A cropping system having direct seeded rice (DSR)-mustard blackgram under conservation agriculture was adjudged as the best practice in terms of C-sequestration, C-stabilization, biological activity with higher system productivity, energy use efficiency and reduced carbon footprints. This technology was unique as it was developed for the rice-fallow ecosystems of eastern plateau and hill region of India for the first time. In the Eastern Plateau and Hill regions, where natural resources are fragile and agriculture is heavily reliant on environmental conditions, conservation agriculture-based farming systems will offer a sustainable and climate-resilient alternative. By improving soil health, water conservation, and biodiversity, CAFS supports long-term agricultural productivity and rural livelihoods.

Impact:

This technology was unique as it was developed for the rice-fallow ecosystems of eastern plateau and hill region of India for the first time. In the Eastern Plateau and Hill regions,

where natural resources are fragile and agriculture is heavily reliant on environmental conditions, conservation agriculture-based farming systems will offer a sustainable and climate-resilient alternative. By improving soil health, water conservation, and biodiversity, CAFS supports long-term agricultural productivity and rural livelihoods.



Rice



Mustard



Black gram

Direct seeded rice (DSR)–mustard–black gram under conservation agriculture

Commercial potential:

The technology can be offered through consultancy services or outsourced design to private companies, State Agricultural Department, Development agencies like Millets Mission, RKVY, NGOs, and farmers' groups.

Agro-ecoregions suitability:

Rice fallow areas of India's Eastern Hill and Plateau

Reference:

Naik SK, Mali SS, Jha BK, Kumar R, Mondal S, Mishra JS, Singh AK, Biswas AK, Choudhary AK, Choudhary JS, Hans H, Das A, Babu S, Layek J, Upadhyaya A, Bhatt BP, Chaudhari SK. 2023. Intensification of Rice-Fallow Agroecosystem of South Asia with Oilseeds and Pulses: Impacts on System Productivity, Soil Carbon Dynamics and Energetics. *Sustainability*, 15(2): 1054. <https://doi.org/10.3390/su15021054>

Agroforestry Models for Rehabilitation of Coal Mine Affected Areas in Eastern Plateau & Hill Region

Period of development: 2014 - 2023

Developers:

PK Sarkar, MK Dhakar, SS Mali, Bikash Das, SK Naik, Dharamjet Kherwar, DK Raghav, BP Bhatt

Background:

In the coal-rich state of Jharkhand, extensive mining activities have led to severe land degradation, rendering vast areas unfit for agriculture. With over 180 coal mines spanning approximately 6,377 km², deforestation, soil erosion, and contamination have disrupted traditional farming systems and local ecosystems. One such affected region is Phusri, a tribal village historically dependent on coal-based livelihoods. The villagers primarily engaged in quarrying and selling raw coal, as the degraded land offered little scope for farming. However, this unsustainable dependence on coal mining led to fluctuating incomes, environmental hazards, and a lack of alternative employment opportunities. Over time, soil fertility declined, water sources were contaminated, and the community faced socioeconomic instability, struggling to secure a sustainable future.

Description of the technology:

For transforming degraded coal mine lands, covering an area of 5 hectares the ICAR Research Complex for Eastern Region introduced an agri-horti-silvi-pastural system in Phusri since 2015. To restore the barren land involved planting agroforestry species such as Bael (*Aegle marmelos*), Jackfruit (*Artocarpus heterophyllus*), Mango (*Mangifera indica*), Mahogany (*Swietenia mahogany*), Teak (*Tectona grandis*), and Bakain (*Melia azedarach*) at 150–200 trees/ha. Other species like Karanj (*Pongamia pinnata*), Guava (*Psidium guajava*), and Pomegranate (*Punica granatum*) were also included. Kans grass (*Saccharum spontaneum*) was planted as fodder between trees, providing 8-10 tons/ha/year, while Bhoomi Sudha (*Tephrosia candida*) was used as green manure and fodder, yielding 2.5–3 tons/ha/year. Intercrops were also introduced for additional income. However, caution is advised against cultivating food crops, especially fruits, due to their recorded tendency to absorb heavy metals like Arsenic, Cadmium, Chromium, Nickel, and Lead from the soil in these areas. Soil and water conservation measures included plastic-lined Dobha/Jalkund (3m × 1.5m × 1m) with a 4,500-liter capacity, and techniques like contour trenching (20 trenches/ha) and mulching. Zero tillage practices were also adopted. Regular field management and data analysis showed 85% tree survival rates and improvements in soil organic carbon by 0.5% over 9 years, helping to restore productivity and reduce soil erosion.

Commercial potential:

The technology can be offered through consultancy services or outsourced to the State Agricultural Department, Development agencies like Forestry Board, RKVY, NGOs, and farmers' groups. rehabilitating coal mine-affected areas effectively.



Impact of developed agroforestry models at coal mine affected areas

Impact:

Agroforestry interventions in coal mine-affected areas of Jharkhand have successfully restored degraded lands using Multipurpose Tree Species (MPTs) like Teak, Mahogany, and fruit crops, improving soil stability and biodiversity.

Agro-ecoregions suitability:

Jharkhand and other coal mine affected States

Reference:

Sarkar PK, Dhakar MK, Das B, Kumar PR, Maurya S, Mali SS, Shinde R, Choudhary JS, Naik SK, Kherwar D, Chakrabarti A, Raghav DK, Singh AK and Bhatt BP. 2019. Healthy plant: Foundation for nutritional and environmental sustainability. *LEISA INDIA*, pp. 6-10.

Technologies

Soil and Water Conservation Measures



Modified Drip Fertigated Mulched Planting System for Commercial Cultivation of Vegetable in East India Plateau

Period of Development: 2018 - 2023

Developers:

BK Jha, SK Naik, AK Thakur, JS Chaudhary, AK Singh

Background:

Vegetables were grown generally under conventional surface irrigation method in Eastern Plateau and Hill region of India and are characterized by high labour and pumping costs. In this method, the major proportion of irrigation water is lost by surface evaporation, deep percolation and other losses, resulting in lower irrigation efficiencies. Moreover, there is a tendency of farmers to apply excess water when it is available. Drip irrigation, with its ability to provide small and frequent water applications directly in the vicinity of the plant root zone has attracted interest because of decreased water requirement and possible increase in production

Description of the technology:

The soil-plant interaction may help in maximizing crop productivity with simultaneous improvement in the soil quality. A field experiment with six treatments (flat-bed, broad-bed, and ridge-furrow, with/without 25-micron polythene mulch) was conducted using drip irrigation. Cauliflower (120:45:45 kg NPK/ha) and eggplant (60:40:40 kg NPK/ha) were grown in succession, with weekly fertigation for 16 weeks. Drip irrigation was applied thrice weekly (cauliflower) and four times weekly (eggplant) for 30 minutes per session. The mulching with polythene increased temperature and moisture during the early growing season, but lowered temperature during the later growing season, ensuring a favorable coupling of temperature and moisture to improve the yield of cauliflower and eggplant. The broad-bed and ridge-furrow systems of planting enhanced the soil nutrient status compared to the flat-bed system, irrespective of polythene mulching. The SMBC, acid phosphatase, and dehydrogenase activity was highest in mulched ridge-furrow planting. The highest yield of cauliflower curd and eggplant fruit was obtained in mulched ridge-furrow planting. The results concluded that the soil moisture, soil temperature, soil available nutrient, microbial biomass carbon, dehydrogenase activity, phosphatase activity, and yield of crops performed better in mulched ridge-furrow planting. The ridge-furrow with polythene mulching provides an excellent opportunity to enhance crop productivity, while maintaining and increasing soil quality in hot and sub-humid climate in eastern regions of India.

Commercial potential:

The technology can be offered through consultancy services, licensed, or outsourced to the State Agricultural Department, Private Sector & Agri-Entrepreneurs, RKVY, NGOs, and farmers' groups for effective implementation and outreach.

Impact:

Drip irrigation with polythene mulching enhances fertilizer-use efficiency through frequent nutrient application while improving soil moisture retention and topsoil temperature. It is highly efficient for water-scarce areas, ensuring sustainable and productive vegetable cultivation



Raised bed polythene mulched drip fertigation in vegetable

Agro-ecoregions suitability:

Hot and sub-humid climate in eastern regions of India.

Reference:

Naik, S.K., Jha, B.K. and Singh, A.K. 2022. Drip Fertigated Planting Systems with Polythene Mulching on Cauliflower–Eggplant Cropping Systems in Hot and Subhumid Climate: Impact on Soil Health and Crop Yield. *Communications in Soil Science and Plant Analysis*, 53(10): 1261-1276.

Modified Drip Fertigation Technology for Vegetable Production in Eastern India

Period of Development: 2018 to 2023

Developers:

BK Jha, SS Mali, SK Naik, AK Singh

Background:

Farmers in the eastern region traditionally practice conventional manual fertilizer application in two splits, which does not align with the varying nutrient demands of crops during different growth stages. Drip fertigation, applying fertilizers in multiple doses aligned with crop growth stages, significantly improved nutrient management, water use efficiency, and crop yields.

Description of the technology:

Growth stage linked fertigation pattern and planting geometry affect the nutrient uptake, nutrient recovery, yield and water productivity of chilli pepper. Under denser planting geometries, the yield increase compensated the increase in irrigation water and maintained higher WP of chilli pepper. Planting of chilli pepper in triangular arrangement with row-to-row distance of 40 cm and plant-to-plant spacing of 30 cm was the best geometry for chilli pepper cultivation with drip irrigation. The next best alternative was to plant the chilli pepper plants in a triangular pattern with slightly higher plant-to-plant distances (50 cm). Growth stage based variable application of water-soluble fertilizers performed better over the uniform fertigation dose with every event. Application of higher percentage of recommended dose of fertilizer during 8th to 13th week (at early reproductive stage) after transplanting of chilli in triangular arrangement with row-to-row distance of 40 cm and plant-to-plant spacing of 30 cm resulted in 31.1, 59.3, 57.6 and 42% increase in N-recovery, NUE, chilli yield and WP, respectively over the normal farmer practice of uniform fertilizer dose during the entire crop cycle through drip fertigation with lesser planting density (75 × 50 cm spacing). However, for tomatoes, a triangulated planting geometry of 50x40x60 cm with higher fertigation during the fruiting stage resulted in the highest yield of 80.9 t/ha, water productivity of 34.8 kg/m³, and nitrogen use efficiency of 48%. In chili cultivation, the 30x40x60 cm layout with uniform weekly fertigation produced top yields of 14.4 t/ha, water productivity of 5.2 kg/m³. Broccoli thrived with a 30x40x60 cm layout and higher fertigation during the vegetative stage, yielding 31.3 t/ha with a water productivity of 15.8 kg/m³ and nitrogen use efficiency of 52%. Sweet corn achieved its peak yield of 21.3 t/ha with a 75x50 cm geometry and higher fertigation during fruiting, reaching a water productivity of 7.4 kg/m³. These advancements demonstrate the transformative potential of integrating strategic planting geometry with stage-specific fertigation. Overall, results suggested that adjustments in fertigation dose and maintaining optimal plant population improved yield and increased nutrient and water use efficiencies.

Commercial potential:

The technology can be offered through consultancy services or outsourced to the State Agricultural Department, Development agencies like National Horticultural Mission (NHM), RKVY, NGOs, and farmers' groups.



Planting geometry and fertigation in broccoli



Field view of tomato crop cultivated under various fertigation patterns and geometries

Impact:

The impact of Modified Drip Fertigation Technology (MDFT) on vegetable production in Eastern India has been increasingly recognized as a transformative tool for improving agricultural productivity, resource use efficiency, and environmental sustainability. Given the region's diverse agro-climatic conditions, where water scarcity, erratic rainfall, soil degradation, and nutrient imbalances are common challenges, MDFT can significantly contribute to overcoming these barriers and enhance the profitability of vegetable farming.

Agro-ecoregions suitability:

Vegetable production areas in Eastern India, which is characterized by diverse agro-climatic zones.

Reference:

Mali SS, Naik SK, Jha BK, Singh AK, Bhatt BP. 2019. Planting geometry and growth stage linked fertigation patterns: Impact on yield, nutrient uptake and water productivity of Chilli pepper in hot and subhumid climate. *Scientia Horticulturae*, 249: 289-298.

***Tephrosia* Biomass Mulching Technology for Improving Soil Health and Productivity of Fruit Orchard**

Period of development: 2014 - 2023

Developers:

Bikash Das, MK Dhakar, SK Naik, PK Sarkar, S Maurya, BP Bhatt

Background:

Increasing demand for organic produce as well as increasing cost of manure and fertilizers warrant alternative cheaper options on sustainable nutrient management. Growing of biomass yielding plants and recycling of harvested biomass in the plant basin of fruit trees have been found to improve soil fertility and plant growth of number of fruit trees. In the light of this, an attempt was made to test the effectiveness of different biomass yielding plants in fruit orchards. Enriching the plant basins with leafy biomass can effectively improve soil organic matter and nutrient content. Facing difficulties in eradication of and high seed dispersal of Subabul plants, there was a need for identification of an equally effective substitute biomass yielding plant.

Description of the technology:

The developed technology includes improvement in soil fertility of fruit orchards through biomass mulching of *Tephrosia candida* in the basin of fruit trees viz. Mango, Guava and Bael growing under rainfed conditions of EPHR. Experiment I evaluated four biomass-yielding crops (Tephrosia, Leucaena, rice bean, and vegetable soybean) for their impact on soil and bael health by applying their biomass in plant basins. Experiment II standardized Tephrosia mulching doses (1–3 kg dry biomass/m²) in mango, guava, and bael orchards under rainfed conditions. Both studies assessed soil properties, nutrient recycling, and fruit yield. *Tephrosia candida* is a leguminous perennial shrub with high biomass producing capacity (4.0-5.0 kg dry biomass/m²) with a lifespan of five to six years under regular lopping conditions. The Tephrosia plants can be grown either in the alley area in young orchards and as a hedge in the orchard border and the harvested biomass which can be used in basin enrichment.

Application of Tephrosia biomass @ 3.0 kg dry wt/m² have resulted in improvement in soil properties viz. total soil organic carbon (18.43-21.32%), available nitrogen (13.68-23.02%), available phosphorus (73.18-96.76%), exchangeable potassium (41.60-47.47%), leading to increase in content of leaf nitrogen (35.59-39.06%), phosphorus (27.58-35.01%), potassium (103.3-111.11%) and fruit yield (mango-25.03%, guava-42.25% and bael-100.0%).

Commercial potential:

Under rainfed conditions of eastern plateau and hill region, the productivity of different fruits with biomass mulching of Tephrosia was as follows

Sl. No.	Fruit crop	Variety	Age (years)	Spacing (m)	Yield potential (t/ha)
1.	Bael	Pant Aparna	6	2.5m x 5.0m	3.36
2.	Mango,	Amrapali	18	2.5m x 2.5m	40.43
3.	Guava	Allahabad Safeda	15	1.0m x 2.0m	20.20

The technology can be offered through consultancy services or outsourced to the State Agricultural Department, Development agencies like National Horticultural Mission (NHM), RKVY, NGOs, and farmers' groups.



Tephrosia plant



Tephrosia mulching in mango



Tephrosia mul

Impact:

This technology is recommended for the OFT by ATARI Patna for Bihar and Jharkhand KVKs. This technology is being popularized by State Agricultural Management and Extension Training Institute (SAMETI), Govt. of Jharkhand. This is also included under Birsa Munda Aam Bagwani Yojna of Department of Rural Development, Government of Jharkhand.

Agro-ecoregions suitability:

Rainfed conditions of eastern plateau and hill region

Reference (Publication etc.)

Das B, Sarkar PK, Dhakar MK, Naik SK, Maurya S, Singh AK, Kumar S, Bhatt BP. 2021. Basin enrichment of bael plants (*Aegle marmelos* Correa) through alley cropping of biomass producing plants: Effects on plant growth and soil properties. *Fruits*, 76(2): 61-71.

Low-Cost Non-Weighing Lysimeter for Assessing Nutrient Leaching Loss

Period of Development: 2018 - 2023

Developers:

SK Naik, SS Mali

Background:

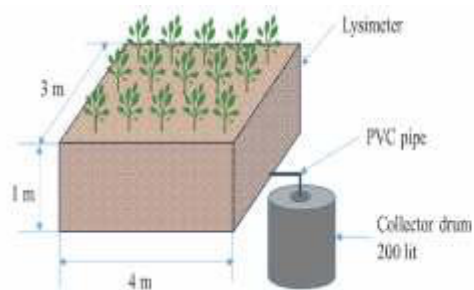
The major fertilizer inputs to agriculture in the form of nitrogen, phosphorus, and potassium applied to the soil, which undergoes series of transformations in soil by different physical, chemical, and biological processes leading to availability to the crops as well as vulnerability to leaching loss. The soils of Jharkhand have typically low levels of N, P, K, organic carbon and suffer from excessive run-off and leaching loss of nutrients. Because of the high permeability of the sandy soil, most of the applied fertilizers are susceptible to leaching loss through infiltrated water. The quantification of leaching loss of nutrients in the acidic soils of the eastern plateau and hill region of India has not been reported or very scanty.

Description of the technology:

The weighing type lysimeter is very cost intensive and is costing about 10 lakhs, which cannot be afforded by academicians, researchers and persons involved in nutrient management. Thus, the present low-cost non-weighing lysimeter (Rs 10000/unit) is developed for quantification of nutrient leaching loss and soil water balance studies. Non-weighing lysimeters were constructed by digging out the pits of size $4.0 \times 3.0 \times 1.0$ m (length $\times$ width $\times$ depth) in the field. Black polythene of 500-micron thickness was used for lining of each lysimeter to avoid inflows and outflows from the lysimeter boundaries. The excavated soils from different depths of 0–15, 15–30, 30–45, 45–60, 60–75, 75–90, and 90–100 cm of the pits were filled up in the lysimeters at their corresponding depths. A 63 mm diameter of PVC pipe was fitted at the bottom of pit to carry the leachate from lysimeter to the collector drum placed inside the collector-trench. Leaching losses of nutrients in winter crops of tomato and pea cultivated in acidic soils of eastern plateau and hill region were studied using non-weighing type lysimeters under different nutrient management practices. The treatment receiving 100% recommended dose of NPK as inorganic form recorded highest N, and K leaching loss of 22.1, 14.8 kg ha⁻¹ in tomato accounting 13.7 and 21.1% of applied fertilizer, while in pea, it was 9.14 and 10.8 kg ha⁻¹, respectively, accounting 20.3 and 20.4% of applied fertilizer.

Impact:

The leaching loss measurement in the developed lysimeter involves low cost and non-weighing type compared to the available lysimeter in the market, which is of weighing type and involves lot of manpower for installing in the field as well as for measurement of leaching loss of nutrients.



Non-weighing lysimeter for quantification of nutrient leaching loss and soil water balance study

Commercial potential:

This technology non-weighing Lysimeter can be outsourced in research organization, agricultural university farm and other non-governmental organization engaged in the quantification of leaching loss of nutrients from the soil and its further mitigation strategies.

Agro-ecoregions suitability:

All over India

Reference

Naik SK, Mali SS, Kumar O, Singh AK, Bhatt BP. 2021. Assessing Nutrient Leaching Loss Using Non-weighing Lysimeters in Acidic Soils of Eastern Plateau and Hill Region of India. *Communications in Soil Science and Plant Analysis*, 52 (9): 1023–1036.

Fertilizer Recommendation in Mango Using Leaf Nutrient Standard

Period of Development: 2015 - 2018

Developers:

SK Naik, Bikash Das

Background:

Acid soil infertility is a major limitation of mango yield in the state of Jharkhand in eastern plateau and hill region of India. Poor nutrition, marginal lands and senile orchards are some major factors contributing to declining yield and quality in this area, though no local guidelines are available. Enhancing mango productivity in the region requires adequate nutrition. While visual diagnosis of nutrient deficiencies is used, it is reliable only when symptoms are distinct. The Diagnosis and Recommendation Integrated System (DRIS), which uses the nutrient ratio as a stable criterion in relation to the age of plants and the position of leaf tissues, has proven useful in the interpretation of leaf tissue analysis.

Description of the technology:

Information about leaf nutrient concentration is very much required for proper fertilizer application and thus developed leaf analysis based diagnosis and recommendation integrated system (DRIS) indices in relation to fruit yield of mango orchard in eastern plateau and hill region of India. A survey was carried out in eastern plateau and hill region of India comprising of Gumla, Ranchi and Lohardaga districts of Jharkhand state in 27 mango orchards. A total of 270 mature leaf samples were collected from 27 mango orchards of different ages. Sampling consisted of recently matured leaves from 3rd and 4th leaf of the terminal end of 7–8 months-old branch in the month of October. About 30 leaves were plucked from each mango tree and packed in the polysheet. At maturity, the fruit yields of all the trees sampled were recorded in kg per plant and expressed as tons per hectare. Leaf samples were air dried at 70 °C and ground using Wiley grinding machine to pass through a 60-mesh stainless steel sieve to obtain homogeneous samples. As per DRIS indices, a relative deficiency for magnesium, zinc, and boron corresponding to relative sufficiency for calcium, nitrogen, phosphorus, sulfur, and potassium was detected in 9-year-old mango orchards. For the younger orchards (6–7 year old), the order of requirement of nutrients was found to be calcium > sulphur > potassium > boron > nitrogen > phosphorus > magnesium > zinc. Boron was found as the most yield-limiting elements in all age group of plants. When the DRIS indices were compared on the basis of soil pH, calcium and magnesium were most yield-limiting nutrients below pH 5.5, while nitrogen, zinc, and boron were found to be most limiting above pH 5.5. The developed DRIS indices is required by the mango grower in acidic soils to get optimum yield.

Impact:

This concept of mango leaf nutrient standards can be popularised in research organization, agricultural university farm and other non-governmental organization engaged in efficient nutrient management of mango for higher yield in eastern plateau and hill region of India.



Experimental view of leaf nutrient management of Orchard

Commercial potential:

The technology can be offered through consultancy services for Development agencies like National Horticultural Mission, RKVY, NGOs, and farmers' groups.

Agro-ecoregions suitability:

Eastern plateau and hill region of India.

Reference:

Naik SK, Bhatt BP. 2017. Diagnostic leaf nutrient norms and identification of yield-limiting nutrients of mango in Eastern plateau and hill region of India. *Communications in Soil Science and Plant Analysis*, 48(13), pp.1574-1583.

Doba Technology of Water Harvesting for Orchard Establishment in Uplands

Period of development: 2008 - 2010

Developers:

PR Bhatnagar, Santosh S Mali, Pradeep Dey, AK Sikka

Background:

The unavailability of irrigation water is a significant constraint for establishing fruit crops in the plateau region of eastern India. Due to the region's undulating topography and low soil water-holding capacity, storing available rainwater becomes a major challenge. The semi-humid climate, with uneven rainfall distribution, exacerbates the issue, leaving the region dry during non-monsoon months. Water harvesting structures in upland areas can help capture and store rainwater, reducing irrigation costs and ensuring water availability for fruit crops during dry periods.

Description of technology:

A Doba is a small, underground water storage tank designed to collect and store direct rainfall, particularly in areas with moderate rainfall. Typically measuring 3 meters in length, 1.5 meters in width, and 1 meter in depth, the Doba is lined with a 200-micron thick black polythene sheet to prevent water seepage. A bund is constructed around the tank's border to stop surface runoff from entering, which helps prevent silting. With an average annual rainfall of 1440mm, a Doba can hold up to 4500 L of water, which is critical for life-saving irrigation for about 10 fruit plants, especially during dry periods from March to May. The polythene lining is anchored by a trench and secured by surrounding soil to prevent shifting, while the corners are folded carefully to avoid wrinkles and ensure durability. The structure is topped with a thatch made from locally sourced materials, which minimizes evaporation, protects against foreign matter, and prevents animals from falling in. This cost-effective, efficient water storage solution is particularly suitable for small-scale farmers in areas with seasonal rainfall. The Doba technology provides substantial benefits in water conservation, significantly reducing water loss and helping conserve up to 45,000 L of water for a hectare of mango plantation. Additionally, the stored water is used for life-saving irrigation, reducing plant mortality due to water stress. It also ensures plant health by maintaining consistent moisture levels in the root zone, improving disease and pest resistance, and ultimately leading to healthier crops and better yields. The cost of construction of one Doba is approximately ₹ 1800/- to ₹ 2000/-. Orchard plantation with 5x5 meter spacing, require 40 Doba per hectare.

Commercial potential:

State governments can integrate Doba water harvesting in watershed management projects. NABARD has successfully incorporated this technology in the Wadi project, demonstrating its effectiveness in enhancing water availability and improving crop yields for farmers.



Doba Technology for Water Harvesting for orchard establishment in uplands

Impact:

The Doba technology, a low-cost water harvesting solution, has already been successfully adopted by NABARD, with over 3,000 Dobas constructed under the Wadi project in Jharkhand. This technology, particularly suitable for upland areas, saves approximately 45,000 liters of water per hectare, significantly reducing plant mortality, especially for fruit crops.

Agro-ecoregions suitability:

Rainfed upland conditions of Eastern Plateau and Hill Region.

References:

Naik SK, Mali SS, Das B, Bhatnagar PR, Kumar S, Sikka AK. 2016. Rainwater harvesting using plastic-lined Doba technology for orchard establishment in the eastern plateau and hill region of India. *Current Science*, 111(11): 1751-1753.

Subsurface Drip Fertigation in Vegetable Crops

Period of development: 2009-2012

Developers:

Santosh S Mali, Ranveer Singh, MK Meena

Background:

Efficient water application and proper fertilizer management are essential in vegetable production, especially in regions with water scarcity. In the Eastern Plateau region, water availability is a major constraint for vegetable crops during the summer months. Subsurface Drip Irrigation (SDI) provides a practical solution for economic vegetable production under limited water supply. High soil evaporation in the region further increases water requirements, but SDI addresses this by applying water directly below the soil surface, significantly reducing evaporation and deep percolation losses. Determining the optimum depth for lateral placement is crucial for improving wetting in the root zone while minimizing water loss. There is a need to develop a comprehensive water and fertilizer management strategy specifically tailored for SDI in vegetable cultivation to ensure efficient irrigation and nutrient distribution.

Description of the technology:

The sub-surface drip irrigation system is designed and laid out based on factors such as crop type, plot size, and water source availability. In this sub-surface drip irrigation system, laterals are placed at a depth of 10 cm below the soil surface to ensure water reaches the root zone efficiently. Non-clog or self-cleaning emitters are used to ensure consistent water flow and prevent blockages. A 50-micron polythene mulch is applied and properly fixed for each row to reduce evaporation and maintain soil moisture. The system can apply water and nutrients directly to the root zone, ensuring efficient use of resources.

Irrigation scheduling follows standard procedures to ensure that the crop receives adequate moisture. Fertigation is also integrated into the system, with N, P, and K (200-120-120 kg/ha) fertilizers being delivered through the drip system. Fertilizer injection occurs twice a week with the rate of application adjusted as the crop matures. Initially, a lower fertilizer application rate is used, gradually increasing until the crop reaches its mature stage, and then tapering off towards the end of the growing season. Pre-plant application of vermicompost (1:0.8:0.8) is done at a rate of 2 tons per hectare to enhance germination, applied as a spot application (150 g for a pair of plants) at the planting site.

Commercial potential:

Subsurface drip irrigation (SDI) has strong commercial potential in government programs like the National Mission on Micro Irrigation (NMMI). Private companies benefit from the growing demand for SDI systems, driving innovation and offering long-term cost savings for agricultural businesses.

Impact:

Subsurface drip irrigation (SDI) significantly improved bitter gourd yield, with higher yields (21.9 t/ha). The systems can achieve higher irrigation water use efficiencies 5 t/ha/cm with water savings in the range of 10-15%.

**Subsurface Drip Fertigation Technology for vegetable crops****Agro-ecoregions suitability:**

Eastern plateau and hill region of India, Indo Gangetic Plains

References:

Mali SS, Jha BK, Singh R, Singh AK, Meena M. 2017. Bitter gourd response to surface and subsurface drip irrigation under different fertigation levels. *Irrigation and Drainage*. DOI: 10.1002/ird.2146.

Drum Kit System for Drip Irrigation

Period of development: 2007 - 2009

Developers:

Santosh S Mali, Shivendra Kumar

Background:

In Eastern India, unreliable electricity supply and the high initial cost of pressurized drip irrigation systems pose significant challenges for farmers. The need for continuous power to operate pumps makes conventional drip systems less viable, especially for small-scale farmers. Additionally, the high upfront investment in pressurized systems is often beyond the reach of those with limited financial resources. The Drum Kit System, however, offers a more suitable solution for small-scale farmers. It is cost-effective, requires minimal electricity, and can be easily installed and maintained. This makes it a practical option for improving water-use efficiency and crop productivity, even in areas with erratic power supply and limited capital. The Drum Kit System's low cost and adaptability to local conditions make it an ideal choice for addressing irrigation challenges in Eastern India.

Description of the technology:

Drum kits are compact, gravity-fed drip irrigation systems designed for small-scale agricultural use, especially in areas with limited water resources and unreliable power supply. These systems operate without the need for external electricity, making them ideal for rural conditions. The system is typically used for growing vegetables, flowers, and other horticultural crops on flat or mildly sloped land, with a range of 100 to 1000 m² in system size. A water tank, usually placed at a height of 1 to 1.5 meters, provides the necessary pressure for water distribution. This tank can be a plastic barrel, an iron drum, or even a water harvesting pond, and it can be filled manually or using small pumps. The simplicity and low-cost nature of the Drum Kit make it a suitable solution for small farmers, helping them manage water use efficiently even during times of water scarcity.

The pipe network in the Drum Kit system consists of a main supply line connected to the water tank, with water filtered before reaching the plants. The water flows through small-diameter LDPE pipes, known as laterals, which are connected to the main line using press-fit joints. These laterals, equipped with emitters, distribute water directly to the root zones of plants. Depending on the crop type, a single lateral can irrigate multiple rows, ensuring efficient water usage. The system's low-pressure design and small emitter size make it ideal for areas with limited head height, providing precise water delivery even in challenging conditions. Additionally, the Drum Kit helps maintain an optimum soil-moisture regime by applying the required amount of water at the right frequency. For shallow sandy soils, frequent daily irrigation is necessary, while deep clay loam soils require less frequent irrigation (every 2-3 days). During early crop growth, when roots are shallow, frequent irrigation with lower amounts of water is essential, while in the flowering or late vegetative stage, water consumption peaks, making an adequate water regime crucial for proper crop growth. The Drum Kit system is an affordable, effective solution for small-scale farming in

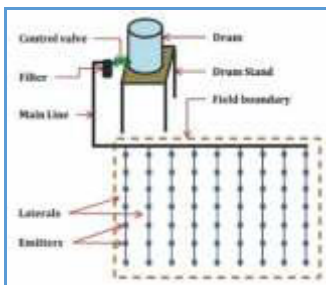
regions with water and power constraints, offering a sustainable and scalable method of irrigation.

Commercial potential:

The commercial potential of Drum Kit systems for irrigation can be realized by partnering with agricultural equipment manufacturers, as well as government programs such as the National Mission on Micro Irrigation and NABARD. Collaborating with NGOs, and retailers such as UPI Irrigation can further promote the system. Farmer Producer Organizations (FPOs) and state agriculture departments can help expand its reach.

Impact:

Drum Kit systems promote efficient water usage by minimizing wastage, ensuring that water is delivered directly to the root zone. This leads to improved crop yield and quality through consistent and precise irrigation. Demonstrations of these systems have proven effective in encouraging the adoption of pressurized drip irrigation, showing up to 55% water savings, a 45% reduction in labor requirements, and nearly double the crop yields in vegetable cultivation.



Drum Kit System for Drip Irrigation

Agro-ecoregions suitability:

Agro-ecological regions facing water scarcity and limited electricity, such as semi-arid, sub-humid, and coastal areas

References:

Mali SS, Kumar S. 2009. Economic water productivity of Drum Kit Drip Irrigation Systems for vegetable production in Eastern Plateau Region of India." Conference on Food and Environmental Security through Resource Conservation in Central India: Challenges and Opportunities. CS&WCR&TI, Research Centre, Chhalesar, Agra-282006. 16-18 September 2009.

Modified Non-weighing Paddy Lysimeter

Period of development: 2020 - 2023

Developers:

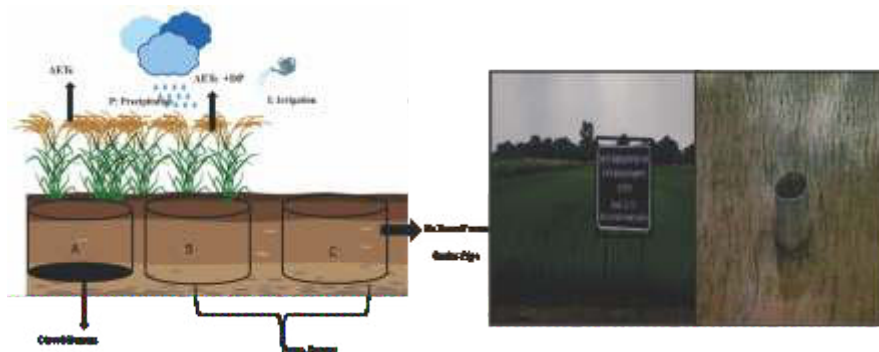
Arti Kumari, Ashutosh Upadhyaya, Pawan Jeet, Ved Prakash, Kirti Saurabh, Anup Das

Background:

A lysimeter and eddy covariance can be used to estimate actual evapotranspiration (AET) directly. However, these technologies are costly, making in-situ ET determination difficult, particularly in developing countries. Keeping in view, a prototype of modified non-weighing paddy lysimeter was designed and fabricated to estimate actual crop evapotranspiration (ET) and stage-wise crop coefficient values (K_c) of transplanted puddled rice, along with soil water balance components at regional scale. This type of methodology could also be used in other edaphoclimatic and data-scarce regions where lysimeters are unavailable to estimate actual evapotranspiration in paddy areas. In addition, the derived stagewise K_c values at the regional scale may help to improve irrigation scheduling in water-intensive rice crop for similar agro-climatic conditions.

Description of the technology:

The developed modified paddy lysimeter was used to estimate actual crop evapotranspiration (ET_c) and crop coefficient values (K_c), along with water balance studies in transplanted puddled rice. A modified paddy lysimeter, incorporating an outlet positioned at the recommended bund height of 25 cm for the region, consisted of set of three drums—designated as A, B, and C—each with a diameter of 50 cm and a height of 128.75 cm. These drums were partially embedded in the field, with approximately one-fourth of their height extending above the ground surface. Additionally, Drum A had a closed bottom, while Drum B and C had open bottoms. The outlet pipe was installed at bund height (25 cm) in container C for precise runoff estimation. The difference in water level over two successive days in drum A represents actual evapotranspiration. In contrast, percolation loss is estimated as the daily difference in water levels between drums A and B. However, runoff is estimated by measuring overflow from drum C throughout the season.



Field view of Modified Non-weighing Paddy Lysimeter with their components

Commercial potential:

Popularized among research institutions, agricultural universities, and agribusinesses engaged in efficient water management, irrigation planning etc

Impact:

The developed non-weighing paddy lysimeter provides a cost-effective solution for measuring actual evapotranspiration, requiring significantly less manpower and simpler installation compared to conventional weighing lysimeters available in the market.

Agro-ecoregions suitability:

Eastern regions and similar agroclimatic regions where commercial lysimeters are unavailable.

Reference :

Kumari A, Upadhyaya A, Jeet P, Al-Ansari N, Rajput J, Sundaram PK, Saurabh K, Prakash V, Singh AK, Raman RK, Gaddikeri V. 2022. Estimation of actual evapotranspiration and crop coefficient of transplanted puddled rice using a modified non-weighing paddy lysimeter. *Agronomy*, 12(11), 2850.

Prioritized Map for Identifying Drought Susceptible Zones in Sakri Basin

Period of Development: 2021 - 2024

Developers:

Pawan Jeet, AK Singh, Ashutosh Upadhyaya, Anup Das, Rakesh Kumar, PK Sundaram, Arti Kumari, Kirti Saurabh

Background :

Land and water are the most important finite natural resources, which are diminishing at a faster pace due to indiscriminate and unscrupulous exploitation. The penchant for water intensive agriculture and rapid urban industrialization are also putting huge pressure on the fragile freshwater resources, resulting in over-exploitation of ground water, declining water levels and deterioration of water quality. Apart from it, climate variability create drought like situations in districts covered in Sakri river basin of Bihar and Jharkhand, rendering improved water use efficiency is a mandatory objective to maintain the current food supply. In this context, agriculture in Bihar and Jharkhand suffers from irregularity in monsoonal rainfall which leads to droughts in the district covered under Sakri river basin. In the context of basin, prioritization of sub-watershed has gained significance in the natural resource management. So, efforts were made to prioritize the sub-watershed of the Sakri basin using a multivariate geomorphometric approach such as GIS, remote sensing, PCA and WSA.

Description of the technology:

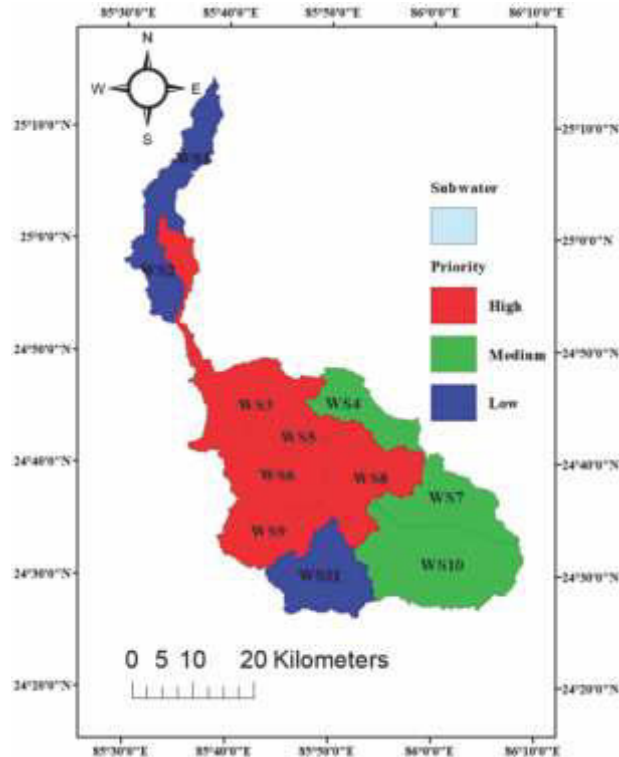
The present study demonstrates the utility of multivariate geomorphometric approach-based analysis in prioritizing sub-watershed. It can be used for evaluation and planning of rainwater harvesting and groundwater recharge structures in the Sakri basin. The seventeen morphometric parameters were assessed for all eleven sub-watershed of the Sakri river basin. Based on these parameters, soil erosion prone regions are demarcated by applying the morphometric analysis and PCA approaches, which provides a priority ranking of sub watersheds concerning with their soil erosion susceptibility. Priority ranking was used to classify the basin into high, medium and low, sensitivity of sub-watershed towards soil erosion and droughts. Based on the results of morphometric and PCA approaches, approximately 46.82%, 32.46% and 20.73% of the basin areas, and approximately 56.56%, 23.66% and 19.7% of the basin areas comes under high, medium and low priority, respectively. The priority map was developed for evaluating the surface runoff and soil erosion in the Sakri river basin. The morphometric analysis-based prioritization is more reliable and for decision making in soil and water conservation planning at sub-watershed level than the PCA approach.

Commercial potential:

A strong commercial potential in agriculture, irrigation, water management, policy planning, infrastructure, and environmental consulting.

Impact:

This technology is highly relevant in planning and developing of suitable soil and water conservation structures for mitigation and prevention of drought in the region. By leveraging this technology, various stakeholders can develop targeted climate-smart solutions, enhancing resilience, profitability and sustainability in drought-affected regions.



Priority of sub-watershed based on morphometric analysis

Agro-ecoregions suitability :

Entire areas of Sakri basin covering regions of Bihar and Jharkhand etc.

References:

Jeet P, Singh AK, Upadhyaya A, Das A, Kumar R, Sundaram PK, Kumari A, Saurabh K, Singh D, Kumar PP. 2024. A multivariate geomorphometric approach to prioritize drought prone Sakri basin for land and water resource management. *Journal of the Indian Society of Remote Sensing*. 10.1007/s12524-024-01884-4.

Model Framework for Water Harvesting Planning using Multivariate Techniques

Development period: 2020 - 2024

Developers:

Arti Kumari, Pawan Jeet, Ashutosh Upadhyaya, Anup Das

Background:

To address the growing global challenge of water scarcity, geovisualization tools such as remote sensing (RS) and geographic information systems (GIS) play a crucial role in assisting planners and decision-makers in making more accurate and effective decisions for the implementation of water harvesting strategies aimed at maximizing rainwater utilization. In this study, a weighted sum approach was employed to analyse hydrological behaviour and prioritize watershed-level interventions in Nalanda, Bihar, for the strategic construction of water harvesting structures. Based on the hydrological assessment, water harvesting interventions such as farm ponds, check dams, tanks, ahar-pynes, and conservation ditches were identified as suitable for prioritized locations to optimize surface runoff management and groundwater recharge. The findings of this study provide a scientific framework for water harvesting planning and management at the watershed and basin levels, with potential applications in diverse agro-ecological regions worldwide.

Description of the technology:

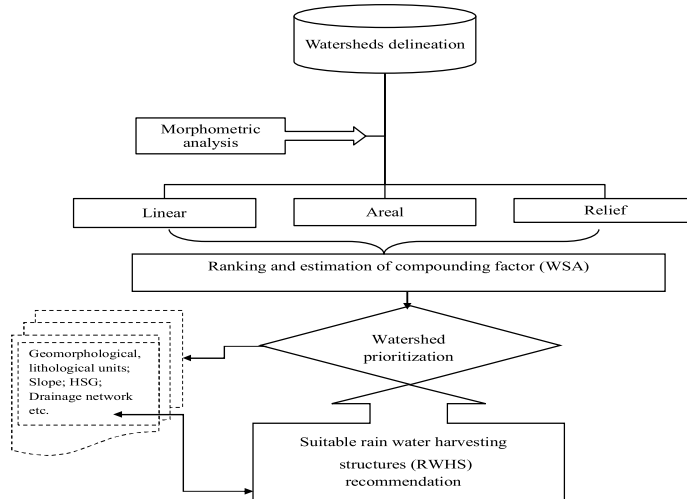
To effective water harvesting planning in Nalanda, Bihar, a detailed morphometric analysis was conducted at the watershed level using geospatial tools. Additionally, watershed-level prioritized mapping was performed utilizing the Weighted Sum Approach, incorporating various parameters such as morphometric variation, slope, hydrologic soil group, geomorphology, and lithology. The detailed methodology is illustrated below. The analysis revealed that approximately 56.30% of the study area like Rajgir falls under very high priority, followed by 30.5% under moderate priority, while 2–7% of the area was classified as low to very low priority for the implementation of water harvesting interventions. In high-priority zones, water harvesting solutions such as farm ponds, check dams, tanks, ahar-pyne systems, bunding, broad bed and furrows, and conservation ditches were recommended to enhance water resource availability and management. The findings of this study provide a scientific framework that can support policymakers, government agencies, water user associations, and other stakeholders for execution of water harvesting activities in Nalanda, Bihar.

Commercial potential:

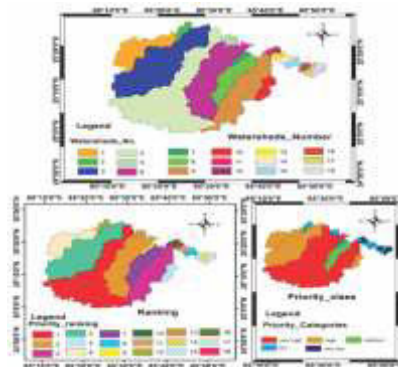
A strong commercial potential in agriculture, irrigation, water management, policy planning, infrastructure, and environmental consulting facilitating data-driven policy decisions.

Impact:

The model framework facilitates optimized water resource management, supports policy formulation and resource allocation by delivering actionable insights for effective water conservation, ensures scalability by identifying priority areas for conservation, strengthens adaptation strategies against drought and erratic rainfall, and actively engages local water user associations in sustainable water management, fostering collaborative decision-making and long-term stewardship.



Detailed Methodology for Prioritization of watersheds for water harvesting planning



Overall ranking and final priority map for water harvesting planning in Nalanda, Bihar

Agro-ecoregions suitability:

Nalanda, Bihar; similar agro-ecoregions across eastern India

References:

Kumari A, Upadhyaya A, Jeet P, Ahmed A, Prakash V, Suna, T. 2023. Morphometric Analysis and Prioritization of Watershed for Water Management using Weighted Sum Approach and Geospatial Tools: A Case Study of Harohar Sub-basin, India. *J Geol Soc India* 99, 859–867 (2023). <https://doi.org/10.1007/s12594-022-2393-y>.

Mapping Flood Prone Areas of Bihar based on Frequency

Period of development: 2020 - 2024

Developers:

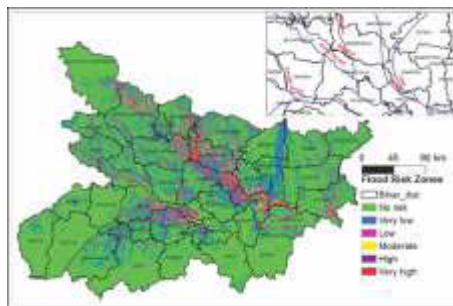
Akram Ahmed, Arti Kumari, Shivani, Ashutosh Upadhyaya, Anup Das

Background:

Bihar, one of India's most flood-prone states, faces recurrent floods that severely impact its agrarian economy by damaging crops, soil fertility, and rural livelihoods. To address this, a high-resolution flood-prone area map with submergence, depth, and duration details at the panchayat level is essential. This map serves as a scientific tool for precise flood risk assessment, enabling farmers and policymakers to make informed decisions regarding crop selection, planting schedules, and flood-resilient farming practices. By integrating this spatial information into agricultural planning, it becomes possible to enhance productivity in flood-prone areas through adaptive measures such as promoting flood-tolerant crops, improving drainage systems, and implementing water management strategies, ultimately contributing to sustainable agriculture in Bihar.

Description of technology:

The flood prone areas in Bihar was mapped up to panchayat level resolution as well as the zoning of the flood prone areas was carried out as per the flood frequency of pixel (191 m x 191 m) using Remote Sensing and Geographical Information technique. Zoning of the flood prone areas will help to identify and implement suitable area-specific agricultural interventions which will help to enhance the land and water productivity of those areas. Results showed that about 26073.0 km² area (27.6% of geographical area) of Bihar is flood prone and about 75.0% of the flood prone areas are in the North Bihar. Some of the mostly flooded districts in the state are Darbhanga, Madhubani, Purba Champaran, Muzaffarpur, Samastipur etc. Zoning of the flood prone revealed that about 525.1 km² area of the state comes under very high risk, 804.1 km² under high risk, 2461.6 km² under moderate risk, 5738.2 km² under low risk and 16544.0 km² under very low risk zone. It was also observed that most of the area under very high, high, and moderate risk flood hazard areas are located in Darbhanga, Muzaffarpur, Samastipur, Purba Champaran, Khagaria districts of the state.



A high resolution map showing flood prone areas in Bihar

Commercial potential:

Commercial potential across various sectors like Insurance companies, Real estate and urban planners, agri-tech firms to provide crop insurance and advisory services, Disaster management agencies and government bodies etc

Impact:

Scientific tool for precise flood risk assessment, enabling farmers and policymakers to make informed decisions regarding crop selection, planting schedules, and flood-resilient farming practices.

Agro-ecoregions suitability:

Flood- prone areas of Bihar

Technologies

Livestock & Fish Production and Protection



Serological Diagnosis (Indirect ELISA) of *Theileria annulata* using Recombinant spm2 Antigen.

Period of development: 2018-2022

Developers:

Pankaj Kumar, Manish Kumar, MK Tripathi

Background:

Theileriosis, caused by *Theileria annulata*, is a significant tick-borne disease affecting ruminants in tropical and subtropical regions. The disease leads to substantial economic losses due to reduced productivity, morbidity, and mortality in cattle. Bihar, located in the Gangetic plains of India, has a large crossbred cattle population that remains vulnerable to *T. annulata* infection due to high vector prevalence and climatic conditions favorable for tick propagation.

Description of the Technology:

Theileria is tick-borne apicomplexan parasite that mainly infects ruminants in tropical and subtropical regions. The present study was directed to investigate the serological methods for diagnosing theileriosis in crossbred cattle. Blood samples (n = 176) were collected from the regional cattle populations of Bihar state situated at the Gangetic plains of India. Microscopic examination of blood smears from the cattle revealed the presence of tick-borne infectious organisms (*Theileria* and *Anaplasma*) in the region, PCR-based detection of Tams1 (*Theileria annulata* merozoite surface antigen) gene and the sequencing of 18S rRNA amplicon from the blood samples confirmed *T. annulata* as the primary causative agent of theileriosis in cattle of the Bihar region. For the large-scale epidemiological investigation, sporozoite and macroschizont (spm2) partial gene from *T. annulata* was cloned in pET-28a (+) vector and overexpressed in *E. coli* BL21. Overexpressed recombinant-Spm2 (43 kDa) was purified and was used for immunodetection of theileriosis in cattle serum samples. Recombinant-Spm2 antigen was explicitly recognised by the immunoglobulins (IgG) of the cattle naturally infected with *Theileria*. Further, an indirect ELISA was developed using partial r-Spm2 antigen that exhibited high sensitivity (100%) and specificity (90.9%). Thus, this study suggests that partial r-Spm2 can be used as a diagnostic antigen for sero-epidemiological studies of *T. annulata* infection in cattle.

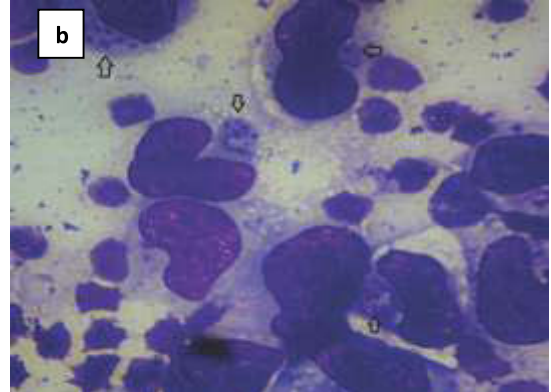
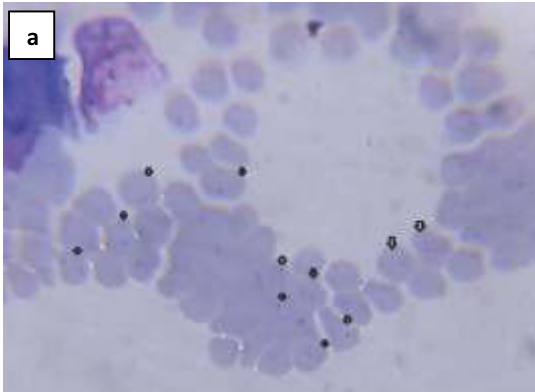
Commercial potential:

The technology can be offered through consultancy services or outsourced to the State Animal and Livestock Department, Veterinary Colleges, Development agencies, NGOs, and farmers' groups.

Impact:

Expected impact implies based on its use by practicing veterinarians and diagnostic laboratories for early specific treatment. This can prevent losses to livestock farmers in terms of reduction in the cost of treatment and production losses. The total bovine population in India is about 307 million which can get *Theileria* infection by tick bite.

However, nearly 50 million crossbred cattle population are at more risk. More than 10 million Livestock farmers throughout India can have an impact by using this technology.



- a. Giemsa stained (blood) smear examination of cattle with RBCs infected (arrow) with *Theileria* infection. b. Lymph node aspirate with infected lymphocytes with Koch's blue bodies or macro-schizont (arrow) of *T. annulata* (100x).

Agro-ecoregion suitability:

All over India

Reference:

Kumar Pankaj, Kumar A, Sarma K, Sharma P, Kumari RR, Kumar M. 2022. Development of multiplex PCR for rapid diagnosis of coinfection of tick-transmitted in bovine. *Indian Journal of Animal Research*. 55(12):1504-1509

Identification of CCL8 and CXCL10 as Early Pregnancy Biomarker in Buffaloes

Period of development: 2018 - 2022

Developers:

Rajni Kumari, S Dayal, PC Chandran, PK Ray, Sanjay Kumar, Jyoti Kumar, Reena Kamal, A Dey, Kamal Sarma

Background:

Successful pregnancy establishment has a major influence on reproductive efficiencies of dairy buffaloes. And this success depends on coordinated communications between conceptus and maternally derived cells and any disturbance in this communication network during this process leads to early embryonic losses. Present investigation aimed to understand the expression dynamics and correlation pattern of chemokines during peri-implantation period in dairy buffalo through transcriptional profiling followed by Principal Component Analysis. Our study revealed up regulation of all the candidate genes in maternal whole blood across the parity, emphasizing the involvement of immune responses as signatures for healthy pregnancy.

Description of the technology:

The study was conducted to determine the functional involvement of chemokines by studying expression profile of chemokine biomarker CCL8 and CXCL10 genes during peri-implantation period in whole blood of artificially inseminated dairy buffaloes. For this, expression profile of both these chemokine genes in whole blood of Murrah buffaloes on day 12, 15, 18 and 21 post artificial insemination (AI) using SYBR green chemistry based quantitative real time reverse transcription PCR. Our investigations revealed a consistent increase in transcriptional abundance of CCL8 and CXCL10 genes during this period, although the difference in expression level was not significant between day 15 and 18 post AI for CXCL10 gene. Study also included the effect of parity on the expression profile of these two genes and found that expression level of both these genes is independent of parity status of the animal. Our results indicate that increased expression of both these chemokines is a pregnancy dependent event and thus their expression profiling can be used as early pregnancy biomarker on any day between days 12 to 21 post artificial insemination in buffaloes. Irrespective of their parity status. The study will help in determination of positive pregnancy during early gestation in buffaloes and therefore, will improve fertility in buffaloes.

Commercial potential:

The technology can be offered through consultancy services or outsourced to the State Animal and Livestock Department, Veterinary Colleges, Development agencies, NGOs, and farmers' groups.

Impact:

The use of this biomarker may lead to socio-economic upliftment of dairy farmers

Agro-ecoregions suitability:

All over India

Reference

Kumari R, Dayal S, Sharma I, Kumar S, Chandran P C, Dey A, Ray P K, Kamal R K, Kumar J and Sarma K. 2021. Expression profiling of chemokines CCL 8 and CXCL10 during peri-implantation period in murrah buffaloes as a possible signature of embryonic implantation. *Indian Journal of Animal Sciences*, 91(8): 632-635

Spent Mahua Flower as Growth Promoting Pig Diet

Period of development: 2022-2024

Developers:

Reena Kamal, Amitava Dey, PC Chandran, Sushil Prasad, Singray Kullu

Background:

Mahua flowers are traditionally used in liquor production, leaving behind a nutrient-rich residue known as spent mahua. This byproduct contains crude protein (8-10%), and offering functional benefits beyond basic nutrition. Rich in phytochemicals like saponins and polyphenols, spent mahua supports gut health, immune modulation, and nutrient utilization in livestock. Its supplementation in pig diets promotes growth, enhances feed efficiency, and maintains digestive balance. Proper processing ensures safe inclusion by minimizing antinutritional factors. As a natural growth promoter, spent mahua holds promise for improving pig productivity and overall health.

Description of the technology:

A standard good-performance pig feed formulation incorporating 15% spent mahua has been developed to enhance growth, feed efficiency, and sustainability. The optimized diet consists of maize (50%), wheat bran (25%), groundnut cake (18.5%), fish meal (5%), mineral mixture (1%), common salt (0.5%), vitamin B complex (20 g per 100 kg of feed), and spent mahua (15%). The nutrient composition of spent mahua shows 8.80% crude protein, 12.10% crude fiber, 3.40% ether extract, and 68.50% nitrogen-free extract, contributing to improved digestion and energy utilization. Compared to the standard concentrate diet, the inclusion of spent mahua enhances fiber content, organic matter, and nitrogen-free extract. Its bioactive compounds improve gut health, nutrient absorption, and immunity, aligning with the growing demand for plant-based feed additives. With a sustainable supply from liquor industries, proper processing can enable large-scale feed formulation. Its integration into commercial feed products can create new business opportunities while supporting eco-friendly pig farming. This formulation offers a sustainable alternative feed resource. This technology leverages the nutritional potential of spent mahua to improve growth performance, feed efficiency, and overall health, and promote sustainable pig farming.



Spent Mahua flower and pigs fed spent mahua-supplemented diet

Commercial potential:

Spent mahua has strong commercial potential as a natural growth promoter in livestock feed, particularly for pigs...

Impact:

Pigs supplemented with 15% spent mahua flower achieved the highest daily weight gain of 405.98 g/pig/day) and better feed conversion, at 3.29 ± 0.16 kg feed/kg gain, indicating improved feed efficiency and optimized resource utilization.

Agro-ecoregions suitability:

Agro-ecoregions where mahua trees (*Madhuca longifolia*) are naturally abundant, particularly in tropical and subtropical regions of India. Widely available in the Eastern Plateau and Hill Region, Central Plateau, and Western Ghats, covering states like Jharkhand, Chhattisgarh, Odisha, Madhya Pradesh, and Maharashtra

Low-Cost Feed Formulation for T&D Pig

Period of development: 2022-2024

Developers:

Reena Kamal, Amitava Dey, PC Chandran, Sushil Prasad, Singray Kullu

Background:

The increasing demand for alternative, cost-effective feed ingredients has driven the exploration of agro-industrial by-products like left-over fermented rice (LFR), a by-product from traditional Handia fermentation. Handia is a locally made alcoholic drink made from rice. LFR is abundant in rice-producing regions and holds potential as a sustainable feed resource for growing piglets. The piglets fed diets containing varying levels of LFR is a cost-effective and sustainable feed solutions for small-scale farmers.

Description of the technology:

A cost-effective and nutritionally balanced feeding strategy has been developed for Tamworth and desi cross (T&D) pigs, incorporating fermented rice as a partial replacement for maize and wheat bran. This approach enhances growth performance, nutrient utilization, and reduces overall feed costs, making pig farming more sustainable and profitable. The optimized feed mixture consists of fermented rice (28%), maize (42%), wheat bran (8%), groundnut cake (14%), fish meal (5%), mineral mixture (2.5%), and common salt (0.5%), ensuring an adequate supply of essential nutrients for optimal growth. The formulated diet provides 18.28% crude protein and 2814 kcal/kg metabolizable energy (ME), supporting efficient weight gain while maintaining cost efficiency. The feed cost is significantly reduced to Rs. 34.67/kg, making it a viable alternative to conventional feed formulations. The recommended feeding strategy involves providing grower pigs with 1.5 kg per pig in the morning and 1.5 kg in the evening, ensuring adequate nutrient intake throughout the day for steady growth.

This technology leverages the benefits of fermented rice, which enhances gut health, improves digestion, and increases feed palatability, leading to better nutrient absorption and overall animal well-being. By partially replacing expensive ingredients like maize and wheat bran, this formulation offers a sustainable and affordable solution for pig farmers, making it particularly beneficial for small- and medium-scale livestock enterprises.

Commercial potential:

Technology can be licenced to Livestock feed companies, entrepreneurs, input dealers etc.

Impact:

Using locally fermented rice (LFR) in poultry feed reduces reliance on costly maize and groundnut cake, cutting feed costs to ¹ 26.17/kg while maintaining growth performance. LFR inclusion (20-28%) optimized growth (389.47-392.33g/day) and significantly lowered feed costs, enhancing profitability for both poultry and pig farmers. This sustainable approach supports eco-friendly, cost-efficient livestock farming.



**Left-over fermented rice (LFR)
after making Handia (Alcoholic drink)**



Pigs fed with LFR mixture

Agro-ecoregions suitability:

Highly suitable for agro-ecological regions with abundant rice production and active pig farming like Eastern Plateau and Hill Region (Jharkhand, Odisha, Chhattisgarh, West Bengal, Assam)

Sustainable Poultry Feed Formulation for Desi Chicken

Period of Development: 2022-2024

Developers:

Reena Kamal, Amitava Dey, PC Chandran, Sushil Prasad, Singray Kullu

Background:

Traditional poultry farming, particularly with desi (native) chicken, relies on locally available feed resources to enhance growth and productivity. Left-over fermented rice (LFR) is a promising alternative feed ingredient due to its improved digestibility, enriched nutrient profile, and beneficial effects on gut health. The fermentation process enhances nutrient availability by breaking down complex carbohydrates and reducing antinutritional factors, making LFR a suitable energy source for desi poultry.

Description of the technology:

The primary source of waste fermented rice is *Handia*, a traditional local herbal preparation, which contains 85-90% moisture. To utilize it in poultry feed, it should be dried to 30% moisture, coarsely ground, and then mixed at 20-40% levels with basal concentrate feed. A cost-effective poultry feed formulation has been developed by partially replacing groundnut cake and maize with locally fermented rice (LFR) to enhance growth performance and feed efficiency. The optimized formulations include 51% crushed maize and 20% LFR (Formulation 1) and 36% crushed maize with 40% LFR (formulation 2), while groundnut cake is progressively reduced from 5% (Formulation 1) to 0% (Formulation 2). Other ingredients such as wheat bran (18%), fish meal (5%), mineral mixture (2%), and common salt (0.5%) remain constant. Formulations provide crude protein (CP) of 16.30% to 17.42% and metabolizable energy (ME) of 2870 to 2753 kcal/kg. Formulation 2 recorded the highest body weight gain (414.54 g) with an efficient feed conversion ratio (FCR: 1.56) at a significantly reduced feed cost of ¹ 26.17/kg, compared to conventional formulations. This approach demonstrates the potential of LFR as a sustainable and economical alternative to conventional protein and energy sources in desi poultry feed.



**Left over fermented rice (LFR) after
Hadia extraction**



**Poultry fed with fermented rice
formulated feed**

Commercial potential:

This technology can be licensed to livestock feed companies, entrepreneurs, and input dealers. Feed manufacturers, startups, and farmer cooperatives can adopt this formulation to enhance profitability and promote eco-friendly poultry farming.

Impact:

Inclusion of LFR @ 20-40% in desi chicken grower ration demonstrated the highest body weight gain (410.04 to 414.54 g/bird) and the best feed conversion ratio (FCR: 1.56), providing the optimal balance between performance and cost.

Agro-ecoregions suitability:

Highly suitable for agro-ecological regions with abundant rice production and active backyard poultry farming like the Eastern Plateau and Hill Region (Jharkhand, Odisha, Chhattisgarh, West Bengal, Assam)

References: प्रसार पुस्तिका संख्या:—E-225/Ranchi-88 (2024) सूखे किण्वित चावल से देशी मुर्गियों का आहार: लागत प्रभावी एवं स्थायी विकल्प

Breeding, Rearing and Juvenile Seed Production of Magur Fish (*Clarias magur*)

Period of Development: 2017-2020

Developers:

Kamal Sarma, Surendra Kumar Ahirwal, Bavithra R, Jaspreet Singh, Ujjwal Kumar, Tarkeshwar Kumar

Background:

Clarias magur, popularly known as magur, is the most promising but endangered species among the catfishes for freshwater aquaculture in India. It was declared as the state fish of Bihar. Its population is decreasing at an alarming rate due to high fishing pressure, pollution, habitat loss, injudicious use of herbicides, etc. The non-availability of quality fish seed is one of the major bottlenecks to culture this species. So, efforts were made to standardize and develop induced breeding technique in magur and subsequently, rearing of fry for the production of juveniles to sort out the seed scarcity related issues.

Description of the technology:

Magur, is a commercially important and high value fish species. Breeding and growth performance of magur at various stages were estimated and an optimum protein requirement for high growth and survival rate for juvenile was standardized for commercial seed production. Seed production from breeding to juvenile can be done in three steps:

Spawn production:

Good quality magur should be collected and maintained in the earthen pond before the onset of breeding. Breeding performance of this species was estimated using the WOVA-FH hormone. Out of four hormonal doses (0.5, 1.0, 1.5 and 2.0 ml/kg body weight of female), the percentage of fertilization (70.23%), percentage of hatching (85%), and survival rate (40.75%) were the highest when females were injected with 1.0 ml of WOVA-FH hormone per kg of body weight. Hence 1.0 ml WOVA-FH hormone per kg of body weight can be applied for magur breeding.

Fingerling production:

A 120-day growth performance studies has been carried out on magur fry to develop quality fingerlings. For that, eight-day-old fries (Av. weight 2.85 mg) can be collected and used for fingerling production. It was found that fined meshed egg custard, fishmeal-based



Stepwise method for juvenile seed production of magur species

starter feed (38-40% protein) etc., achieved better growth and survival. At the end of the 120 days of rearing around 26-35% survival can be achieved.

For juvenile production:

A 90-day growth performance study was carried out on magur fingerling (average 19.10 g) to optimise the protein requirement. Results revealed that 30-35 % protein level is the best for growth of *C. magur* fingerlings and hence should be given, which can be prepared by mixing different locally available feed ingredients.

Commercial potential:

It has huge potential as there is hardly any commercial seed production farm available in Bihar to produce magur seed.

Impact:

Seed production of magur enables conservation and propagation of this endangered species in freshwater aquatic ecosystem.

Agro-Eco regions suitability:

Suitable for aquatic ecosystem of Bihar and Assam

Reference:

Sarma K, Bavithra R, Singh J, Ahirwal SK, Kumar U, Kumar T, Dubey MK. 2025. Standardization of breeding and rearing of the endangered Indian catfish *Clarias magur* (Hamilton, 1822) for juvenile production, *Aquaculture Reports* 40 (2025) 102600, <https://doi.org/10.1016/j.aqrep.2024.102600>

Optimization of Integrated Fish Farming Systems for Livelihood Improvement of Small and Marginal farmers of Eastern Region

Period of Development: 2016-2024

Developers:

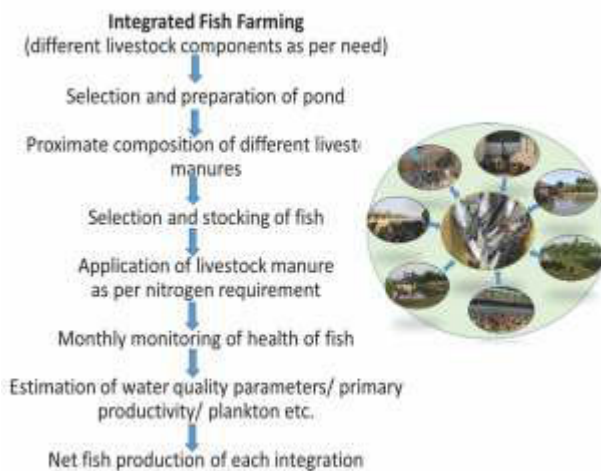
Kamal Sarma, Amitava Dey, Snatashree Mohanty (CIFA, Bhuaneswar), Tarkeshwar Kumar, SK Ahirwal, Jaspreet Singh, BP Bhatt, Anup Das

Background:

Integrated fish farming system (IFFS) is a diversified and coordinated method of farming system, where agriculture and/or animal husbandry are integrated with fish so that wastes or by-products generated from each sub-system are used as inputs to other sub-systems. IFFS is ecologically efficient and generated less pollution as most of the materials are recycled. Cattle, buffalo, poultry, pig, duck and goat are most common farm animal and most of farmers maintained them. Research gap lies in standardization of stocking density of fish seed and livestock/birds in varied agro-climatic zones; assessment of water quality parameters; microbial profile; etc. Hence, study was conducted to optimise the fish production system from different animal dung.

Description of the technology:

Because of high cost of feed (nearly 50% of total production cost), many poor and marginal farmers in traditional system, do not use any feed in the pond and thereby get very low level of production (1.0 t/ha) as well as survival. Using animal dung in fish production can result in relatively much higher fish production compared to traditional systems. Efforts were made for Standardization of application of different manures to optimize fish production under IFFS.



Integration of livestock manures for IFFS

The techniques were developed from study in eight identical fish ponds (800 m²) with an average depth of about 1.5 m. Six integrations were attempted *viz.* cattle- fish, buffalo – fish, goat- fish, duck –fish, poultry – fish and pig-fish along with one in only artificial feed and another without any feed and manure (traditional system). For this integration advance fingerlings of six species *ie.* rohu, catla, mrigal, grass carp, batta and puthi were stocked in the fish pond at a stocking density of 10,000 per ha. Results shown that critical parameters

were within the tolerance limit of fish culture and there was no health issues in fish in all the six integrations. The average productivity was highest for cattle-fish (4.0-4.50 t/ha) followed by pig-fish integration (3.4-4.0 t/ha). The data also revealed that the fish rearing with concentrate feed was able to increase a fish yield to 5.3-5.9 t/ha/y while traditional system can yield only around 0.8-0.9 t/ha.

Commercial potential:

It has good potential to enhance farm productivity and income of small and marginal fish farmers having small land holding.

Impact:

This technology will be beneficial for small and marginal farmers, especially those having livestock with them. With minimum expenditure relatively higher production compared to traditional farming system can be achieved. These techniques will also facilitate efficient utilization of animal excreta for production purpose.

Agro-Eco regions suitability:

Suitable for small holders of whole eastern region of India.

Formulation of Vitamin-mineral Enriched Diet for Quality Seed Production and Survival of Rohu (*Labeo rohita*)

Period of Development: 2016 - 2019

Developers:

Kamal Sarma, SK Ahirwal, Ujjwal Kumar, Amitava Dey, SK Nayak, Tarkeshwar Kumar

Background:

The aquaculture sector of Bihar offers great potential for enhancing fish production for the domestic market. Despite various development in seed rearing technologies, the survival rate of spawn and fry is very low, which is one of the most crucial factors determining sustainability of carp seed hatcheries. The average survival rate of carp fry hardly exceeds 25-35%. Rice bran and mustard oil cake are the most common feed ingredients used extensively by the farmers. Various methods and inputs were attempted by researchers to increase the survival of fry by adding various feed supplements. An attempt was made to produce a fortified traditional feed with vitamin- mineral mixture.

Description of the technology:

Rice bran and mustard oil cake purchased from the local market and powdered. As per the requirements for a week, these two ingredients were mixed in equal proportions and stored in moist-free condition. Every day other supplements like vitamin- mineral mixer (commercially available), vitamin C and minerals (inorganic form ie. ZnSO_4 , MnSO_4 and CuSO_4) were mixed thoroughly. Two formulations of fish feed were prepared as per following details:

Feed 1: Rice bran + oil cake at 1:1 ratio (99%)+vitamin-mineral mixture (0.9%)+vitamin C (0.1%)

Feed 2: Rice bran + oil cake at 1:1 ratio (99%) + vitamin- mineral mixture (0.9%)+vitamin C (0.1%)+minerals (i.e, Zn: 30 mg kg⁻¹ feed; Cu: 3 mg kg⁻¹ feed and Mn: 10 mg kg⁻¹ feed).

Feeding can be done in the morning and afternoon hours at the rate of 10% of the body weight. With the feeding of Feed 1 and Feed 2, survival rate of fish could be enhanced. Similarly higher percentage weight gain could be achieved compared to traditional feed. This may be because of positive effect of vitamin C and mineral supplementation.

Commercial potential:

The technology can be utilized to produce bio fortified fish feed.



Impact:

Many farmers are practicing farm-made feed for feeding fishes in the nursery, rearing as well as in composite fish culture system. By incorporation of vitamin C and minerals along with rice bran and mustard oil cake can be more remunerative in terms of generating higher revenue from selling fish seed, apart from influencing higher growth and survival of fish.

Agro-Eco regions suitability :

Suitable for fresh water aquaculture in eastern region of India.

Reference:

Sarma K, Subhash C, Kumar U, Dey A, Nayak SK. 2022. Effect of vitamin C and mineral enriched diet on growth and survival of *Labeo rohita* fry. *Indian J. Fish.*, 69 (3): 28-35. doi:10.21077/ijf.2022.69.3.112822-04.

Grass Carp Cultivation Using Seasonal Forage and Aquatic Crops

Period of development: 2017-2019

Developers:

Surendra Kumar Ahirwal, Kamal Sarma, Amitava Dey, Tarkeshwar Kumar, Vivekanand Bharti, Jaspreet Singh, Rakesh Kumar

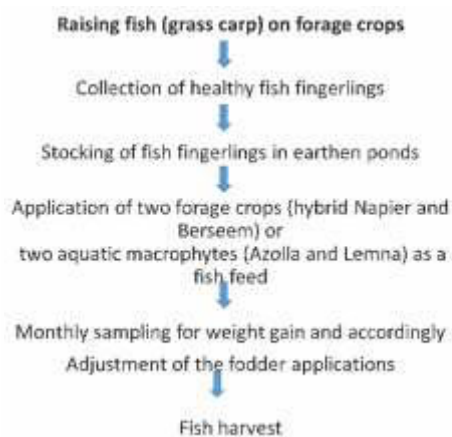
Background:

Fish feed accounts for almost 50-70% of the total production costs based on types of culture systems, feeding intensity and cost of feed ingredients. Growth of fish to attain marketable size within the shortest possible time depends on a high-quality, nutritionally balanced diet. Higher demand of conventional protein sources such as fish meal, fish oil etc., forced poor fish farmers to look for cheap and locally available ingredients for fish diets. Grass carp can survive on various green grasses and aquatic vegetation and can be cultured without supplemental concentrate feed. Hence, an attempt was made to record the comparative performance of forage plants and aquatic macrophytes on the growth performance of grass carp in a pond culture system.

Description of the technology:

Low-input fish production has significant importance under village level production system. Farmers often raise the fish without supplementation of concentrate feed due to high cost of feed. Grass carp production could be achieved using forage crops without supplementation of concentrate feed. Two forage crops (hybrid Napier and Berseem) and two aquatic macrophytes (Azolla and Lemna) were used directly as fish feed.

The overall specific growth rate (SGR%), average daily weight gain, feed conversion ratio, average fish body weight, harvested biomass and estimated fish production were significantly higher under feeding regimes of forage crops, while the survival rate was significantly high under feeding regimes of aquatic macrophytes. Fish reared under forage crops showed significantly higher estimated net fish production (6.18 tonnes/ha), harvested biomass (401.98 kg), and final average body weight of around 1.14 kg. It is a low input production system without supplementation of concentrate feed. The system is self-sustained as forage crops are grown on pond dyke or on the pond water.



Commercial potential:

Our research demonstrates that, in comparison to the utilization of aquatic macrophytes, the aquaculture of grass carp with forage crops at 10% of feeding rate gives higher fish production. Hence, farmers can use terrestrial forage fodder for feeding fish also.

Impact:

Use of forage crops and chopped Napier grass for fish had significant impact as overall specific growth rate, average daily wt. gain and feed conversion ratio of grass carp were higher. So, this can be utilized by farmers for better growth.

Agro-Eco regions suitability:

Suitable for resource poor fish farmers of eastern India.

Reference

Ahirwal SK, Sarma K, Dey A, Kumar T, Bharti V, Singh J. 2024. Investigations on growth performance of grass carp *Ctenopharyngodon idella* (Cuvier and Valenciennes, 1844) under forage crops and aquatic macrophyte feeding regimes, *Indian J. Fish.*, 71 (1): 121-127. doi:10.21077/ijf.2024.71.1.134996-14

Mitochondrial Genome Maps of Duck Germplasm Inhabiting Eastern Region of India

Period of development: 2020-2024

Developers:

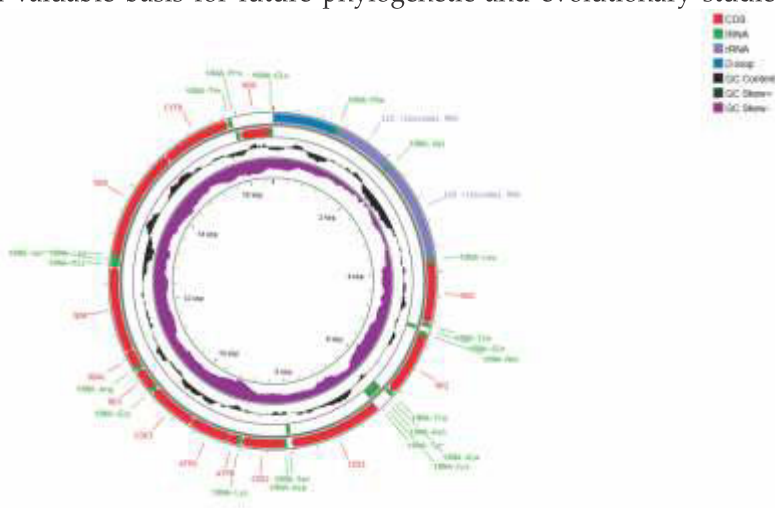
Rajni Kumari, Ratna Prabha (IARI, New Delhi), PK Ray, Shankar Dayal, Reena Kumari Kamal, PC Chandran, Amitava Dey, Jyoti Kumar, M K Tripathi, Sanjay Kumar (Dept of Animal Nutrition, BVC, Patna), Kamal Sarma

Background:

Eastern India accounts for 64.5% of the duck population in the country. Recognizing the mitochondrial genome as a crucial tool for breed preservation and lineage tracking, sequencing and mapping of the mitochondrial genomes of duck germplasm in this region was conducted to aid conservation efforts and genetic studies in future.

Description of the technology:

This is the first report on the complete mitochondrial genome characterization of various duck germplasms from eastern India. The mitochondrial genomes of ducks from eastern India (Indian Runner, Khaki Campbell, Chhattisgarh, White Pekin, Bihar, Bengal, and Maithili) were generated with accession numbers OQ561754 to OQ561760. These genomes exhibited typical circular structures with similar lengths, ranging from 16,604 bp (Bengal, Chhattisgarh, Indian Runner, Khaki Campbell) to 16,607 bp (Maithili). Each genome contained 37 genes, including 22 tRNAs, 2 rRNAs, 13 protein-coding genes (PCGs), and a non-coding D-loop region. In these mitogenomes, most PCGs (except ND6 and COX1) and rRNAs were located on the heavy strand. Most tRNAs, except for tRNA Ile, tRNA Trp, tRNA Ala, tRNA Asn, tRNA Cys, tRNA Thr, and tRNA Pro, were also found on the heavy strand. Gene order and AT content were consistent across all seven genomes. These findings provide a valuable basis for future phylogenetic and evolutionary studies on Anatidae species.



Representative circular mitochondrial genome map of Chhattisgarh duck

Commercial potential:

It will be utilized in future for conservation and propagation of indigenous ducks in Eastern Region. The genetic profiling of these resources will help in developing scientific breeding strategies focused on conservation efforts.

Impact:

These findings offer significant insights into the genomic evolution of native duck species and may serve as a basis for future research on their evolutionary links and domestication process. Moreover, this information will contribute to the development of strategies for safeguarding these genetic resources.

Agro-Eco regions suitability:

Suitable for developing breeding strategies in Eastern India.

Reference

Kumari R, Prabha R, Ray PK, Dayal S, Rao GT, Kamal RK, Chandran PC, Dey A, Kumar J, Tripathi MK, Kumar S, Sarma K. 2024. Molecular characterization and sequencing of the whole mitochondrial genome of native duck breed Maithili (*Anas platyrhynchos*), *Gene Reports* 37: 102087. DOI: 10.1016/j.genrep.2024.102087.

HSP70 as Marker for Heat Stress in *Murrah* Buffalo

Period of development: 2015-2019

Developers:

Shanker Dayal, Birendra Kumar (BASU, Patna), PK Ray, Rajni Kumari, Jyoti Kumar, PC Chandran, Kamal Sarma

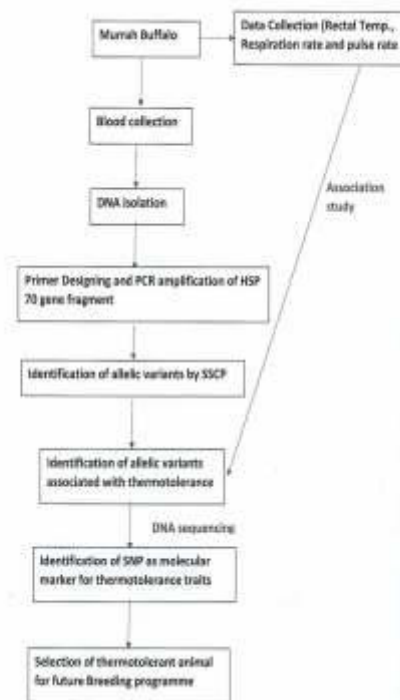
Background:

Buffaloes particularly have poor heat tolerance capacity compared to other domestic ruminants and are more stress prone due to scarcely distributed sweat glands, dark body colour and sparse hair on the body surface. There is considerable genetic variation exist among animals for cooling capacity, which suggest that more heat tolerant animal can be selected genetically. The HSPs are a group of highly conserved proteins that are induced by elevated temperatures or a variety of cellular stresses. Among the HSPs, HSP70 plays a significant role in cellular thermo-tolerance by escalating the chaperone activity in the cytoplasm and its expression acts as a potential indicator of animal adaptation to harsh environmental stress.

Description of the technology:

A total of 50 Murrah buffaloes were selected & their Genomic DNA was isolated. Primers were designed on the basis of published sequences available at NCBI. A 503 bp fragment of HSP 70 gene was amplified. Single strand conformation polymorphism (SSCP) technique was used for identification of various allelic variants of HSP70 gene in *Murrah* buffalo. Identified allelic variants are associated with various physiological parameters like rectal temperature, respiration rate, pulse rate, blood profile and Hormonal profile as indicator of heat stress.

Three genotypes (AA, AB and BB) for HSP 70 gene in Murrah buffalo were identified through SSCP. The allelic variants were due to single nucleotide substitution at 55th base position leading to a change of threonine (A) to methionine (B) in amino acid sequence. The SSCP genotypes had significant effect on different thermo-tolerance traits in summer with thermo-humidity index of e'' 84. Buffaloes with



Identification of molecular markers for heat stress in murrah buffalo

AA genotype had the highest ($P \leq 0.05$) summer evening rectal temperature, respiration rate and pulse rate, inferring that the buffaloes carrying AA genotype had more stress in summer than those with AB and BB genotype. The sequence alignment of both allelic variants A and B revealed that B allele differed from A by having thymine instead of cytosine at 55th position of nucleotide sequence. This substitution of cytosine into thymine led to change in amino acid sequence where threonine (T) in A allele got replaced by Methionine (M) in B allele. These alleles can be used as marker for thermotolerance in Murrah buffalo.

Commercial potential:

Multiple sectors, including livestock breeding, dairy farming, veterinary diagnostics, precision livestock farming, biotechnology, and climate resilience initiatives

Impact:

These findings will help in selection thermotolerant animal for future breeding program for mitigating effect of heat stress leading to increase in milk production and prevention of various diseases. This will increase the profitability of livestock farmers.

Agro-Eco regions suitability:

All over India

Reference

Kumar B, Sahoo AK, Dayal S, Das AK, Taraphder S, Batabyal S, Ray PK, Kumari R. (2019) Genetic pro-filing of Hsp70 gene in Murrah buffalo (*Bubalus bubalis*) under sub-tropical climate of India. *Cell Stress Chaperones*, 24(6): 1187–1195

Effect of Glucosamine Supplementation on Egg Laying Performance of Chicken

Period of development: 2017-2019

Developers:

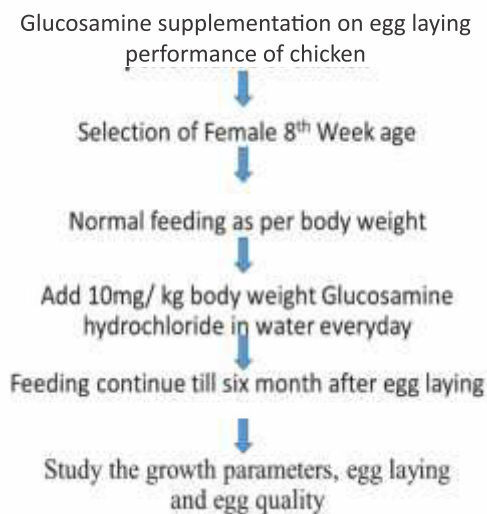
MK Tripathi, Reena Kumari Kamal, Rajni Kumari, RK Raman, Pradip Ray, PC Chandran, Shankar Dayal, Amitava Dey, Kamal Sarma

Background:

Egg laying performance is an important desirable trait for poultry farmers. Glucosamine, an amino derivative of glucose and the basic structural unit of chitin and chitosans, is a dietary supplement. There are reports that supplementation of glucosamine sulphate in the diet resulted in enhanced weight gain in broilers and can be included in the diets of broiler chickens to prevent and reduce the incidence of locomotor problems. Glucosamine rapidly activates leptin production which has role in onset of puberty. Feeding glucosamine may reduce the age of onset of sexual maturation and result in the greater egg production in poultry.

Description of the technology:

The study was conducted on Vanraja chicken maintained at ICAR-RCER, Patna, Bihar. The parent stock was maintained in deep litter system. Eggs were collected, cleaned and transferred to automated incubator at optimum temperature and humidity. The hatched chicks were grown as per standard protocol. Female birds at 8 weeks of age having similar body weights were divided into three equal groups i.e. control (C), Group 1 (G1), and Group 2 (G2) and kept in cage housing system. Group 1 and Group 2 were supplemented with glucosamine hydrochloride @ 10 and 20 mg/kg body weight/day, respectively, in the drinking water. All the birds were kept under good nutritional and management condition. Egg production was recorded for six months from all the groups. The age at first egg laying in control, G1 and G2 groups was 164.16 ± 5.41 , 159.16 ± 3.31 and 162.33 ± 7.42 days respectively. A significant difference ($p < 0.05$) was observed in G1 group as compared to control. The data revealed that the age of first egg is lesser in G1 and G2 as compared to control. Total egg production per bird in control, G1 and G2 from start of egg laying to six month were 78.77, 85.07, 73.85 eggs respectively showing the highest egg production for first six month in G1 group.



Commercial Potential:

Various sectors like poultry farming, feed industry, veterinary pharmaceuticals, biotechnology, and nutraceuticals.

Impact:

Stakeholders may be benefitted by using glucosamine in the feed @10 mg/kg body weight.

Agro-Eco regions suitability:

Suitable for poultry rearing regions of Eastern India.

References:

Tripathi MK, Kamal RK. 2024. Effect of glucosamine supplementation on egg laying Performance of chicken, Compendium of Lead papers and abstract, APACON 2024, Pp-170.

Identification of Novel SNP Marker within the PROP1 Gene Associated with Growth Characteristics in Goat

Period of development: 2022-2024

Developers:

Rakesh Kumar, PC Chandran, Shanker Dayal, Rajni Kumari, Reena Kamal, PK Ray, Jyoti Kumar, Amitava Dey, SK Ahirwal, Kamal Sarma, Anup Das

Background:

Growth is a key economic feature of the goat industry. The PROP1 gene, known as the Prophet of POU1F1, is crucial in regulating the expression of growth hormone, prolactin, and thyrotropin subunits via the PIT1 factor. This research aims to identify genetic variants of the PROP1 gene and evaluate their relationship with growth traits in Assam Hill goats, providing valuable insights for conserving goat genetic resources and enhancing breeding strategies.

Description of the technology:

The current research investigated the genetic variations within the targeted regions (Intron 1, exon 1 and exon 2) of PROP1 gene in Assam Hill goats. Blood samples were collected from the Assam Hill goat, and genomic DNA was extracted utilizing the Qiagen DNeasy Blood and Tissue Kit. Two sets of PCR primers were designed using Primer3 Plus software, explicitly targeting regions of the PROP1 gene. PCR-RFLP was employed to genotype every individual. In the present study, two single nucleotide polymorphisms (g.748G>A and g.1860C>T) within the PROP1 gene were reported for the first time in the Assam Hill goat. AA and CC genotypes displayed slightly higher values in most of the morphometric traits than other genotypes; however, body length, chest girth, and wither height were statistically significant ($P<0.05$) in Assam hill goat. Hence, AA and CC genotypes are considered molecular markers for superior growth traits in tested breed.



Fig.1 PCR amplification product of PROP1 Gene in Assam Hill goat

Fig.2 PCR-RFLP of SNP locus (g.748G>A) in PROP1 gene of Assam Hill goat

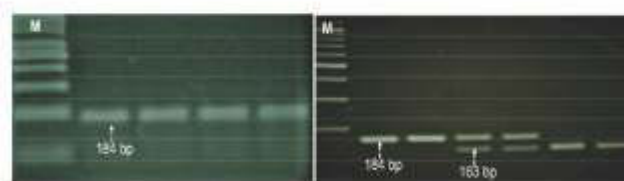


Fig.3 PCR amplification product of PROP1 Gene (g.1860C>T) in Assam Hill goat

Fig.4 PCR-RFLP of SNP locus (g.1860C>T) in PROP1 gene of Assam Hill goat

Commercial potential:

A viable candidate gene for goat breeding, used in goat farming industry, feed industry, veterinary pharmaceuticals.

Impact:

Researchers can use this technology for formulation of future goat breeding policy.

Agro-Eco regions suitability:

Suitable for conservation and breeding of goats in eastern India.

References:

ICAR RCER Newsletter

Genetic effects of STAT3 gene polymorphism on body Size traits in Assam Hill goats

Period of development: 2022 - 2024

Developers:

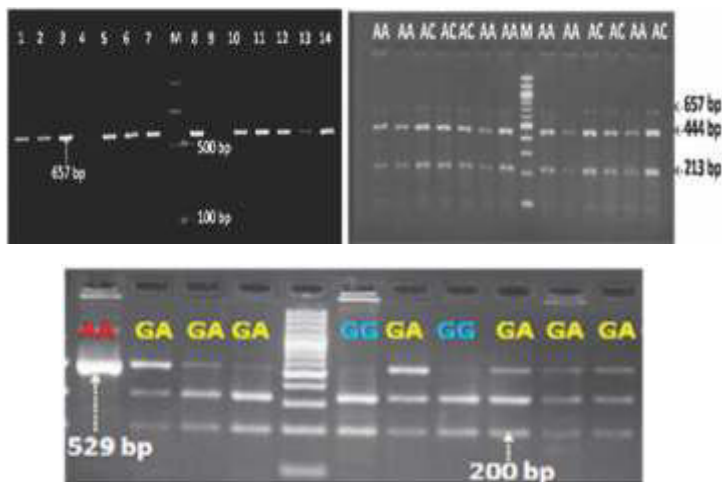
Rakesh Kumar, PC Chandran, Shanker Dayal, Rajni Kumari, Reena Kamal, Amitava Dey, PK Ray, Jyoti Kumar, MK Tripathi, SK. Ahirwal, Kamal Sarma and Anup Das

Background:

Body size represents a pleiotropic array of characteristics crucial for livestock's genetic breeding programs. Signal transducers and activators of transcription (STATs) are a vital group of transcription factors essential for the cellular growth triggered by cytokines. Hence, STAT3 may be a promising candidate gene for applications in livestock breeding and genetics. This is the first report to identify and assess the genetic impacts of candidate genes linked to growth and development in Assam Hill goats.

Brief description of the technology:

Blood samples were collected from the Assam Hill goat, and genomic DNA was extracted utilizing the Qiagen DNeasy Blood and Tissue Kit. PCR primers were designed using Primer3 Plus software, explicitly targeting regions of the STAT3 gene. We employed PCR-RFLP to identify polymorphic loci (SNP1: g.42111147A>C-*Msp*I & SNP2: g.42111756 G>A-*Taq*I) and investigated their relationship with growth parameters, marking the first report in Assam Hill goats. Association studies indicate that the AA and GG genotypes showed marginally elevated values for specific biometric traits compared to the other genotypes; however, only body length and chest circumference revealed a significant correlation ($P < 0.05$). Consequently, the AA and GG genotypes could serve as promising markers for enhanced growth characteristics in the examined goat breed. However, additional studies involving larger sample sizes and a variety of breeds will be necessary to confirm these findings.



PCR product and genotypes of STAT3 gene

Commercial potential:

The results of our research demonstrate that the AA and GG genotypes show superior growth traits in comparison to other genotypes, indicating that STAT3 may be a promising candidate gene for goat breeding.

Impact:

Genotypes that impact the growth performance of goats have been identified to aid in the implementation of marker-assisted selection, following validations conducted across a wider variety of goat breeds and larger population sizes.

Agro-Eco regions suitability:

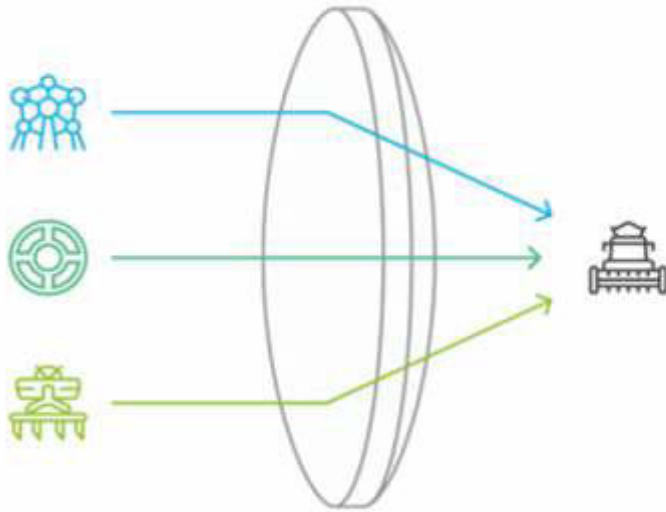
Suitable for marker assisted breeding of goats in eastern India.

References:

Abstract presented in “XVIII Annual Convention of ISAGB and National Conference ISAGBCON 2024 on New Vistas in Harnessing Genetic Resources for sustainable Animal Production, 21-22 November, 2024” at BASU, Patna (Bihar)-800014.

Technologies

Farm Mechanization and Post-Harvest



Design and Development of Solar Operated Hold-on Type Paddy Thresher

Period of development: 2018 - 2022

Developers:

SS Mali, JS Choudhary, PK Sundaram

Background:

Traditional paddy threshing methods, including manual beating and liquid fuel-based threshers, are labour-intensive, time-consuming, and environmentally unsustainable. The increasing cost and scarcity of fossil fuels further highlight the need for energy-efficient, eco-friendly alternatives in smallholder rice farming.

Description of the technology:

The developed solar operated hold-on type paddy thresher is an ergonomically designed thresher-winnower as an alternative to non-environment friendly, liquid fuel-based paddy threshers. The machine performs winnowing and threshing operations simultaneously leading to considerable savings in time, labour and money involved in paddy threshing. The solar operated paddy thresher is provided with three solar panels of 325W each leading to peak time power generation of 975 Wp. The winnower and threshing drum are provided with two separate DC motors of 500W and 250W capacity, respectively. The capacity of the solar panel is designed to provide 6-7 hours of continuous operation on a particular day. The machine is designed for battery less operation leading to reduced capital and maintenance costs. The speed of winnower fan and the threshing drum can be controlled to prevent blowing away of good quality grains or to avoid mixing of straw parts in the clean grains. The present thresher-winnower is configured for easy transport with provision of rubber matted four-wheel support along with a mechanism for folding and unfolding of solar panels during transport



Solar Operated hold-on type paddy thresher

Commercial potential:

High commercialization potential through licensing the design to private companies, State Agricultural Department, development agencies, FPOs, NGOs, and farmers' groups.

Impact:

The solar-operated paddy thresher enhances efficiency, sustainability, and cost-effectiveness by eliminating fossil fuel dependence and reducing operational costs. Its simultaneous threshing and winnowing save time, labor, and money, while adjustable speed controls ensure better grain quality. Designed for easy transport and battery-less operation, it provides 6–7 hours of continuous use, promoting clean energy adoption and sustainable farming.

Agro-ecoregions Suitability:

All over India

Solar Irrigation Pump Sizing Tool

Period of development: 2021 - 2022

Developers:

SS Mali, PB Shirsath, S Verma and AK Sikka

Background:

In most regions in the 'Global South' solar photovoltaic pumps can offer 1,400-2,200 peak-hours of reliable and affordable green energy for Irrigation with unit costs declining by the day, and significant promotion by state and union government, it is not surprising that solar pumps are rapidly expanding in India. Over the next few years, PM-KUSUM, the Government of India's ambitious campaign is expected to invest 34,035 crores (US\$ 4.6 billion) to support the installation of 3.5 million solar irrigation pumps. This can help significantly expand irrigated area; make irrigation more affordable and accessible for smallholders, reduce pressure an electricity utility to supply electricity to farmers, eliminate pump irrigation's carbon footprint, and improve the overall returns from agriculture. Selection of optimally sized solar pumping systems is a challenging task, not least because farmers' demand for energy for irrigation is a complex, derived demand.

Description of the technology:

The solar pumping system sizing involves a set of complex algorithms, each addressing the specific module in the design procedure. Several technical, biophysical and social factors govern the pump set size, which needs to be properly taken care while designing a matching solar pumping system. The Solar Irrigation Pump Sizing (SIPS) tool is aimed at assisting farmers, researchers and technical persons involved in adoption and promotion of solar pumping systems across India. The tool has universal applicability in the sense that it uses nationwide datasets on climate, soils and crops. Wherein users can fetch the required data for the location of interest. It is comprised of four modules viz. crop water requirement module. Discharge estimation module, head loss estimation module and the pump selection module which works on the principles laid down by the Ministry of New and Renewable Energy (MNRE).



Solar Irrigation Pump Sizing Tool

Commercial potential:

The technology can be offered through licensed, or outsourced to the State Agricultural Department, development agencies, FPOs, NGOs, and other beneficiaries.

Impact:

The SIPS tool optimizes solar pump selection by accurately assessing crop water needs, discharge, and head loss, ensuring efficient irrigation and cost savings.

Agro-ecoregions suitability:

All over India

References:

Mali SS, Shirsath PB, Verma S, Sikka AK. 2021. Solar Irrigation Pump Sizing Tool. Version 1.0 User Manual, ICAR, CCAFS-CIMMYT, IWMI and GIZ collaborative project. New Delhi.

Custom Hiring Centre (CHC) for promotion of Climate Resilient Agriculture

Period of development: 2020 - 2024

Developers:

Abhay Kumar, Ujjwal Kumar, Mohd Monobrullah, PK Sundaram, DK Singh, Rakesh Kumar, RK Raman, Ramkewal, Anup Das

Background:

Climate-resilient technologies like zero tillage, laser land leveling, and raised bed planting require costly machinery, which most small and marginal farmers in Bihar (>90%) cannot afford. A Custom Hiring Center (CHC) provides an affordable solution by offering farm equipment on rent, benefiting both farmers and service providers at reasonable rate. Under the Climate Resilient Agriculture (CRA) Program, ICAR-RCER, Patna, and KVK, Buxar, identified the need for a CHC through a survey and established a well-equipped center in Buxar since 2019. This initiative has promoted large-scale adoption of resource conservation technologies, enhancing farm mechanization and climate resilience.

Description of the technology:

A Custom Hiring Centre (CHC) was established at Krishi Vigyan Kendra, Buxar, Bihar, to improve access to agricultural machinery and promote the adoption of climate-resilient farming practices. The center provides a range of resource conservation machinery, including the Happy Seeder, Multi Crop Planter, Raised Bed Planter, Tractor Mounted Sprayer, Cultivator, and Laser Land Leveler for rent. To assess the needs of local farmers, a baseline survey was conducted, identifying the lack of major farm machinery as a significant barrier to adopting resilient sowing methods, efficient fertilizer application, and harvesting techniques. Based on these findings, a list of essential machinery was procured under the CRA program. The rental rates were set at affordable levels to ensure accessibility for small and marginal farmers, many of whom cannot afford to purchase such equipment. A large number of training and skill development programs were organized, with on-field demonstrations conducted to increase awareness and encourage the adoption of these modern farming techniques. In the 2022-23 period, the CHC generated a revenue of ₹ 1,77,646, covering 119.5 ha of land. The centre became a vital resource for nearby farmers, particularly those outside the CRA program, allowing them to reduce labour costs and improve productivity. Furthermore, the availability of these machines significantly accelerated the adoption of climate-resilient agriculture practices, offering a path toward more efficient, cost-effective farming in a region where many farmers face economic constraints.

Commercial potential:

The CHC model has strong commercial potential as a hub for agricultural machinery supply and services, enhancing farmers' access to equipment. The institute currently generates around ₹ 1 lakh annually from the CHC center in Buxar. This technology can be

outsourced to the State Agricultural Department, development agencies, FPOs, NGOs, and farmers' groups for wider adoption.



Custom Hiring Centre (CHC) at Buxar

Impact:

The custom hiring centers provide machineries for planting, fertilizer application, weeding and harvesting purposes in different crops. Use of zero tillage method resulted in increase in wheat productivity by 10-15% while for lentil, chickpea and mustard productivity increased by 15-25%. Due to mechanization & saving of labour, cost of cultivation significantly reduced by Rs 4-6 thousand per ha. The results showed saving of water also by 20-30 %.

Agro-ecoregions suitability:

Small and Marginal Farmers of Bihar

References:

Annual Report, ICAR Research Complex for Eastern Region, Patna (2021).
<https://icarrcer.icar.gov.in/annual-reports/>

Over the Plant (OTP) Manual Weeder for Row Crops

Period of development: 2011 – 2014

Developers:

Prem K Sundaram, A Rahman, A K Singh

Background:

Weed infestations can reduce crop yields by over 45% and degrade produce quality. Effective early-stage weed control is essential, with non-chemical methods preferred to avoid ecological harm. Mechanical weeding improves soil aeration, loosening, and moisture conservation. While manual weeders are cost-effective for small farms (0.25–2.0 ha) in India, they struggle to remove weeds near crops. To address this, a prototype manual weeder with adjustable blades was developed, offering flexible working widths and improved ergonomics for local farmworkers.

Description of the technology:

A prototype manual-operated weeder was developed based on design considerations and past research. It was designed to be effective for weeding up to 45 days after crop establishment, as weeds tend to be suppressed by the crop canopy afterward. The weeder's wheel diameter was set at 300 mm, and the separation between the wheels was 240 mm, considering the crop's potential canopy size after a month. The handle, made from 25 mm mild steel pipes, was designed to accommodate the average grip size of female workers, with adjustable length to fit different operators. The wheel frames were connected by curved rods for plant safety and height adjustments. The cutting blades were designed to slice weeds at a shallow depth of 10-25 mm, in line with research. To ensure comfort and safety, the weeder's weight was kept under 10 kg, based on the body weight of farm women, as they are the primary workforce in the region's agriculture.



a. Schematic diagram of the developed weeder b. Developed weeder

Commercial potential:

The technology can be licensed to Farm machinery companies, development agencies, NGOs and farmer groups, Farmer Producer Organizations (FPOs).

Impact:

The low-cost Over the Plant (OTP) Manual Weeder has a transformative impact on row crop cultivation in hill and plateau regions, where conventional mechanized weeding is impractical due to small landholdings, uneven terrain, and limited access to farm machinery.

Agro-ecoregions suitability:

Hill and plateau regions.

Manual Makhana Seed Grader

Period of development: 2018 - 2020

Developers:

Prem K Sundaram; Bikash Sarkar, Indu Shekhar Singh, Ashutosh Upadhyaya

Background:

Makhana seed grading is essential for post-harvest processing, but traditional manual sieving using iron-sheet mesh frames is time-consuming and inconsistent. While research on makhana graders is limited, insights from grading machines for other crops guided the development of a hand-operated inclined grading unit. Keeping in view, A prototype grader was for grading makhana into different sizes.

Description of the technology:

A hand-operated makhana grader was developed in a systematic approach, including the study of makhana seed properties, design considerations, prototype fabrication, and performance evaluation. The study of physical properties involved analysing seed size distribution, shape, density, coefficient of friction, and angle of repose to optimize the grading mechanism. The core grading unit consisted of a circular drum for rotational seed separation, cylindrical bars to facilitate movement through grading slots, and mesh sizes selected based on seed size distribution, categorizing seeds into five sizes: 14 mm, 12 mm, 9 mm, 7 mm, and less than 7 mm. The drum was inclined to ensure smooth seed movement from larger to smaller sizes. For durability and ease of operation, the frame was fabricated using mild steel, while the drum was constructed with perforated metal sheets. The hand-operated mechanism was ergonomically designed, with a mild steel handle mounted adjustably for user comfort. The grader had an average processing capacity of 250–280 kg per hour, with makhana seeds poured into a hopper and separated as the cylinder was cranked at an average speed of 30–35 rpm. The cylinder was fabricated in four parts, each with different spacing between the iron bars to achieve precise grading.



Manual Makhana Seed Grader

Commercial potential:

The technology can be licensed sourced to Farm machinery companies, development agencies, NGOs and farmer groups, Farmer Producer Organizations (FPOs).

Impact:

The Manual Makhana Seed Grader is a low-cost, efficient, and easy-to-use tool that addresses manual sorting, labor dependency, and post-harvest processing challenges benefiting farmers and processors in Bihar, Assam, and other Makhana-growing regions of India.

Agro-ecoregions suitability:

Bihar, Assam, and other Makhana-growing regions of India

Peripatetic Fish Vending Cart

Period of development: 2018 - 2021

Developers:

Prem K Sundaram, Bikash Sarkar, Ashutosh Upadhyaya, Pawan Jeet

Background:

The peripatetic fish vending cart allows fish vendors to move freely within local markets, urban areas, and residential neighbourhoods. This mobility ensures that fish can be sold in different locations, reaching a broader customer base and increasing sales opportunities.

Description of the technology:

A prototype of the peripatetic fish vending cart was designed and fabricated. The cart includes a water tank for live fish storage, a solar-powered aerator, a box for frozen fish storage, cutting tools, a toolbox, and a dustbin. The rear wheel was replaced with a pair of tires and tubes, and the rim was fabricated from 20 mm MS hollow pipe to support additional load. Before fabrication, a layout design was created to allocate space for essential features such as the live and frozen fish boxes, cutting and processing areas, water



Peripatetic fish vending cart

storage, utility space, and waste disposal. The rear base platform, measuring 1600 mm in length and 1000 mm in width, was constructed using MS angles (40×40×5 mm and 25×25×5 mm), flat bars (25×5 mm), MS rods (ø 8 mm), and a 16-gauge GI sheet, with all joints securely

welded. The fabrication process commenced with the rider seat, followed by the construction of a utility/toolbox made from an MS sheet (53×30×35 mm). Additionally, a solar panel frame was designed with dimensions of 1090×660 mm to accommodate the required energy components. On the base frame, a 100-liter polyethylene insulated (PUF) box was placed for frozen fish, and a 250-liter live fish container was positioned. Three 5-liter plastic tubs were placed at the rear for waste disposal, easily removable when full. The cutting and processing area (650×500 mm) was built using a 4 mm thick ACP sheet over an MS structure to prevent fish contamination. Continuous aeration is provided by two 40-watt solar PV panels connected to a storage battery, which charges during the day and provides power during off-sunshine hours. The driving mechanism uses a simple chain drive, and a cutting knife (Boti) is mounted with nuts and bolts on the side of the processing area. The Boti is positioned for fish dressing and can be removed when not in use. The peripatetic fish vending cart meets the needs of fish vendors by providing mobility, improved storage, sustainability, hygiene, and operational efficiency, making it an essential tool for modern fish vending businesses.

Commercial potential:

The technology can be licensed/ outsourced to development agencies, NGOs and Fishery farmer groups, Fish vendors, manufacturers.

Impact:

The Peripatetic Fish Vending Cart enhances mobility, accessibility, and sales opportunities for fish vendors by allowing them to move freely within local markets, urban areas, and residential neighbourhoods.

Agro-ecoregions suitability:

Chilika & Coastal Odisha (East Coast Plains); Bihar, Assam, & Eastern Uttar Pradesh (Middle & Upper Gangetic Plains); Madhya Pradesh & Chhattisgarh (Central Indian Plateau & Eastern Plateau)

Farm Machinery Hiring Calculator: A Web Based Tool

Period of development: 2021 - 2022

Developers:

Prem Kumar Sundaram, Bikash Sarkar, Ujjwal Kumar, Dushyant Kumar Raghav, Ramkewal, Pawan Jeet, Ashutosh Upadhyaya, Anil Kumar Singh, Sanjeev Kumar, Rakesh Kumar

Background:

This web app assists farmers in determining the optimal rental price for their agricultural machinery, helping them decide the appropriate rate to charge for renting out their equipment. It provides rental values for individual machines as well as tractor attachments. Farmers need to input a few details, such as the cost of the machine, fuel consumption, fuel price, etc., to receive accurate results. If these details are not provided, default values will be used automatically.

Description of the technology:

The backend process is based on MS excel calculation where fixed cost and operational cost of the machines are calculated. It considers the life of machine, working hours, depreciation, interest, repair and maintenance cost, fuel cost etc. Technology platform used for web app: Front end: Html; Vanilla Javascript; jQuery; CSS; Backend: PHP; MYSQL. The user can get a minimum threshold value below which he should not rent his/her machines. This type of web app providing such information is not available. Also, the interface is very user friendly. The tractor can be clubbed with different machinery and their optimum rent value can also be found.

The screenshot displays the web application interface for the Farm Machinery Hiring Calculator. The header features the logos of the Indian Council of Agricultural Research (ICAR) and the Eastern Region Research Complex (ERRC), Patna. The main heading is "मशीन किराये पर देने की रकम की गणना करें" (Calculate the amount to be paid for hiring machinery). Below this, a green banner shows the "कुल प्रतिफलन लागत = ₹ 111.80 प्रति घंटा" (Total production cost = ₹ 111.80 per hour). The interface includes a sidebar with a list of machinery types, such as "कृषि" (Agriculture), "जल" (Water), "मृदा" (Soil), "वायु" (Air), "अन्य" (Other), and "सभी" (All). The main content area contains input fields for "मशीन का नाम" (Machinery Name), "मशीन का मूल्य" (Machinery Value), "मशीन का जीवनकाल" (Machinery Life), "मशीन का दैनिक घंटा" (Machinery Daily Hour), "मशीन का दैनिक दूरी" (Machinery Daily Distance), "मशीन का दैनिक ईंधन" (Machinery Daily Fuel), and "मशीन का दैनिक मरम्मत" (Machinery Daily Maintenance). A "गणना करें" (Calculate) button is located at the bottom right. The footer credits the developers: "Developed By" followed by the names of the team members.

Web Based Application of Machinery Hiring Calculator

Commercial potential:

A digital tool for optimizing farm equipment rental services. It benefits farmers, state agencies, government extension workers, Krishi Vigyan Kendras (KVKs), officials, and Subject Matter Specialists (SMS) by streamlining the hiring process and improving access to mechanization.

Impact:

The Farm Machinery Hiring Calculator has a transformative impact on farm mechanization accessibility, cost efficiency, and decision-making for farmers, government agencies, and extension workers.

Agro-ecoregions suitability:

May be suitable for any region where farmers are poor and works in community approach.

Solar Cabinet Dryer for Leafy Vegetables

Period of development: 2017 - 2018

Developers:

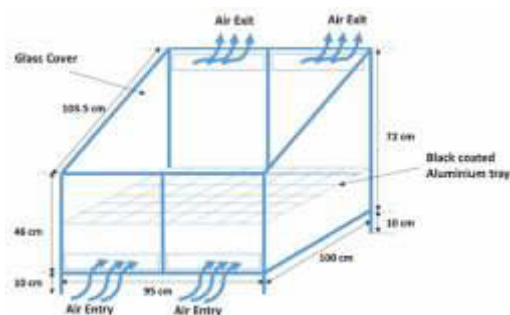
Santosh S Mali, Anuradha Srivastava, Tania Seth

Background:

Leafy vegetables are a rich source of nutrients and micronutrients, available at a low cost, and play a vital role in the diet of the tribal population in Eastern India. However, most leafy vegetables are highly perishable and only available during specific seasons. Drying helps extend their shelf life, ensuring year-round availability. While sun drying is the most common method, it is unhygienic and labour-intensive. To overcome these challenges, a low-cost solar dryer was developed to reduce both the time and manpower required for drying leafy vegetables. This solar dryer offers a more efficient, hygienic, and sustainable solution, preserving the quality of the produce and reducing post-harvest losses.

Description of the technology:

The low-cost solar dryer is designed to provide an efficient and hygienic method for drying leafy vegetables, using solar energy to reduce time and labor compared to traditional sun-drying. The dryer features a cabinet made from compressed wood and is topped with a 6 mm thick glass cover that helps protect the contents from dust and foreign matter. The base measures 95 x 100 cm, and the inclined size is 95 x 103.5 cm. Inside, a black-coated perforated aluminum tray is used to spread the vegetables evenly for drying. Two air inlets at the base and two air outlets at the upper backside of the dryer facilitate proper airflow, enhancing the drying process. A thermometer is installed both inside and outside to monitor and compare the temperatures, ensuring optimal drying conditions are maintained.



Schematic diagram of the solar dryer



Drying operation of leafy vegetables using solar dryer

With the capacity to dry up to 2.5 kg of leafy vegetables per batch, the solar dryer significantly reduces drying time, taking only 2.0 to 2.5 hours for small and large-sized vegetables, in contrast to the 3.75 to 10 hours required for sun drying. This makes the technology highly efficient and suitable for use in areas where time, hygiene, and labor are critical factors. The development of drying curves (time vs moisture content) for various underutilized leafy vegetables further optimizes the drying process, making this solar dryer a valuable tool for preserving food and reducing post-harvest losses in rural farming communities.

Commercial potential:

The commercial potential of the low-cost solar dryer can be realized through partnerships with solar energy agencies, state rural development programs, and manufacturers of affordable agricultural technologies. Collaborating with Farmer Producer Organizations (FPOs), agri-tech startups, and local cooperatives can further promote its adoption.

Impact:

While the SCD takes less time than sun drying (which can take up to 10 hours), it offers better quality and efficiency, drying vegetables in 2.0 to 2.5 hours. This method harnesses solar energy, making it an affordable, environmentally friendly solution for small-scale farmers. By ensuring quicker, safer drying, the SCD helps farmers preserve leafy vegetables for year-round availability and allows them to sell their produce at higher prices during the off-season.

Agro-ecoregions suitability:

Eastern Plateau and Hill Region, arid and semi-arid areas where solar radiation is abundant, seasonal fluctuated rainfall areas

References:

Tania Seth, RS Pan, SS Mali, SK Naik, AK Singh. 2020. Comparative evaluation of sun, solar cabinet and electric cabinet drying methods for drying of lesser-known leafy vegetables in Jharkhand. *Vegetable Science* (2020) 47(2): 189-195.

Hybrid Solar Light-Pheromone Insect Trap

Period of development: 2018 - 2022

Developers:

Santosh S Mali, Jaipal S Choudhary, P K Sundaram

Background:

Insect pests like stem borers, fall armyworms, and thrips significantly damage crops, leading to reduced yields and increased costs for farmers. Traditional pesticide methods pose environmental and health risks. To address this, an eco-friendly, solar-powered insect trap has been designed, using light and pheromone-based attraction to target a range of pests. Operating automatically from dusk to dawn, it runs on solar energy, making it a sustainable solution for vegetable, fruit, and grain crops. This trap provides an effective, chemical-free alternative to traditional pest control methods, promoting healthier crops and eco-friendly farming practices.

Description of the technology:

The solar-operated insect trap is an innovative, eco-friendly solution designed to control a wide range of agricultural pests. The trap operates in hybrid mode, utilizing light and pheromones to effectively attract insects. The trap features a unique flight interruption and impact injury mechanism: as insects are drawn towards the light, their flight path is interrupted by transparent baffles placed vertically around the bulbs. These baffles cause the insects to collide and fall into a collecting hopper, where they are drowned in a soap solution. This mechanism ensures efficient insect capture and minimizes the use of harmful pesticides.

The trap is powered by a 30 Wp solar panel and a 12 Ah battery, providing up to six hours of operation per day. It includes a telescopic height adjustment system, allowing the trap's height to be set between 1.0 to 1.5 meters, making it adaptable for different crop heights. In version 1.0, the trap relied solely on light-based attraction with three 3W LED lights positioned at 120° intervals to cover an area of 35-40 meters. Additionally, pheromone bottles, placed at the edge of the collector hopper, release their scent into the air to further attract pests.



Hybrid Solar Light-Pheromone Insect Trap

The trap is equipped with a special light sensor that automatically switches the system on at dusk and off at dawn based on ambient light intensity, ensuring efficient energy usage. The sensitivity of this sensor can be adjusted using a knob on the switch. With low operational and maintenance costs, only 3-4 traps are required per hectare, making it a highly cost-effective and sustainable pest control solution. The solar-powered insect trap supports organic farming practices and integrated pest management by offering a zero-emission alternative to traditional pesticide methods.

Commercial potential:

The solar-powered insect trap can be commercialized by licensing the technology to equipment manufacturers and startups, expanding its reach. It can also be incorporated into government subsidy programs.

Impact:

The solar-powered insect trap reduces pest damage, promoting healthier crops and enhancing yields. It offers an eco-friendly, cost-effective alternative to chemical pesticides, minimizes labor and pesticide use, and supports sustainable farming practices with low maintenance costs.

Agro-ecoregions suitability:

Agro-ecoregions within India where daily sunshine hours exceed 4.5 -5.0 hours, particularly suitable for eastern plateau and hill region, western and southern regions of India

Mixed Para-Pheromone Fruit Fly Trap for Horticultural Crops

Period of development: 2012 - 2014

Developers:

Jaipal S Choudhary, Santosh S Mali, Bikash Das

Background:

Fruit flies are the major pests of vegetable and fruit crops in India. They are polyphagous in nature and cause commercial fruit loss of up to 30-100% in horticultural crops. Male annihilation techniques through para-pheromone traps are effective and very species-specific. Since fruit and vegetables are grown in combination and in nearby vicinity, effective para-pheromone traps which target the multiple fruit fly species are essential. Different mixture combinations of methyl eugenol and cue lure to attract multiple fruit fly species infesting fruit and vegetables.

Description of the technology:

A mixed para pheromone-based fruit fly trap was developed to manage the fruit flies in fruit and vegetable crops with a single trap against all major fruit fly species. Presently, single lure fruit fly traps are available in the market to manage fruit fly species in fruits and vegetables, separately. Different combinations of methyl eugenol and cue lure were tested and the specific mixture of both resulted in a higher number of fruit fly catches recommended. A cardboard with 3x 2x 1.5 cm was used to absorb tested effective combinations of mixed lure solutions (cue lure and methyl eugenol) with DDVP (Spinosad) as an insecticide in the lure solution. Low-cost plastic cups have been designed to protect the lures against temperature and water. This trap was preliminarily tested at ICAR-RCER, Patna, and its centre Ranchi and found effective as compared to single lured one and market available traps. This trap is effective in managing the fruit fly species in mango, sapota, guava, citrus, litchi, bottle gourd, bitter gourd, pumpkin, cucumber, and other cucurbit crops as well in fruit trees intercropped with vegetables.



Mixed Para pheromone fruit fly trap for horticultural crops

Commercial potential:

The technology can be commercialised through licencing the design to private firms. This has already been licensed to Aditya Agro Crop Care, Kolkata (India) for large scale production.

Impact:

The best combination of mixed fruit fly traps attracts the male fruit flies of different species infesting fruit and vegetables in field conditions. This developed fruit fly trap can be considered in the integrated pest management of multiple species of fruit flies simultaneously. Reduces fruit fly infestation in different fruits and vegetables by up to 60%.

Agro-ecoregions suitability:

All eco-regions of India.

Technologies

**Socio-Economic,
Extension & Policy**



Climate Resilient Model Villages Developed at Gaya and Buxar districts of Bihar

Period of development: 2019 - 2023 (Gaya); 2020 - 2023 (Buxar)

Developers:

Abhay Kumar, Ujjwal Kumar, DK Singh, Mohd. Monobrullah, Rakesh Kumar, PK Sundaram, RK Raman, Surajit Mandal, Anirban Mukherjee, Sudip Sarkar, Ramkewal, VS Meena

Background:

Climate change is a major issue affecting Indian agriculture. Bihar also faces significant challenges due to changing climate which includes, floods, droughts, frost, changing disease pest dynamics, rainfall pattern etc. The impact of climate change in the state is multi-dimensional and has far-reaching consequences for food security, and livelihood of farmers. Farmers need to adopt climate resilient crop varieties and techniques for profitable agriculture with sustained productivity and income. ICAR RCER, Patna implemented Climate Resilient Agriculture (CRA) Program in Gaya and Buxar district since 2019. This programme focuses on a community-driven approach for wider adoption of climate-resilient technologies. Development of Climate-Resilient Villages are essential for enhancing the adaptation capacity of farmers under changing climate scenario.

Description of the technology:

A total of 10 Climate Resilient Villages (Gaya: Rasalpur Nagar, Rasalpur Manpur, Takeya, Rahimbigha and Rupaspur, Buxar: Dalsagar, Balapur, Churamanpur, Harikishunpur, Ramobariya) has been developed under CRA Programme. Nine cropping systems were followed in the climate smart villages with mixing the coarse cereals millets including:

- Transplanted Puddled Rice (TPR)–wheat (conventional-till)-fallow (CS1),
 - TPR-wheat (zero-till)-mung (ZT) (CS2),
 - Conventional-till direct seeded rice (CTDSR)-mustard (ZT)-mung (ZT) (CS3),
 - ZTDSR-lentil (ZT)-fallow (CS4),
 - Maize (CT)-lentil (ZT)-mung (ZT) (CS5),
 - Bajra (CT)-lentil (ZT)-mung (ZT) (CS6),
 - Bajra (CT)-wheat (ZT)-mung (ZT) (CS7),
 - TPR-chickpea (ZT)-fallow (CS8), and
 - TPR-maize (CT)-fallow (CS9).

It is an integrated approach for adaptation and mitigation of long-term impact of climate change on agriculture sector by farming community. For the development of climate resilient villages, large scale demonstrations like climate resilient crop varieties, management practices and use of climate resilient machineries as well as other precision agriculture technologies like LCC, green seeker etc were laid out in selected villages from

2019-20 to 2022-23. After the initial survey and meetings with farmers, location specific package of climate resilient interventions were identified. Necessary inputs, technology backstopping and capacity development programs like farmers' trainings, exposure visits, awareness camps and farmer-scientists interaction were organized. On-farm demonstrations of climate resilient interventions like direct seeded rice, zero tillage of *rabi* crops (wheat, lentil, chickpea), raised bed of maize and potato, crop diversification with millets, introduction of mungbean in Rice wheat cropping system, intercropping of maize and potato, climate resilient irrigation scheduling and nutrient management, laser land levelling etc. were conducted at farmer's field. Every year, an area of 2936 acre (Kharif: 1190 acre, Rabi: 1246 acre and summer: 500) was covered under these technology demonstrations benefitting almost 1000 farmers in each district during last 3 years. Due to these climate resilient interventions, farmers of these villages now use climate resilient technologies using their own resources and the same is being adopted in nearby areas also.

Commercial potential:

The technology can be offered through consultancy services or outsourced to the State Agricultural Department, Veterinary Colleges, Development agencies, NGOs, and farmers' groups.

Impact:

CRA programme resulted in large scale adoption of climate resilient varieties and technologies. Area under introduced cropping system *i.e* rice-wheat – moong-bean expanded significantly which resulted in increase in system productivity from 85 q/ha in rice-wheat system to 122 q/ha (rice-wheat-moong). The developed villages will act as model village for nearby area and farmers can learn adaptation strategies by seeing fellow farmers.

Agro-ecoregions suitability area:

Bihar and other climate change affected states

References:

Technology certificate from ICAR, New Delhi, Number: ICAR-AEXT-RCER-Model-2024-084, Annual Report of ICAR RCER, Patna

Model for Structural and Functional Analysis of Makhana Value Chain

Period of development: 2017 - 2021

Developers:

DK Singh, Abhay Kumar, IS Singh, Naresh Chandra, Ujjwal Kumar

Background:

Makhana producers faces many issues like inefficient marketing channels, lack of mechanization leading to higher harvesting cost and shortage of organized popped makhana processing industries. Despite higher demand and remunerative price in consumer market, makhana farmers and primary processors are not getting good share in its value chain. In order to enhance the effectiveness and efficiency of makhana marketing system, proper understanding of its value chain is required which can help in devising market policies for enhancing farmers' profitability and their socio-economic status. Present study was conducted to analyse the makhana value chain in the country.

Description of the technology:

A model was developed to analyse the makhana value chain which included different aspects of its production as seed, processing as popped makhana, value addition as different products, marketing and consumption by ultimate consumers. Production aspects included estimation of cost of cultivation of makhana seed as well as cost of processing. Both structural and functional analysis was done for national market of popped makhana. Structural model of makhana value chain was developed to find out the different stakeholders involved at different levels from its production to consumption and their interdependence on one another in the value chain. Marketing margins of these stakeholders was also estimated. Functional model for all value chain actors was also developed to study the role of each stakeholder in the chain. Functional analysis studied the role played by the important value chain actors.

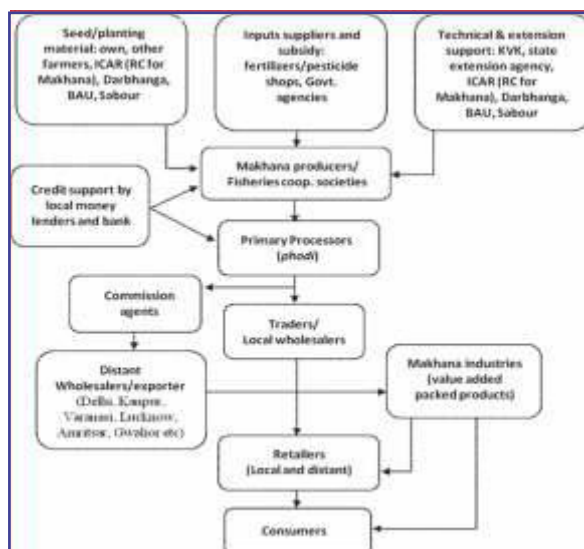
Farmers – Processors - Local wholesalers - Distant wholesalers- Distant retailers - Consumers has been identified as the most important marketing channel of popped makhana contributing almost 70% of total trade. Marketing cost, market margins and price spread were studied at national market and share of each stakeholder in consumer rupees was estimated. It was found that share of farmers, processors, local wholesalers, distant wholesalers and distant retailers in final consumer price was 27.62, 8.63, 5.03, 13.9 and 19.56 per cent respectively. This makhana value chain is prevalent in whole country.

Commercial potential:

The technology can be offered through consultancy services, licensed, or outsourced to the State Agricultural Department, development agencies, RKVY, NGOs, and Makhana growers.

Impact:

Makhana Industry and Policy Makers



Structural model of makhana value chain

Agro-eco region suitability:

North Bihar and Adjoining Makhana producing states

References:

Singh DK, Singh IS, Kumar U, Kumar A. and Bhatt BP. 2018. Traditional Wisdom of Mallah Community regarding Makhana Production and Processing in North Bihar, *Indian Journal of Extension Education*, 54 (2): 76-82.

Strengthening Export Potential of Farmer Producer Organizations (FPO) through One District One Product (ODOP): A Conceptual Model

Period of development: 2019 - 2022

Developers:

Anirban Mukherjee, Shreya Anand, Souvik Ghosh, Ujjwal Kumar, DK Singh, Kumari Shubha, Abhay Kumar

Background:

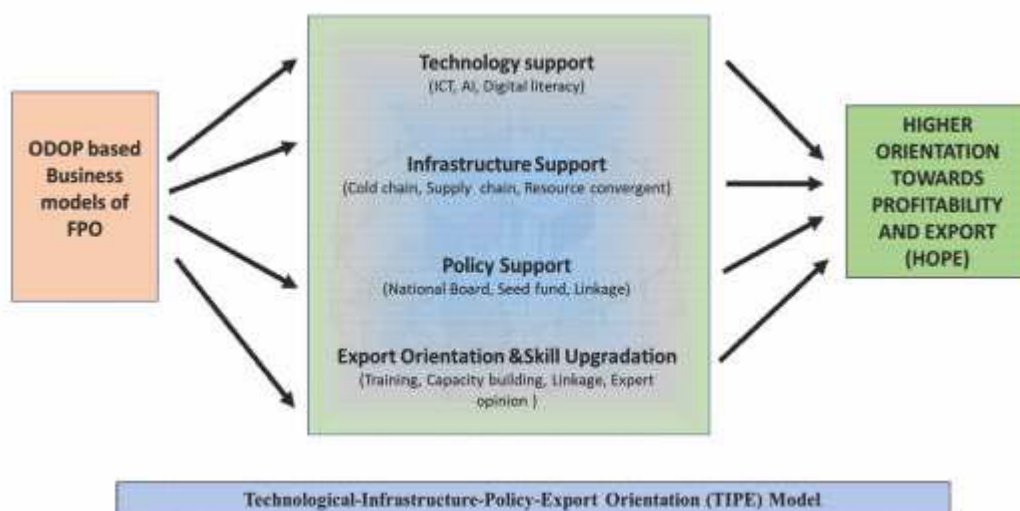
Farmer Producer Organizations (FPOs) play a pivotal role in empowering smallholder farmers by aggregating their produce, improving market access, and enhancing bargaining power. However, their growth and sustainability are often hampered by critical challenges such as limited access to advanced technologies, inadequate infrastructure, insufficient policy support, and constrained export opportunities. Addressing these gaps is imperative to transform FPOs into robust, sustainable business entities capable of thriving in both domestic and international markets. A strategic plan was required so that FPOs can unlock their full potential, ensuring better livelihoods for farmers and contributing significantly to the agricultural value chain.

Description of the technology:

The TIPE model—Technology, Infrastructure, Policy, and Export Orientation—is a comprehensive framework developed under the ICAR-NASF project (2019–2022) to strengthen Farmer Producer Organizations (FPOs) and enhance their profitability and export potential. Aligned with the One District One Product (ODOP) scheme, the TIPE model integrates four key pillars:

- I. Technology Support:** Leveraging cutting-edge technologies such as ICT, AI, and blockchain to boost productivity, reduce costs, and ensure export-quality standards.
- II. Infrastructure Development:** Establishing commodity-specific cold chains and post-harvest facilities to meet global quality and compliance standards.
- III. Policy Backing:** Facilitating streamlined business operations, seed funding, and the creation of a dedicated National Board to support FPOs in navigating export markets.
- IV. Export Orientation & Skill Upgradation:** Providing intensive training and capacity-building programs to equip FPOs with the skills and knowledge required to compete in global trade.

The TIPE model has been successfully applied to key agricultural sectors in Bihar, including Makhana, Litchi, Banana, and Mango. By fostering sustainable growth, enhancing international competitiveness, and ensuring long-term business viability, the model empowers farmers and FPOs to achieve higher profitability and secure a prominent position in global markets.



Process model of Technology–Infrastructure–Policy–Export Orientation (TIPE)

Commercial potential:

The technology can be offered through consultancy services, licensed, or outsourced to the State Agricultural Department, development agencies, FPOs, NGOs, and farmers' groups.

Impact:

The TIPE model has enhanced FPOs' profitability, technology adoption, infrastructure, policy support, and export readiness, ensuring sustainable growth and global market access.

Agro-ecoregions suitability:

Bihar

References:

Anand S, Ghosh S, Mukherjee A. 2023. Strategies for strengthening farmer producer organizations in India based on the One District One Product scheme. *Current Science*, 125(6), 614-622.

Seed Based Technology Delivery Model through Farmers Producer Organization (FPO)

Period of development: 2019 - 2022

Developers:

Anirban Mukherjee, Ujjwal Kumar, DK Singh, Kumari Shubha, VK Yadav, Shubhadeep Roy, Kausik Pradhan

Background:

Farmers in many regions continue to rely on outdated crop varieties due to the unavailability of improved seeds at the right time. Existing seed-producing institutions, such as ICAR institutes, universities, and state seed farms, face resource constraints, limiting their capacity to meet demand. To bridge this gap, the Seed-Based Technology Delivery Model (SBTDM) leverages Farmer Producer Organizations (FPOs) as key stakeholders. FPOs, with their business-oriented approach and focus on profitability, are uniquely positioned to ensure timely and sustainable delivery of quality seeds.

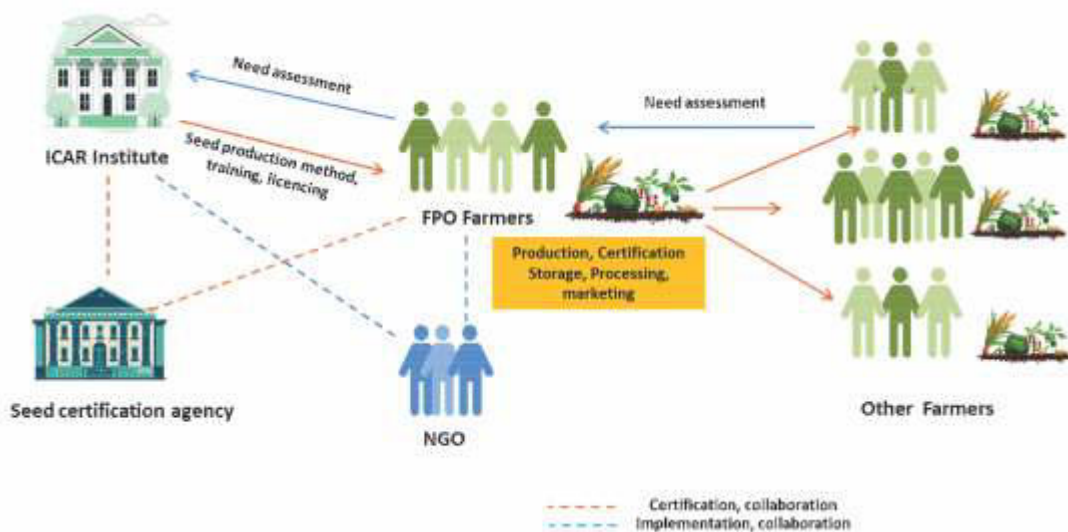
Description of the technology:

This model comprises two sub-components: (A) Need-based variety selection and testing, and (B) multiplication at specialized FPO farmers' fields, certification, processing, and sale to other farmers. The Seed-Based Technology Delivery Model (SBTDM) is designed to enhance farmers' access to improved agricultural varieties, boost productivity, and strengthen Farmers' Producer Organizations (FPOs) in Eastern India.

The methodology follows a structured, multi-phase approach:

- I. Identification of Farmer Needs:** Baseline surveys and stakeholder consultations, using the Fuzzy AHP method, identified farmer-specific needs. Key criteria included crop duration, grain quality, disease resistance, water requirements, and yield potential.
- II. Variety Selection and Testing:** Collaborations with ICAR institutes provided access to diverse varieties. A team of 200 progressive farmers (100 FPO and 100 non-FPO) was formed, trained in variety selection, post-harvest handling, and marketing. Progressive FPO Farmers Index and Random Forest Classification identified factors influencing FPO participation. Social Network Analysis mapped communication networks, guiding targeted interventions.
- III. Multiplication and Certification:** FPOs established seed multiplication fields, ensuring genetic purity and quality through best practices. Certification was facilitated in collaboration with state agencies.
- IV. Seed Distribution and Marketing:** A robust seed value chain was developed. Partnerships with extension agencies and NGOs promoted improved varieties via awareness campaigns, training, and field demonstrations, positioning FPOs as central marketing agents.

- V. **Monitoring and Evaluation:** Farmers' Empowerment Index and PCA-based weightage assessed empowerment and functional effectiveness. Decision Tree Regression identified key factors influencing FPO operations. Regular feedback sessions informed continuous improvements.
- VI. **Scaling Up:** Successful models were replicated across new FPOs, supported by capacity-building initiatives and iterative refinements.



Process Model of Seed-Based Technology Delivery Model (SBTDM)

Commercial potential:

The technology can be offered through consultancy services, licensed, or outsourced to the State Agricultural Department, development agencies, FPOs, NGOs, and farmers' groups.

Impact:

Over the three-year period, these practices, coupled with the knowledge generating system, significantly enhanced farmers' productivity (rice: 18-22%; wheat: 15-25%; summer moong: 30-45%). The effectiveness of the model was calculated based on effectiveness index comprising (i) functional efficiency, (ii) sustainability (iii) Income (iv) empowerment. The effectiveness score of this model was calculated as 70.54.

Agro-ecoregions suitability:

Bihar

References:

Annual Report of ICAR-RCER Patna year 2021 and 2022

Flood Prone area Identified as Fruit Hub in Bihar: A Policy Framework

Period of development: 2020 - 2023

Developers:

RK Raman, Jyoti Kumar, Jaspreet Singh, DK Singh, Ujjwal Kumar, Abhay Kumar, Akram Ahmed, Rakesh Kumar, Anirban Mukherjee, Anup Das

Background:

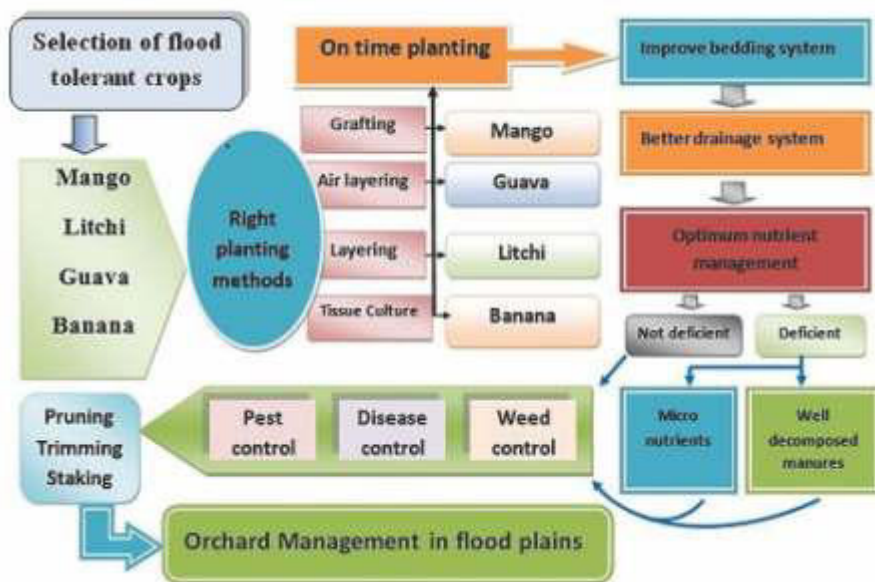
The study addresses recurrent flooding in Bihar, Eastern India, which causes significant crop losses, especially during the Kharif season, affecting farmers' livelihoods. To mitigate this, the study explores flood-tolerant fruit crops like banana, mango, litchi, and guava as alternatives. These crops provide stable income despite floods. Using advanced statistical and geostatistical tools, including the Structural Time Series Model (STSM), Kruskal-Wallis statistics, Principal Component Analysis (PCA), and GIS mapping, the study identifies productive areas for these fruit crops in Bihar. It finds the North West Alluvial Plain is ideal for banana, litchi, and mango, while South Bihar is best for guava. The STSM model forecasts an increase in banana production until 2025. The study also develops management strategies for orchards in floodplain wetlands, offering practical guidance for farmers and stakeholders on orchard management in flood-prone regions.

Description of the technology:

Flooding is a recurrent phenomenon in the state of Bihar of Eastern India. There is a massive loss of major food crops like rice and maize during *kharif* season. In this scenario flood-tolerant fruit crops like banana, mango, litchi and guava provide alternate source of income to farming communities. Keeping in view the importance of fruit production as a mitigating option of flood risks, a policy framework has been developed using structural time series model (STSM), Kruskal–Wallis statistics, principal component analysis (PCA) and GIS mapping for identification of productive area for fruit crops and its management strategies. The model identified North West alluvial plain of Bihar as highly productive zone for banana, litchi, and mango, while South Bihar alluvial plain zone was for Guava. Through the STSM forecasting model, it was predicted that the banana production in Bihar will increase continuously till 2025. The management strategies for orchards in floodplain wetland ecosystems was developed in the form of flow diagram which will be very useful to farmers and other stakeholders. Hence, this policy measure can be utilised for researchers and policy makers for devising effective strategies for production and management of fruit crops in flood plain ecology.

Commercial potential:

The technology can be offered through consultancy services, licensed, or outsourced to the State Agricultural Department, development agencies, National Horticulture Board, NGOs, and farmers' groups.



Orchard management in flood plain in Bihar

Impact:

Enhanced Resilience to Flooding, Informed Decision-Making, Improved Crop Management, Policy Development

Agro-ecoregions suitability:

Flood affected states of India

Reference:

Raman RK, Singh DK, Sarkar S, Singh J, Kumar A, Kumar U, Kumar R, Ahmed A, Mukharjee A, Mondal S, Upadhyaya A. 2023. Scenario of Major Fruit Crops in Flood-Prone Areas in Eastern India: Case Study of Bihar. *Erwerbs-Obstbau*, 65(4), pp.1139-1151.

Nutri-garden Model Addressing Anaemia and Hypovitaminosis Challenges of Eastern India

Period of development: 2019 to 2023

Developers:

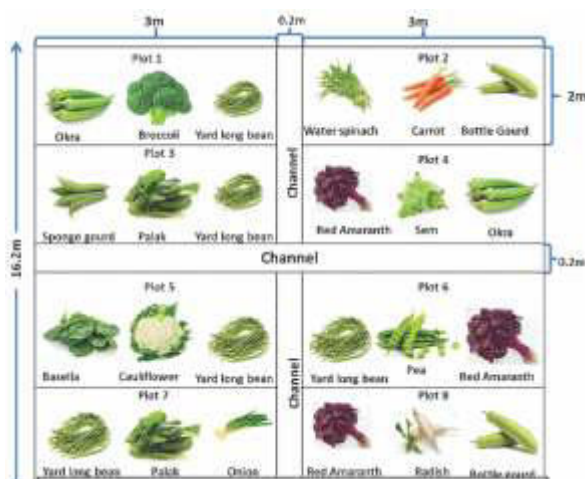
Kumari Shubha, Akram Ahmed, TK Koley, Anirban Mukherjee, Abhishek Kumar, Sanjeev Kumar, Shivani, Ujjwal Kumar, Anup Das

Background:

The latest National Family Health Survey (NFHS-5) has brought to light a concerning trend-there is a noticeable increase in both maternal and child malnutrition in Eastern region particularly Bihar. In our earlier survey we found the problem of mal nutrition prevalence in some part of Bihar and West Bengal. This emphasizes the pressing need for effective interventions for poor households. In this context, Nutri-garden emerges as a low-cost viable solution for Vitamin and minerals

Description of the technology:

A 100 m² Vegetable Based Nutrigarden model focusing on Iron and Vitamin rich vegetable sources was developed and validated at ICAR-RCER, Patna during 2019-2023. Standardization and validation of the model to fulfill the ICMR recommendations of vegetable intake (200g fruit vegetables, 50g leafy vegetables and 50g root vegetables) was considered. In Pea-Red Amaranth-YLB cropping pattern was found nutrition-wise highest energy (23892 Kcal), protein (1849.9 g) and fat (143.2 g). However, highest Vitamin A (1876380 IU) and Vitamin C (20888 mg) was found in Carrot-Bottle gourd-



**Model showing combination of vegetables
for dietary diversity**

Water spinach and Cauliflower-YLB-Poi cropping pattern respectively. The cropping pattern Pea- Red Amaranth -YLB was found highest in iron, and Vitamin B particularly thiamine (58.55 mg), riboflavin (68.52 mg) and niacin (653.7 mg). This model was developed for backyard of house for 4 member households. The validation and dissemination of the Nutrigarden Model involved a three-year field study (2021-2023) across three agroclimatic zones in Bihar (North-West Alluvial Plane (East Champaran), North-East Alluvial Plane (Katihar), and South Alluvial Plane (Patna, Buxar) as well as West Bengal.



Vegetable based Nutri-garden established at ICAR-RCER, Patna

Commercial potential:

The technology can be offered through consultancy services as master trainer to the State Agricultural Department, development agencies, NGOs, SHGs and farmers' groups.

Impact:

Nutritional Security, Cost Savings, Health Benefits Women Empowerment Climate Resilience

Agro-ecoregions suitability:

Rural households of Eastern Indian States

Reference :

K Shubha, A Mukherjee, U Kumar, TK Koley, AK Choudhary. 2022. Development of Climate Resilient Year-Round Home Garden Model for Improving Food and Nutritional Security of Resource-Poor Households in Eastern India. Proceedings of the International Symposium Southeast Asia Vegetable 2021 (SEAVEG 2021) pp. 258-269. https://doi.org/10.2991/978-94-6463-028-2_28

Policy Measures for Tenant farmers of Bihar

Period of development: 2019 - 2021

Developers:

Ujjwal Kumar, DK Singh, Kamal Sarma, RK Raman, AG Navaraj

Background:

Tenant farming refers to a system where a farmer, known as the tenant, rents land from a landowner in exchange for a share of the produce or a fixed cash rental payment. This practice is prevalent in many parts of India. In Bihar, significant area under agriculture is cultivated by tenant farmers who are largely small and marginal farmers having very less or no land holding and very limited resources. Tenant farmers are highly vulnerable to environmental risk and uncertainty. Since they don't have legal rights over land, they don't get benefits of central or state government schemes.

Description of the technology:

The study was conducted in 3 districts of Bihar *viz.* Bhojpur, Vaishali and Muzaffarpur using various tools of social sciences research *viz.* survey method using structured interview schedule, focused group discussion and personal observation by team of experts. It was observed that out of total area owned by household. Around 31% area was leased in which suggested that tenant-based agriculture is a prevalent practice in study area with nearly one third of area under tenancy. More than 85% tenant farmers of the study area of Bihar were either landless or marginal. This was indeed a major problem since, fragmentation of land holding is a hindrance to commercial farming as well as mechanization of agriculture. Three major types of tenancy were found to be prevalent in the study area tenants fixed cash, fixed produce and sharing of produce in some proportion. Sharing of produce (50:50) or Butaidari system was more prevalent in Bihar followed by fixed cash system. In case of cash-based system, land owner demanded Rs. 10,000-15,000 per acre from tenant for one year, based on quality of land. All the leasing was based on verbal consensus between land owner and tenant farmers.

Commercial potential:

The technology can be offered through consultancy services to State Agricultural Department, policy makers, FPOs, NGOs, and farmers' groups.

Impact:

It is a policy level recommendation based on primary field study conducted in Bhojpur, Vaishali and Muzaffarpur district of Bihar using various tools of social sciences research related to tenancy farming in Bihar. It was found that tenant farmers are mostly marginal farmers and landless labourers who face a lot of problems during cultivation. Without ownership of land, they don't get benefits of government schemes in case of crop failure due to natural disaster like flood and drought. The state Government should protect the rights of tenant farmers, since, as per findings of this study they were more vulnerable group who can be evicted from the land by owner at any time without giving any reason.

Provision for a lease document can be made which can act as legal document in absence of ownership of land. This document can be utilized by poor tenants for access to government schemes like subsidy on inputs viz. seed, fertilizers, tools and implements; credit, crop insurance, compensation of loss caused by flood/drought/diseases/pests etc minimum support price etc.

Agro-ecoregions suitability:

Bihar

References (Publication):

Status of Tenancy and Child Well-Being in Bihar, Technical Bulletin No. R-65/Patna-37, ICAR Research Complex for Eastern Region, Patna.

Socioeconomic Status Scale for Farmers of Bihar and Jharkhand

Period of development: 2017 - 2022

Developers:

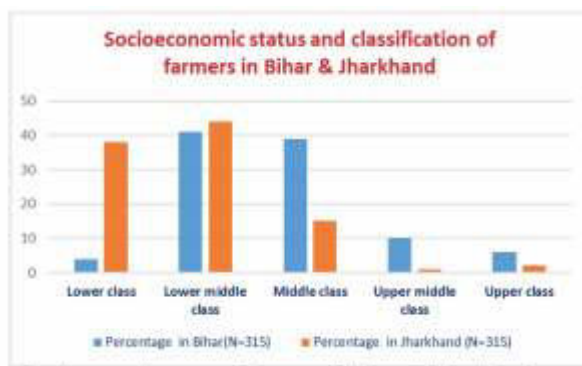
VK Yadav, Ujjwal Kumar, RC Bharti, Pankaj Kumar, RK Raman

Background:

Implementation of Rural development programs, extension projects, etc. are generally based on socioeconomic status (SES) of farmers determined through SES scale developed by Pareek and Trivedi (1964), Prasad (1961) and Kuppaswamy scale (1981). These scales do not include latest socio-economic parameters like mobile, internet, social mobility, social security, etc. Besides this, earlier scales were developed in particular areas and there is scope for development of SES scale in eastern India, as India is culturally and socially very diverse. Income level of farmers is also changing very rapidly which is major parameter of their socioeconomic status. Therefore, there is need of new scale for measuring Socio-economic status of farmers in Bihar and Jharkhand.



Assessing socio-economic status of farmers



Socioeconomic status of farmers of Bihar and Jharkhand

Description of the technology:

Socioeconomic status (SES) is one of the prime factors influencing the health status of a nation. It is the measure of the social standing of the individual or a family and has a wide impact on an individual/family's health, educational attainment, diet, lifestyle, etc., A socio-economic scale has been developed which contains 10 factors and 17 variables to assess socioeconomic status of farmers from Bihar and Jharkhand. However, it may be used for assessing SES of farmers from other states also with suitable modifications. The Maheshwari-Kumar-Jhamtani-Bhaskaran-Dandapani multidimensional scaling method was used to develop a socio-economic status (SES) scale for farmers in Bihar and Jharkhand. Data from 100 farmers, expert opinions, and literature review led to the identification of 181 SES variables, of which 127 were selected using Trivedi criteria and 64 through a relevancy test. A schedule with these 64 variables was used to collect data from 492 farmers across districts. Factor analysis identified 10 factors explaining 93% variance, with 17 key variables weighted by beta values. The final SES scale had a reliability coefficient of 0.97, and Known Group Technique confirmed its validity.

Commercial potential:

The technology can be offered through consultancy services, licensed, or outsourced to the Students, State Agricultural Department, development agencies, FPOs, NGOs, and farmers' groups.

Impact:

SES scale is being used in assessing socio-economic status of farmers by social researchers.

Agro-eco region suitability:

Bihar and Jharkhand and other states having same Socioeconomic level

Reference:

Annual Report, ICAR-RCER, Patna

Participatory Research Application for Year-Round Income and Agricultural Sustainability (PRAYAS): A Process Model for Empowering Weaker Sections

Period of development: 2023 - 2024

Developers:

Anup Das, Anirban Mukherjee, Bikas Sarkar

Associates:

PK Sundaram*, DK Singh*, SK Naik*, BK Jha*, Kamal Sarma*, VK Yadav*, Amitava Dey, Ujjwal Kumar, S S Mali, Abhay Kumar, Kumari Shubha, Rakesh Kumar (DLFM), Banda Sainath, Sudhansu Shekhar, N Bhakta, PC Chandran, Ajay Kumar, AK Choudhary, Ashutosh Upadhyaya, Manibhushan, TK Koley, R K Raman, Shivani, Shankar Dayal, Rakesh Kumar (DCR), Santosh Kumar, Rajani Kumari, PK Ray, Rachana Dubey, Kirti Saurabh, Tarkeswar Kumar, Manisha Tamta, B.K. Jha, R.S. Pan, A.K. Jha, J.S. Choudhary, Jyoti Kumar, Pankaj Kumar, Pawan Jeet, Abhishek Dubey, Vivekanand Bharati, Ved Praksh, Deokaran, Ramkewal, A.K. Jha, Sanjeev Kumar, Bhavana P., Reena K. Kamal, MK Dhakar, Abhishek Kumar, Arti Kumari, Indra Jeet, Dharamjit Kherwar, M. K. Tripathi, Sonaka Ghosh, Meenu Kumari, Reshma Shinde, Prerna Nath, Akram Ahmed, Saurabh Kumar, SK Ahirwal, DK Raghav.

*Note: * Coordinator for respective eastern states*

Background:

Eastern India, comprising seven important states *i.e.* Assam, Odisha, Jharkhand, West Bengal, Chhattisgarh, Bihar and eastern UP, is a region rich in natural resources and cultural heritage. However, it is also home to some of the most marginalized and vulnerable farming communities in the country. Scheduled Caste (SC), and Scheduled Tribe (ST) farmers form a significant portion (22%) of the agricultural workforce in the eastern region. Despite their critical role in food production, these communities face systemic challenges that hinder their progress and perpetuate cycles of poverty. By adopting sustainable agricultural practices, empowering farmers with knowledge, and improving access to markets, these marginalized communities can transform their agricultural practices, increase their income, and achieve long-term sustainability. The PRAYAS model offers a promising pathway to address these challenges and promote inclusive agricultural growth in the region.

Description of the process model:

A total of 16 Villages from 12 districts across the 7 states were adopted under PRAYAS Project. The 16 PRAYAS Villages are *Rewa-Mahaswari, Dhipuji Janpam*, from Assam; *Nurangia Dobe, Selhauri, Guleriyachak*, from Bihar; *Kumekela, Kandora* from Chhattisgarh; *Basantpur* from Uttar Pradesh; *Palandu and Kharsidag, Udlu, Lodma* from Jharkhand; *Mangratoli* from Odisha; *Begunbari, Chandandighi, Hatinada, and Chakkanthalia* from West Bengal. A comprehensive needs assessment survey was conducted, followed by a problem

prioritization process employing multi-criteria decision-making techniques. This methodological approach allowed for a systematic evaluation of the identified needs and gaps, assessing them based on their significance and potential impact. Each identified issue was subsequently assigned a score to denote its priority in enhancing agricultural sustainability and promoting income generation within the targeted regions. The primary aim is to enhance agricultural productivity and sustainability through improved integrated farming practices. PRAYAS also focuses on creating awareness and providing skill development opportunities for resource-poor farmers, enabling them to adopt profitable farming techniques. By establishing linkages with grassroots stakeholders, the project ensures the widespread adoption of these practices.

The PRAYAS process model is a systematic, participatory approach that progresses through distinct phases, each informed by scientific principles and tailored to the local context. The framework is illustrated and described below:

Phase 1: Problem Identification, Needs and technological gap Assessment

- Conducting baseline surveys, participatory rural appraisals (PRAs), focus group discussions (FGDs), stakeholder analysis and SWOT analysis to understand local issues.
- Assessing technological gaps, resource constraints, and socio-economic barriers.
- Use of data-driven insights to prioritize interventions.

Phase 2: Strategic Intervention Design

- Tribal farmers conclave, ice breaking sessions, brainstorming sessions with tribal farmers to understand about their situation and make them familiar with new technological environment. Through these a platform for cultural and knowledge exchange was facilitated. As for example the tribal farmers of Jharkhand (*Santhal and Munda*) exposed the traditional practices of tribal farmers (*Bodo and Rabha*) of Assam.
- Integrated traditional knowledge with modern scientific practices.
- Focused on three core goals:
 1. **Income Enhancement:** Promoted cost-minimizing technologies, secondary agriculture, and market linkages.
 2. **Sustainability:** Introduced climate-resilient practices, water conservation, and organic farming.
 3. **Human Resource Development:** Build farmer capacity through training and skill development.

Phase 3: Collaborative Implementation

- o Engage ICAR institutes, KVKs, and NGOs to provide technical expertise and resources.
- o Implement location-specific programs
- o Conduct frontline demonstrations and field training to ensure practical adoption of technologies.
- o Adopt participatory approach

Phase 4: Capacity Building and Skill Development

- o Organize in-house training sessions, workshops, and exposure visits.
- o Train farmers on improved technologies, such as modern varieties, breeds, and integrated farming systems, income generating activities
- o Promote gender inclusivity by empowering women farmers through skill development and access to resources.

Phase 5: Monitoring, Evaluation, and Impact Assessment

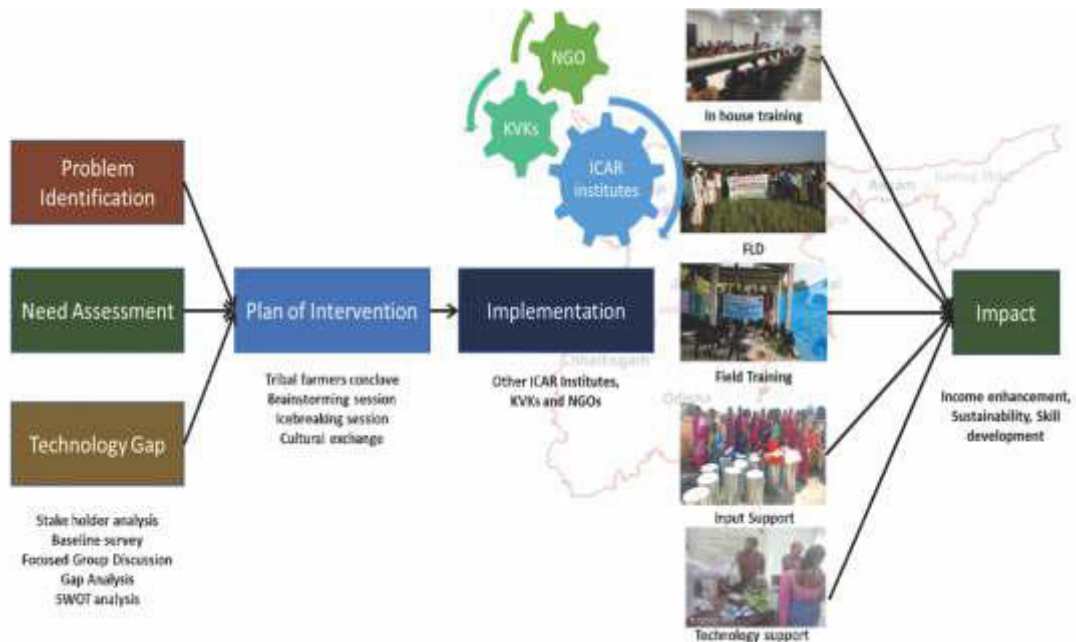
- o Use quantitative and qualitative indicators to assess outcomes, such as income levels, adoption rates, and environmental impact.
- o Conduct periodic reviews with stakeholders to identify gaps and refine strategies.
- o Document success stories and lessons learned for scalability and replication.

Proposed stakeholders

Farming community, planners & policy makers, NGOs, farmers' organizations and researchers working in climate change can visit these model villages and learn new things.

Commercial potential:

This tested and validated process model, supported by various state-specific success stories, is suitable for consultancy-based projects. It can be provided to central and state development ministries, NGOs, and other relevant organizations to support effective planning, implementation, and scaling of development initiatives across diverse sectors.



Process model of PRAYAS

List of Prayas Villages and state specific interventions undertaken

Villages Covered Under SCSP(8)	Villages Covered Under TSP (8)	Interventions made	State
Rewa-Mahaswari Demoria block	Dhipuji Janpam, Chandrapur block	Plantation crops and horticultural based IFS	Assam
Selhauri, Dulhin Bazar Block Guleriyachak, Tekari Block	Naurangia dobe, Ramnagar Block	Promotion of Backyard Poultry, Skilling Women and promotions of Nutrigarden	Bihar
Kumekela, Pathalgaon Block	Kandora Kunkuri block	Goat Based IFS	Chhattisgarh
Basantpur, Sohaon Block	-	Vegetable based interventions	Eastern UP
Udlu Mandu Block	Palandu and Kharsidag, Namkum Block; Lodma Ramgrah Block	Pig based and Horticulture based IFS	Jharkhand
Mangratoli village Nuagaon block	-	Promotion of Backyard Poultry,	Odisha
Begunbari Habibpur Block	Hatinada, Baghmundi Block, Chandandighi, Gazole block Chakkathalia, Bagda Block	Mushroom, Poultry and Goat and Fish based interventions	West Bengal

Impact:

The PRAYAS initiative has significantly empowered tribal and marginalized farmers to adopt climate-resilient varieties and technologies on a large scale. Through extensive awareness programs reaching over 12,000 tribal farmers, the project promoted sustainable agricultural practices, including resilient crop varieties, resource conservation technologies, and improved agronomic management. This comprehensive approach not only enhanced farmers' knowledge and skills but also led to a 20% increase in their income through the adoption of improved technologies. PRAYAS has played a pivotal role in building the capacity of tribal farmers, fostering climate resilience, and ensuring sustainable livelihoods.

References:

- i. Annual Report 2023 ICAR RCER Patna
- ii. Sarkar B, Sundaram PK, Mukherjee A, Shubha K, Jeet P, Kumar R, Jha A K, Raghav D K, Kumari A, Saurabh K, Upadhyaya A, Das A. 2024. Timeless Tools: An Ethnographic Exploration of Tribal Farmers' Heritage in Ajodhya Hills. AATCC Review s Journal (2024) 586-598. DOI : <https://doi.org/10.21276/AATCCReview.2024.12.04.586>

Process Model for Developing Zero Hunger & Zero Technology Gap Village

Period of Development: 2023-2025

Developers:

Anup Das, Anjani Kumar, Dhiraj Kumar Singh, DV Singh, Kumari Shubha, Jyoti Kumar, Anirban Mukherjee, Deokaran, Ramkewal, Rohan Kumar Raman, Pragya Bhaduriya, Arti Kumari, Ujjwal Kumar, Abhay Kumar, Rakesh kumar, Md. Monobrullah, Amarendra Kumar

Background:

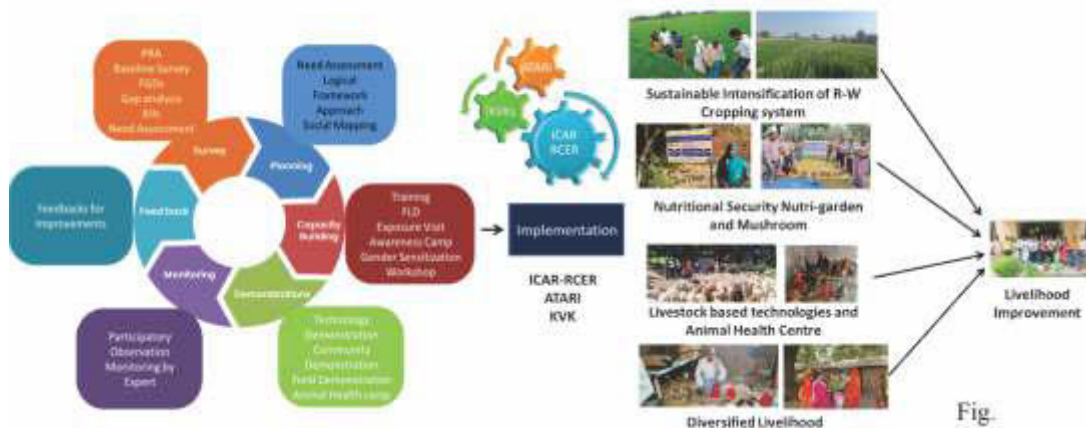
Zero hunger is one of the most important Sustainable Development Goals (SDGs) adopted by United Nations in 2016. Despite significant progress, addressing food and nutritional security at household level still remains an important issue in the country especially in eastern region of India. Almost 14% of the population is undernourished; 20.8% children are underweight and 51.4% of married women are anaemic in the country. Issues like soil fertility depletion, low productivity, inadequate nutritional security, unemployment, low income, poor animal health etc. persist in rural areas. Promoting innovative agricultural technologies in the form of climate resilient high yielding varieties, quality animal breeds and improved agronomic management practices have the potential to tackle the issue of hunger, malnutrition and low productivity. Therefore, Chhotaka Dhakaich village in Simri block of Buxar district in Bihar was selected and efforts were made to develop it as Model village with Zero Hunger & Zero Technology Gap in agriculture using a structured process.

Description of the process model:

Baseline survey was done in selected village indicated that there is hidden hunger among 60-70 of population due to less consumption of protein, vitamin and mineral rich diets like fruits, vegetable, meat, egg, fish, milk etc. Adoption level of improved crop varieties and technologies was also poor (30-40%). The process model for achieving zero technology gap and nutritional security was developed which is a structured, community-driven approach. An assumption was made that if 75% of farmers undertake nutritional practices and adopt selected technologies in agriculture, the village will be considered as Zero hunger, zero technology gap village. The model is implemented jointly by ICAR-RCER, Patna; ATARI, Patna; KVK, Buxar and village institutions ensuring active participation of farmers. The focus of the program were on technologies like sustainable intensification of rice-wheat cropping system, nutri-gardens, livestock based technologies and animal health centre, and livelihood diversification for enhancing productivity, nutritional security, and farmers' income. A robust monitoring and feedback loop ensures continuous refinement and long-term impact.

It begins with surveys using participatory rural appraisal, baseline studies, Focused group discussion (FGDs), gap analyses, and Key informant interviews (KIIs) to identify existing challenges. In the planning phase, needs assessment, logical frameworks, and social

mapping were developed to design targeted strategies. This was followed by capacity building, which included training, Front-Line Demonstrations (FLDs), exposure visits, awareness camps, and gender sensitization workshops. The demonstration phase implements key technologies through community and field demonstrations, supported by animal health camps, to encourage adoption by showcasing tangible benefits. The process model is depicted in fig. 2.



Framework of Process model

Proposed stakeholders:

Farmers, NGOs, planners and policy makers

Commercial potential:

The model village concept can be provided to state development departments for wider application. Consultancy can be provided to NGOs or private organization working in area of climate resilient agriculture.

Impact:

The demonstrated crop varieties of paddy, wheat, chickpea and lentil and moong have shown 10-20% yield advantage over existing varieties. The income of farmers has also increased by 30-40% due to increased system productivity as a result of introduction of moong bean during summer. Introduction of mushroom cultivation and backyard poultry also helped farmers to generate additional income of Rs 3 to 4 thousand per month.

References:

Developing Zero Hunger and Zero Technology Gap Village: An Innovative Approach, Extension Folder No.: E-247/Patna-132, ICAR Research Complex for Eastern Region, Patna

Conceptual Model for Evaluation of Carbon Credit Projects

Period of Development: 2023-2025

Developers:

Banda Sainath, Adeeth AG Cariappa, Ananya Khurana, Ujjwal Kumar, Anup Das

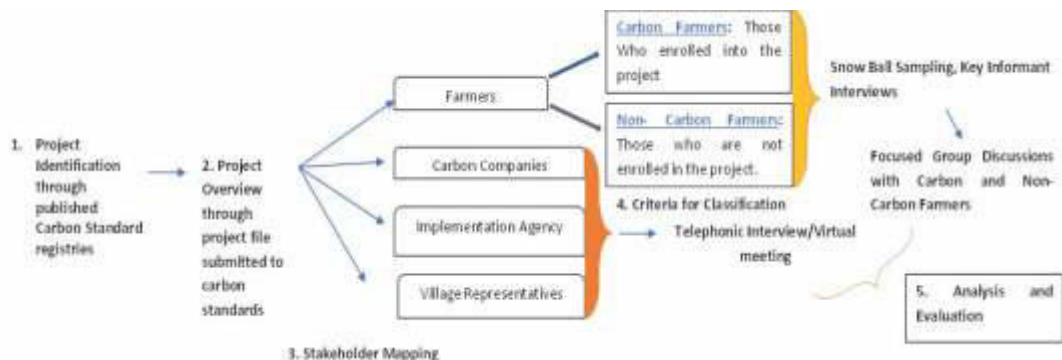
Background:

Carbon credit projects have emerged as key mechanisms to promote sustainable agricultural practices and mitigate climate change. Despite their increasing adoption, the actual impact on farmer participation, project implementation, and overall effectiveness remains underexplored. This conceptual model evaluates existing carbon credit projects, focusing on the participation of farmers, project execution, and associated challenges.

Description of the technology:

This model evaluates existing carbon credit projects in India by categorizing farmers into carbon farmers (enrolled in the project) and non-carbon farmers (not enrolled). This model incorporates a field-based approach, including snowball sampling, stakeholder interviews, key informant discussions, and on-ground verification, to assess project implementation, farmer participation, and the real-world impact of carbon credit mechanisms.

The evaluation process involved:



Schematic representation for evaluating the Carbon Credit Projects

Unlike most carbon credit studies that focus on project-level emissions reduction, this model helps uniquely to examine farmer participation dynamics and identifies challenges in project implementation.

- **Multi-Stakeholder Perspective:** Engages with farmers, project proponents, and implementation agencies to provide a holistic understanding of project efficacy.
- **Practical Insights for Policymakers & Investors:** Identifies barriers to farmer participation and financial flow bottlenecks, helping policymakers refine carbon credit frameworks and investors assess project viability.
- **Field-Based Verification:** Moves beyond theoretical assumptions by verifying carbon credit claims through direct farmer engagement and practice validation.

- **Scalability & Policy Implications:** Findings through this model provide crucial insights for scaling carbon credit projects and ensuring their sustainability in India's agricultural landscape, where such initiatives are still in their early stages.

Commercial potential:

The Proposed conceptual model helps the farmer community, carbon companies and companies involved in carbon offset validation, carbon credit buyers, and Agricultural and Agri-tech sectors.

Impact:

- Identifies implementation gaps and challenges in carbon credit projects at stakeholder level.
- Provides insights to enhance farmer participation and project efficiency.
- Assists policymakers and Project Proponents in refining carbon credit frameworks for improved accessibility.
- Strengthens the business case for carbon markets by ensuring transparency and effectiveness.

Agro-ecoregions suitability:

Pan India

References:

Khurana A, Sainath B, Cariappa AGA. 2023 Carbon farming in India: Case studies of Carbon Credit Projects from Maharashtra and Telangana. TAFSSA Research Note 10. Transforming Agrifood Systems in South Asia (TAFSSA). <https://hdl.handle.net/10883/22765>

Sainath B, 2023. Professional Attachment Training Report on A case study on carbon Farming in Telangana. ICAR RCER and CIMMYT.

Forecasting Kharif Rice Production and Rainfall Assessment in Bihar: ARIMAX and Spatial Interpolation Models for Food Security in Eastern India

Period of development: 2021 - 2023

Developers:

Rohan Kumar Raman, Abhay Kumar, Ujjwal Kumar, Akram Ahmed, Dhiraj Kumar Singh, Narayan Bhakta, Sarfaraj Ahmad, Ved Prakash and Anup Das

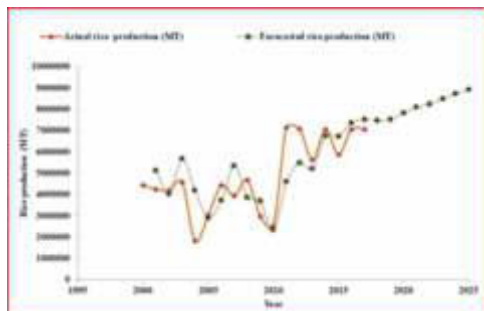
Background:

In the Eastern region of India, particularly in Bihar, rice is predominantly cultivated during the *Kharif* season, which is critical for the state's agricultural economy and food security. Rice cultivation in Bihar spans approximately 33 lakh hectares, with over 80% of this land (around 28 lakh hectares) dedicated to *Kharif* rice production. The *Kharif* season, which coincides with the monsoon period, is highly dependent on the timely and adequate rainfall, making it a crucial factor influencing the productivity of rice crops. Rainfall is one of the most significant weather variables that affect the growth and yield of rice in Bihar. Given the dependence of rice farming on monsoon rains, understanding rainfall patterns and accurately forecasting rice production has become essential for improving agricultural planning, ensuring food security, and enhancing the resilience of the farming community in Bihar. Therefore, model-based approaches, such as ARIMAX for rice production forecasting and spatial interpolation methods like IDW (Inverse Distance Weighting) for rainfall assessment, can provide valuable insights for better managing agricultural practices and mitigating risks related to climatic variations in the region.

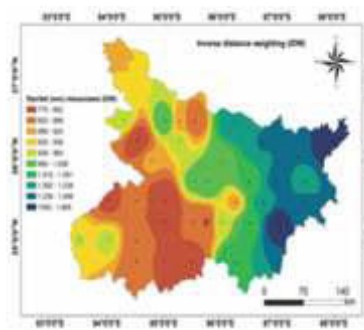
Description of the technology:

Time series annual data on rice production (MT) and rainfall (mm) during *kharif* season for the period 2000 to 2017 from secondary published sources (Directorate of Economics and Statistics, Bihar) and IMD data used for model development. Data for the period 2000 to 2015 was used for time series model development and 2016-17 for model validation. Time series ARIMAX (Auto Regressive Integrated Moving Average with regressors) based model was developed for rice production and forecasting using SAS 9.3 software. Akaike information criterion (AIC) is applied for best model selection. Using 17 years of average annual rainfall data during 2001 to 2017 of 38 districts of Bihar, spatial interpolation of rainfall was carried out using two models i.e. Simple kriging and Inverse Distance Weighting (IDW) interpolation. Maximum production was observed 7.18 million tons during year 2011 and minimum 1.82 in 2004. Maximum rainfall was observed 1433.48 (mm) during 2007 and minimum 792.63 mm during 2009. ARIMAX i.e., ARIMA (2,1,0) with regressor (*Kharif* rainfall) model developed for rice production and forecasting in Bihar. Developed model evaluated with minimum AIC 481.75 values for rice production. Rainfall showed positive significance ($p < 0.03$) impact on rice production. ARIMAX Model validated with original rice production for the year 2016 and 2017 with less than 7 % error prediction. Rice production forecasted till 2025 and observed to be increase in the upcoming years. Using 17 years of average annual rainfall data during 2001 to 2017 of 38

districts of Bihar, spatial interpolation of rainfall was carried out using two models i.e. Simple kriging and Inverse Distance Weighting (IDW) interpolation. Cross-validation technique was used to validate the different interpolation effects. Root Mean Square Error(RMSE) statistics has been used for model comparison. Analysis and mapping was performed using ArcGIS 10.3. IDW model performed better to predict average annual rainfall than Kriging.



Annual actual vs forecasted *Kharif* rice production during 2001 to 2025 in Bihar



IDW model based *Kharif* rainfall (mm) distribution in districts of Bihar during 2001-17

Commercial potential:

The developed ARIMAX model for forecasting rice production in Bihar offers significant commercial potential for improving agricultural planning and decision-making. By accurately predicting rice yields based on rainfall patterns, this model can help farmers, agricultural agencies, and policymakers optimize resource allocation, reduce crop failure risks, and enhance food security. The spatial rainfall interpolation using IDW also enables better water management strategies, ensuring efficient irrigation and improving overall productivity, benefiting both local economies and the rice supply chain.

Impact:

The developed model provides accurate rice production forecasts, enabling better resource management, risk mitigation, and improved agricultural planning. By integrating rainfall data, it enhances crop yield predictions, boosting food security and supporting sustainable farming practices in Bihar.

Agro ecoregion sustainability:

The developed ARIMAX model enhances agro-ecoregion sustainability by optimizing rice production forecasting, resource allocation, and water management, ensuring long-term agricultural resilience and food security in Bihar.

References:

Model Based Inference on Agricultural Crops for Food Security in Eastern India. 2022. Annual Report, ICAR Research Complex for Eastern Region, Patna, 108-09.
Kumar Abhay, Singh RKP, Mishra JS, Singh Dhiraj Kumar, Raman Rohan Kumar, Kumar Ujjwal. 2022. Changing pattern of rice production in eastern India: An economic analysis. *Indian Journal of Extension Education*, 58 (2): 71-76.

Model-Based Resource Mapping and strategies for Rice Cultivars in Flood-Prone Ecosystems

Period of Development: 2022 to 2024

Developer:

Rohan Kumar Raman, Abhay Kumar, Ujjwal Kumar, Akram Ahmed, Dhiraj Kumar Singh, Narayan Bhakta, Jyoti Kumar, Anirban Mukherjee, Banda Sainath, Sarfaraj Ahmad, Ved Prakash, Anup Das

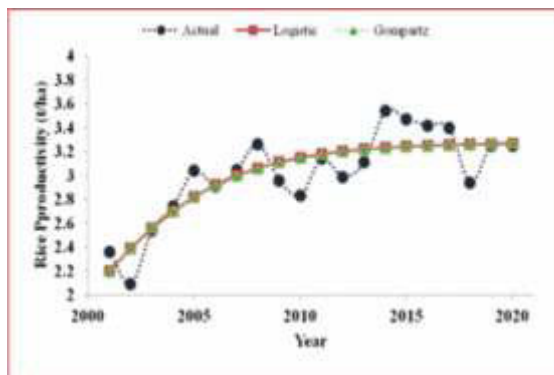
Background:

Recurrent flooding in Southeast Asia significantly impacts rice cultivation, particularly in India, West Bengal, a major rice-producing state prone to frequent flooding. Most of its districts face heightened vulnerability to these events. Since the nature of flood prone ecosystem is heterogeneous, farmers still maintained and cultivated indigenous landraces of rice. These indigenous landraces have poor productivity but having good adaptability to submergence conditions. In this framework study using secondary and primary data of Malda district of West Bengal which faces frequent flooding. The application of statistical growth models, forecasting models and geospatial models, the resources of flood prone ecosystem is assessed. Simultaneously based on resource assessment suitable strategies for rice cultivars are given.

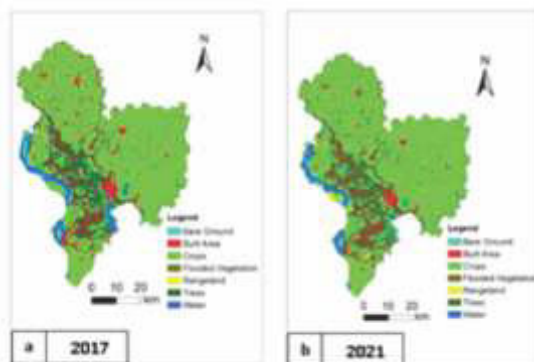
Description of the Technology:

The model was developed for Malda district in West Bengal, India, located between latitude 24° 40' 20" N and 25° 32' 08" N, and longitude 87° 45' 50" E and 88° 28' 10" E. Secondary data on rice production and productivity in Malda district from 2001 to 2020 were used from the "District Survey Report of Malda, 2022" (http://www.dmm.gov.in/pdfs/DSR/DSR_of_Malda.pdf) and the "Directorate of Economics and Statistics, 2023. Flood-affected area data for the district (at a 1:65,000 scale) were sourced from the "Annual Flood Report of West Bengal (2021)", while land use and land cover data (at a 1:50,000 scale) for the period 2017-2021 were obtained from the Bhuvan website. Gridded daily rainfall data (in mm) with a spatial resolution of 0.25° x 0.25° for the period 2000-2017 were gathered from the Indian Meteorological Department (IMD). Additionally, annual time-series data on rainfall and rainy days (defined as days with >2 mm of rainfall) were prepared using the IMD data for the period 2000-2017. Statistical time-series models, including the Gompertz model and the Autoregressive Integrated Moving Average with Explanatory Variables (ARIMAX) model, were applied alongside spatial Inverse Distance Weighting (IDW) interpolation models for comprehensive resource mapping. The results from the IDW model indicated an increase in both the area covered by water bodies and the total cropped area in Malda district between 2017 and 2021. Notably, the northern part of the district received more rainfall, while the southern region experienced a higher number of rainy days. The Gompertz model suggested a positive trend in rice productivity over the past two decades, signaling improvements in agricultural output despite flooding challenges. The ARIMAX (0, 2, 1) model further highlighted that rainfall had a positive impact on rice production, underscoring the significant role of climate in

shaping crop yields. This study offers valuable insights into the dynamics of rice cultivation in flood-prone regions and provides a robust framework for stakeholders and policymakers. It aids in formulating resource-based adaptation strategies that can enhance rice production sustainability in flood-affected, rice-based ecosystems.



Actual versus estimated rice productivity prediction through logistic and Gompertz growth model, Malda, West Bengal, India



Land use and land cover of Malda district during (a) 2017 and (b) 2021

Commercial potential:

Recurrent flooding in West Bengal, India, poses significant challenges to rice cultivation, impacting productivity and economic stability. Despite the frequent floods, farmers continue to cultivate indigenous rice landraces, which, while less productive, are well-adapted to submerged conditions. This model based technology, focusing on Malda district wetlands ecosystem, to assess the resources of flood-prone ecosystems. The application of growth and forecasting models, such as Gompertz and ARIMAX, highlights the adaptive capacity of these ecosystems and provides insights into suitable farming strategies. It will support the development of resource-based strategies to improve rice production sustainability in flood-affected areas.

Impact:

Recurrent flooding in West Bengal disrupts rice cultivation, impacting yields and livelihoods. Despite challenges, farmers grow indigenous rice landraces that adapt well to flooding. This research uses data driven models to assess flood-affected resources, offering insights for adaptive strategies to sustain rice farming and improve resilience in flood-prone areas.

Agro ecoregion sustainability:

This model based technology will be helpful for policy makers to develop strategies, enhancing resilience and ensuring sustainable agricultural practices in wetland ecosystem areas.

Reference:

Model Based Inference on Agricultural Crops for Food Security In Eastern India. (2023). Annual Report, ICAR Research Complex for Eastern Region, Patna, 88-89.

Chapter-2

Climate Resilient Rice Varieties



Swarna Shreya: Climate Resilient ice Variety

Period of development	: 2010-2015
Developers	: Santosh Kumar, SS Singh, SK Dwivedi, Md Idris, UR Sangle, ON Singh, T Ram and Arvind Kumar
Year of release/notification	: 2016
Recommended states	: Bihar, Chhattisgarh and Madhya Pradesh
Breeding method	: Pedigree method
Suitable ecology	: Water limited irrigated as well as drought-prone rainfed
Duration (days)	: 115-120
Yield potential (q/ha)	: 40-45
Characteristics of the variety	: Swarna Shreya is a high yielding drought tolerant aerobic rice variety. Quality wise, this variety possesses high hulling recovery (77.5%), milling (69.2%), head rice recovery (56.2%) with desirable intermediate amylose content (21.87%) and alkali spreading value (ASV=4.0). It has high GC (65.5 mm) with very occasionally chalkiness indicating good cooking quality and having long bold grain type. Swarna Shreya showed resistant to leaf blast and moderately resistant to neck blast, brown spot, RTD and sheath rot diseases and major insect pests like stem borer, leaf folder, gall midge (Biotype 1) and whorl maggot under natural condition.



Proposed stakeholders	: Farmers, Seed Company, NGOs, Central & State departments
Impact	: This variety covers more than 2 lakh hectare rice areas in eastern India.

Swarna Shakti Dhan: Climate Resilient Rice Variety

Period of development	: 2011-2018
Developers	: Santosh Kumar, JS Mishra, SK Dwivedi, N Bhakta, AK Dubey, Md Monobrullah, BP Bhatt, Jyothi Badri, A Anandan, SP Singh, ON Singh and Arvind Kumar
Year of release/notification	: 2020
Recommended states	: Bihar, Jharkhand, Odisha, Haryana, Chhattisgarh, Gujarat and Maharashtra
Breeding method	: Pedigree method
Suitable ecology	: Water limited irrigated & drought-prone rainfed
Duration (days)	: 115-120
Yield potential (q/ha)	: 45-50
Characteristics of the variety	: Swarna Shakti Dhan is a high yielding, drought tolerant aerobic rice variety having high Zinc (23.5 ppm) and Iron (15.1 ppm) contents. Quality-wise, this variety possesses high head rice recovery (63.2%), hulling (76.3%), milling (66.4%) with desirable intermediate amylose content (22.5%) and alkali spreading value (ASV=4.0). It has soft GC (59.3 mm) with very occasionally chalkiness indicating good cooking quality and having short bold type. Swarna Shakti Dhan showed moderately resistant to sheath blight, false smut, leaf blast, bacterial leaf blight (BLB), neck blast, rice tungro, brown spot and sheath rot diseases and major insect pest like stem borer, leaf folder and plant hopper under natural condition.



Proposed stakeholders	: Farmers, Seed Company, NGOs, Central & State departments
Impact	: This variety covers more than 0.50 lakh hectare rice areas in eastern India.

Swarna Samriddhi Dhan: Climate Resilient Rice Variety

Period of development	: 2013-2019
Developers	: Santosh Kumar, JS Mishra, SK Dwivedi, N Bhakta, AK Dubey, Md Monobrullah, BP Bhatt, Mandhata Singh, SP Singh, SK Singh, Nityanad and Arvind Kumar
Year of release/notification	: 2021
Recommended states	: Bihar
Breeding method	: Pedigree method
Suitable ecology	: Irrigated and rainfed shallow lowland ecology
Duration (days)	: 135-140
Yield potential (q/ha)	: 55-60
Characteristics of the variety	: Swarna Samriddhi Dhan is a high yielding, multiple stresses (drought & submergence, tolerant rice variety with desirable grain and cooking quality traits. Swarna Samriddhi Dhan is suitable for cultivation under transplanted condition in irrigated areas as well as rainfed shallow lowland ecosystems. Quality wise, Swarna Samriddhi Dhan possesses 77.8% hulling, 62.0% milling, 55.6 % head rice recovery (HRR) with desirable intermediate alkali spreading value, amylose content (24.33%) with long slender grain type. Beside drought (reproductive stage) tolerant, this variety can also tolerate 08-10 days submergence. In addition, Swarna Samriddhi Dhan showed moderately resistant to leaf blast, brown spot, sheath blight diseases and stem borer, leaf folder, and gall midge insect pest under natural condition.



Proposed stakeholders	: Farmers, Seed Company, NGOs, Central & State departments
Impact	: This variety covers more than 0.75 lakh hectare rice areas in eastern India.

Swarna Unnat Dhan: Climate Resilient Rice Variety

Period of development	: 2015-2020
Developers	: Santosh Kumar, AK Choudhary, JS Mishra, Abhishek Kumar Dubey, Jyothi Badri, Narayan Bhakta, Md Monobrullah, Ujjwal Kumar, SP Singh, ON Singh and Arvind Kumar
Year of release/notification	: 2021
Recommended states	: Bihar, Odisha, West Bengal, Madhya Pradesh and Maharashtra
Breeding method	: Pedigree method
Suitable ecology	: Irrigated ecology
Duration (days)	: 115-120
Yield potential (q/ha)	: 50-55
Characteristics of the variety	: Swarna Unnat Dhan is an early duration, semi-dwarf, high yielding, multiple stresses (drought, disease and insect pest) tolerant rice variety with desirable cooking quality traits. It is suitable for cultivation under transplanted condition in irrigated areas. This is also suitable for cultivation under aerobic condition in water scarcity irrigated areas. Quality wise, Swarna Unnat Dhan possesses high hulling (77.7%), milling (67.4%), head rice recovery (63.2 %) with desirable intermediate alkali spreading value, amylose content (24.34%) with long slender grain type. Rice variety Swarna Unnat Dhan showed moderately resistant to BLB, false smut, sheath rot, leaf blast and brown spot diseases and major insect pests like stem borer, BPH and gallmidge under natural condition.



Proposed stakeholders	: Farmers, Seed Company, NGOs, Central & State departments
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Swarna Shusk Dhan: Climate Resilient Rice Variety

Period of development	: 2015-2020
Developers	: Santosh Kumar, AK Choudhary, JS Mishra, AK Dubey, Rakesh Kumar, Narayan Bhakta, Md Monobrullah, Ujjwal Kumar, Jyothi Badri, SS Singh, ON Singh and Arvind Kumar
Year of release/notification	: 2023
Recommended states	: Uttar Pradesh
Breeding method	: Pedigree method
Suitable ecology	: Drought prone rainfed medium to upland
Duration (days)	: 110-115
Yield potential (q/ha)	: 40-45
Characteristics of the variety	: Swarna Shusk Dhan is an early duration, high yielding, drought tolerant rice variety with desirable quality traits. Quality wise, Swarna Shusk Dhan possesses high hulling (77.4%), milling (66.7%), head rice recovery (59.7 %) with desirable intermediate alkali spreading value (ASV=4.0), amylose content (24.892%) with long slender grain type. Rice variety Swarna Shusk Dhan showed moderately resistant to leaf blast, neck blast, sheath rot and false smut diseases and major pests like stem borer and, leaf folder under natural condition.



Proposed stakeholders	: Farmers, Seed Company, NGOs, Central & State departments
Impact	: This variety covers more than 20 hectare rice areas in eastern India.

Swarna Purvi Dhan 1: Climate Resilient Rice Variety

Period of development	: 2012-2020
Developers	: Santosh Kumar, AK Choudhary, JS Mishra, AK Dubey, N Bhakta, Md Monobrullah, Ujjwal Kumar, P Bhavana, Jyothi Badri, Avinash Pandey, Sudhir Kumar, Binay Kumar Singh, Krishana Prasad, ON Singh and Arvind Kumar
Year of release/notification	: 2023
Recommended states	: Jharkhand
Breeding method	: Pedigree method
Suitable ecology	: Water limited irrigated & drought-prone rainfed
Duration (days)	: 115-120
Yield potential (q/ha)	: 45-50
Characteristics of the variety	: Swarna Purvi Dhan 1 is an early duration, high yielding, drought tolerant aerobic rice variety with desirable quality traits and high micronutrient (20.4 ppm Zinc and 13.8 ppm Iron) content. Quality wise, Swarna Purvi Dhan 1 possesses high hulling (77.6%), milling (66.3%), head rice recovery (68.3%) with desirable intermediate alkali spreading value (ASV=4.6), amylose content (24.47%) with short bold grain type grain type. Rice variety Swarna Purvi Dhan 1 showed moderately resistant to leaf blast, neck blast, sheath rot, brown spot, sheath blight, false smut, and RTD diseases and major pests like stem borer, leaf folder, gall midge (biotype 1), whorl maggot and plant hopper under natural condition.
	
Proposed stakeholders	: Farmers, Seed Company, NGOs, Central & State departments
Impact	: This variety covers more than 15 hectare rice areas in eastern India.

Swarna Purvi Dhan 2: Climate Resilient Rice Variety

Period of development	: 2012-2020
Developers	: Santosh Kumar, AK Choudhary, JS Mishra, AK Dubey, N Bhakta, Md Monobrullah, Ujjwal Kumar, P Bhavana, Jyothi Badri, Avinash Pandey, Sudhir Kumar, Binay Kumar Singh, Krishana Prasad, ON Singh and Arvind Kumar
Year of release/notification	: 2023
Recommended states	: Jharkhand
Breeding method	: Pedigree method
Suitable ecology	: Irrigated
Duration (days)	: 115-120
Yield potential (q/ha)	: 50-55
Characteristics of the variety	: Swarna Purvi Dhan 2 is an early duration, high yielding, drought tolerant rice variety with desirable quality traits. Quality wise, Swarna Purvi Dhan 2 possesses high hulling (78.4%), milling (65.4%), head rice recovery (62.2%) with desirable intermediate alkali spreading value, amylose content (23.2%) with long slender grain type. Rice variety Swarna Purvi Dhan 2 showed moderately resistant to leaf blast, bacterial leaf blight (BLB), sheath blight, leaf scald, Glume discoloration and false smut diseases and major pests like stem borer, leaf folder, rice thrips, gall midge (biotype 5), and caseworm under natural condition.



Proposed stakeholders	: Farmers, Seed Company, NGOs, Central & State departments
Impact	: This variety covers more than 1500 hectare rice areas in eastern India.

Swarna Purvi Dhan 3: Climate Resilient Rice Variety

Period of development:2015-2021

Developers : Santosh Kumar, AK Choudhary, JS Mishra, AK Dubey, Jyothi Badri, Rakesh Kumar, N Bhakta, Md Monobrullah, Ujjwal Kumar, Ashutosh Upadhyaya, A Anandan, LV Subba Rao, ON Singh and Arvind Kumar

Year of release/notification : 2022

Recommended states : Bihar, Uttar Pradesh, Chhattisgarh, Haryana, Rajasthan and Maharashtra

Breeding method : Pedigree method

Suitable ecology : Irrigated ecology

Duration (days) : 115-120

Yield potential (q/ha) : 50-55

Characteristics of the variety : Swarna Purvi Dhan 3 is an early duration, semi-dwarf, high yielding, multiple stresses (drought, disease and insect pest) tolerant rice variety with desirable cooking quality traits. Swarna Purvi Dhan 3 is suitable for cultivation under transplanted condition in irrigated as well as water scarcity areas. This is also suitable for cultivation under aerobic condition in water scarcity irrigated areas. Quality wise, Swarna Purvi Dhan 3 possesses high hulling (80.1%), milling (71.05%), head rice recovery (64.7 %) with desirable intermediate alkali spreading value, amylose content (24.15%) with long slender grain type. Rice variety Swarna Purvi Dhan 3 showed moderately resistant to Bacterial leaf blight (BLB), leaf blast, neck blast, sheath blight, brown spot, false smut, sheath rot and glume discoloration diseases and stem borer, leaf folder, BPH and Gall Midge (Biotype 1) insect pests under natural conditions.



Proposed stakeholders : Farmers, Seed Company, NGOs, Central & State departments

Impact : This variety covers more than 1500 hectare rice areas in eastern India.

Swarna Purvi Dhan 4: Climate Resilient Rice Variety

Period of development	: 2015-2023
Developers	: Santosh Kumar, AK Choudhary, Sanjeev Kumar, AK Dubey, Kumari Shubha, Rakesh Kumar, N Bhakta, Anup Das, Jyothi Badri, A Anandan, JS Mishra, and Arvind Kumar
Year of release/notification	: 2024
Recommended states	: Bihar, Jharkhand, Gujarat and Haryana
Breeding method	: Pedigree method
Suitable ecology	: Water limited irrigated & drought-prone rainfed
Duration (days)	: 115-120
Yield potential (q/ha)	: 45-50
Characteristics of the variety	: Swarna Purvi Dhan 4 is an early duration, high yielding, drought tolerant aerobic rice variety with desirable quality traits. Quality wise, Swarna Purvi Dhan 4 possesses high hulling (77.8%), milling (68.0%), head rice recovery (61.9%) with desirable intermediate alkali spreading value (ASV=4.0), amylose content (23.2%) with long bold grain type. Rice variety Swarna Purvi Dhan 4 showed moderately resistant to leaf blast, brown spot, sheath blight, bacterial leaf blight, sheath rot and glume discoloration diseases and major pests like stem borer, leaf folder, gall midge (biotype 4M), whorl maggot and caseworm under natural condition.



Proposed stakeholders	: Farmers, Seed Company, NGOs, Central & State departments
Impact	: Recently released and notified

Swarna Purvi Dhan 5: Climate Resilient Rice Variety

Period of development	: 2014-2023
Developers	
Lead	: Santosh Kumar
Associate	: AK Choudhary, Sanjeev Kumar, AK Dubey, Kumari Shubha, Rakesh Kumar, Narayan Bhakta, Anup Das, Jyothi Badri, A Anandan, JS Mishra and Arvind Kumar
Year of release/notification	: 2024
Recommended states	: Bihar, Jharkhand, and West Bengal
Breeding method	: Pedigree method
Suitable ecology	: Drought prone rainfed medium to upland
Duration (days)	: 110-115
Yield potential (q/ha)	: 40-45
Characteristics of the variety	: Swarna Purvi Dhan 5 is an early duration, high yielding, drought tolerant rice variety with desirable quality traits and high micronutrient (25.5 ppm Zinc and 13.1 ppm Iron) content. This variety is also suitable for direct seeded aerobic condition. Quality wise, Swarna Purvi Dhan 5 possesses high hulling (74.3%), milling (65.3%), head rice recovery (59.7%) with desirable intermediate alkali spreading value (ASV=5.0), amylose content (21.7%) with short slender grain type. Rice variety Swarna Purvi Dhan 5 showed resistant to neck blast and stem rot and, moderate resistant to leaf blast, brown spot, and sheath rot diseases and major pests like stem borer, leaf folder, gall midge and rice thrip under natural condition.



Proposed stakeholders	: Farmers, Seed Company, NGOs, Central & State departments
Impact	: Recently released and notified

Swarna Mohan Dhan: A high yielding rice varieties

Period of development	: 2014-2024
Developers	: P Bhavana, A Pattanayak, BP Bhatt, AK Singh, Bikas Das, AK Jha, Santosh Kumar, Santosh S Mali, Jaipal S Choudhary, Reshma Shinde, Anup Das, Krishna Prasad, Ekhlague Ahmad
Year of release/notification	: IVRC, 2024
Recommended states	: Jharkhand
Breeding method	: Pure line selection
Suitable ecology	: Rainfed upland and medium upland drought prone and dry direct seeded conditions
Duration (days)	: 110-115 days
Yield potential (q/ha)	: 42.1-46.4 q/ha
Characteristics of the variety	: Swarna Mohan Dhan is semi-dwarf (70-77cm) with medium slender grain, light brown hull and creamish white kernel. High milling (68%) and head rice recovery (59%) and very good cooking quality (amylose 23.4%). Suitable for dry direct seeded condition. High early vegetative vigour, Less leaf rolling and tip dry during stress condition. 30-40 % water saving. Days to 50 % flowering – 75-80 days (early). High yielding (42-46 q/ha) Moderate to high resistant to bacterial leaf blight, Brown leaf spot and leaf Blast under field condition. Moderate to high tolerant to Stem borer, Gall midge, Gundhi Bug and BPH.



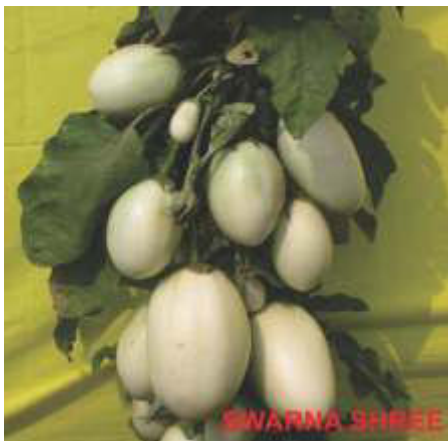
Proposed stakeholders	: Farmers, KVKs, NGO, NSC, State Seed Corporations
Impact	: Farmers /consumers are having very high degree of acceptability of this variety due to its medium slender grain quality, good cooking quality, very good performance even under multiple stages drought stress and direct seeded condition (limited irrigation), 30-40% water saving, high yield potential, semi-dwarf type, early maturity and moderate to high tolerance to disease & pests.

Chapter-3

Improved varieties of Vegetables



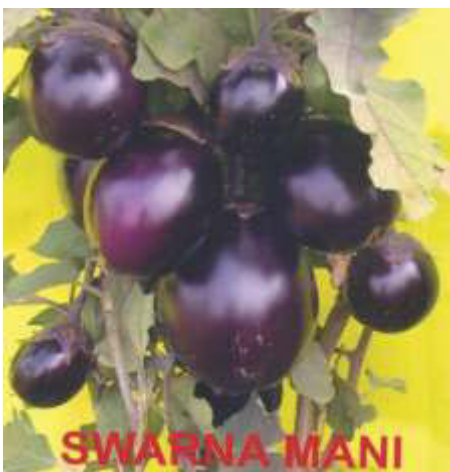
1. Brinjal Variety Swarna Shree



Major traits

- Developed through pure line selection
- Fruit: Creamy white in colour, round to oval, soft and preferred for *bharta* preparation,
- Moderately resistant to bacterial wilt.
- Recommended for Bihar, Jharkhand and adjoining areas.
- Time of sowing: July-August,
- Spacing: 60 cm x 50 cm
- Seed rate: 250-300 g/ha
- Maturity: First harvest 55-60 days after planting
- Average yield: 55-60 t/ha
- Released through CVRC Gazette No. 1422 dt. 28.11.06
Developer: V.S.R. Krishna Prasad and D.P. Singh

2. Brinjal Variety Swarna Mani



- Developed through hybridisation followed by pedigree selection and back cross method.
- Fruit: Attractive, shiny purple in colour, round in shape.
- Moderately resistant to bacterial wilt.
- Recommended for Bihar, Jharkhand and adjoining areas.
- Suitable for bacterial wilt prone areas.
- Time of sowing: July-August.
- Spacing: 60 cm x 50 cm.
- Seed rate: 250-300 g/ha.
- Maturity: First harvest 65-70 days after planting
- Average yield: 60-65 t/ha.
- Released through CVRC Gazette No. 493 dt: 31.5.04
Developer: V.S.R. Krishna Prasad, D.P. Singh, A.B Pal, R.S. Pan, Mathura Rai and J.P. Sharma

3. Brinjal Variety Swarna Shyamli



- Developed through pure line selection
- Fruit: Medium size (250 g), round, attractive green colour with white stripes, Locally preferred for better quality
- Resistant to bacterial wilt
- Recommended for round the year cultivation in Jharkhand, Bihar and adjoining areas
- Time of sowing: July-August
- Spacing: 60 cm x 50 cm
- Seed rate: 250-300 g/ha
- Maturity: First harvest 45-60 days after planting
- Average yield: 50 t/ha
- Released through CVRC Gazette No. 1422 dt. 28.11.06
- Developer: V.S.R. Krishna Prasad, R.S. Pan, Mathura Rai, A.K. Singh and J.P Sharma

4. Brinjal Variety Swarna Pratibha



- Developed through pure line selection
- Fruit: Medium size (250 g), and shiny purple colour
- Resistant to bacterial wilt
- Recommended for Bihar, Jharkhand and adjoining areas
- Time of sowing: July-August
- Spacing: 60 cm x 50 cm
- Seed rate: 250-300 g/ha
- Maturity: First harvest 75-80 days after planting
- Average yield: 45-50 t/ha
- Released through CVRC Gazette No. 493 dt: 31.5.04
- Developer: V.S.R. Krishna Prasad, R.S. Pan, Mathura Rai, A.K. Singh and J.P Sharma

5. Brinjal Variety Swarna Shobha



- Developed through hybridization followed by pedigree selection.
 - Fruit: Round, medium size, weight (300-350 g) and attractive milky white with purple tinge
 - Tolerant to bacterial wilt disease under field condition
 - Time of sowing: July-August
 - Spacing: 60 cm x 50 cm, Seed rate: 250-300 g/ha
 - Maturity: First harvest 55-65 days after planting
 - Average yield : 50-60 t/ha
 - Recommended for Bihar and Jharkhand
 - Released through CVRC Gazette No.398 dt:25.4.06
- Developer: A. K. Singh, R.S. Pan, Mathura Rai, V.S.R. Krishna Prasad, J.P. Sharma and S. Kumar*

6. Brinjal Variety Swarna Abhilamb



- Developed through pure line selection.
 - Fruit: Long (30-35 cm), weight (80-100g) and attractive purple blue colour.
 - Resistant to bacterial wilt and Phomopsis blight disease under field condition.
 - Recommended for Bihar and Jharkhand, Uttaranchal, Himachal Pradesh and Jammu & Kashmir.
 - Maturity: First harvest 55-60 days after planting.
 - Average yield: 60-70 t/ha.
 - Released through CVRC Gazette No. 655, dt: 01.06.2007
- Developer: A. K. Singh, R.S. Pan, , J.P. Sharma and S. Kumar*

7. Brinjal Variety HABR-21



- Developed through pureline selection
- Plants are intermediate in growth habit, with semi upright, stems and leaves are green.
- Fruits are attractive with black color and calyx is dark purple.
- Fruit length (18-20 cm), fruit breadth (7-8 cm), fruit weight (300-350 gm), and yield per plant (2.0-3.0 kg).
- Mean yield potential ranges from 55-60 t/ha.
- Recommended for U.P., Punjab, Bihar and Jharkhand
- *Identified for release during 31st AICRP group meeting held at CSKHPKV, Palampur from 2-5, May 2013 for Zone-IV*

Developer: A. K. Singh, R.S.Pan, , J.P. Sharma, S. Kumar and P Bhavana

8. Brinjal hybrid Swarna Shakti (F1)



- Hybrid developed through heterosis breeding.
- Fruit: Oblong, medium length (15-17 cm), weight (250-300 g) and attractive shiny light purple colour.
- Resistant to phomopsis blight.
- Moderately resistant to bacterial wilt under field condition
- Recommended for Bihar and Jharkhand
- Time of sowing : July-August
- Spacing : 60 cm x 50 cm
- Seed rate : 150-200 g/ha
- Maturity : First harvest 55-65 days after planting
- Average yield: 65-75 t/ha
- *Released through IVRC 2004*

Developer: A. K. Singh, R.S.Pan, V.S.R. Krishna Prasad, Mathura Rai, J.P. Sharma and S. Kumar

9. Brinjal hybrid Swarna Ajay (F1)



- Fruit: Oblong, medium length (10-12 cm)
- Weight (100-120 g) and attractive light purple colour
- Average yield: 70-75 t/ha
- Resistant to bacterial wilt & phomopsis blight
- Recommended for cultivation in Punjab, Uttaranchal, Jharkhand, Bihar and U.P.
- Released through CVRC Gazette notification No. 1422 dt: 28.11.06.

Developer: A. K. Singh, R.S. Pan, Mathura Rai, V.S.R. Krishna Prasad, J.P. Sharma and S. Kumar

10. Brinjal hybrid Swarna Neelima (F1)



- Hybrid developed through heterosis breeding.
- Fruit: Round, medium length (10-12 cm), weight (250-300 g) and attractive light purple black colour.
- Resistant to bacterial wilt and phomopsis blight.
- Maturity: First harvest 55-65 days after planting.
- Average yield- 80-90 t/ha
- Recommended for cultivation in Punjab, U.P., Jharkhand & Bihar
- Released by CVRC Gazette No. 999 dt.18.07.2008

Developer: A. K. Singh, R.S.Pan, J.P. Sharma and S. Kumar

11. Brinjal hybrid Swarna Mohit (F1)



- Hybrid developed through heterosis breeding
- Fruit: Oblong, medium length (10-15 cm), weight (100-150 g) and attractive light purple colour
- Resistant to phomopsis blight
- Moderately resistant to bacterial wilt and phomopsis blight under field condition
- Time of sowing: July-August
- Spacing: 60 cm x 50 cm
- Seed rate: 150-200 g/ha
- Maturity: First harvest 55-65 days after planting
- Average yield: 65-75 t/ha
- Recommended for Bihar and Jharkhand, Karnataka, Kerala & Tamilnadu
- Released by CVRC 2008

Developer: A. K. Singh, R.S.Pan, , J.P. Sharma and S. Kumar

12. Tomato Variety Swarna Lalima



- Developed through pure line selection
- Fruit: Deep red, round, weight (120-125 g) with TSS 4°B
- Resistant to bacterial wilt
- Time of sowing: July-September and February-April
- Spacing: 60 cm x 40 cm
- Seed rate: 150-200 g/h
- Maturity: First harvest 60-65 days after sowing
- Average yield: 50-55 t/ha
- Recommended for Jharkhand and Bihar
- Released through CVRC Gazette No 1422 dt. 28.11.06
- Developer: V.S.R. K.Prasad, Mathura Rai, R.S. Pan, A.K.Singh and J.P. Sharma

13. Tomato Variety Swarna Naveen



- Developed through pure line selection
- Fruit: Weight 60-70 g, oblong, deep red with TSS 5°B
- Resistant to bacterial wilt
- Time of sowing: July-September and February-April
- Spacing: 60 cm x 40 cm
- Seed rate: 150-200 g/ha
- Maturity: First harvest 55-60 days after sowing
- Average yield: 60 t/ha
- Recommended for Jharkhand, Bihar and adjoining areas.
- Released through CVRC Gazette No 1422 dt. 28.11.06
- Developer: V.S.R. K. Prasad, Mathura Rai, R.S. Pan, A.K.Singh and J.P. Sharma

14. Tomato hybrid Swarna Baibhav(F1)



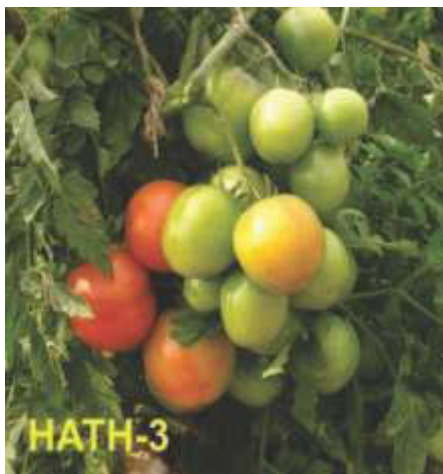
- Determinate F₁ hybrid
- Fruit: Round, deep red color, firm, weight (140-150 g), contain high pulp
- Suitable for long distance transportation & processing
- Recommended for Punjab, Uttaranchal, Jharkhand, Bihar and Uttar Pradesh
- Time of sowing: August-September
- Spacing: 60 cm x 40 cm
- Seed rate: 125-150 g/ha
- Maturity: First harvest 55-60 days after transplanting
- Average yield: 70-80 t/ha
- Released through CVRC Gazette No. 493 Dt 31.05.04
- Developer: V.S.R. K. Prasad, D.P. Singh, R.S. Pan and Mathura Rai

15. Tomato hybrid Swarna Samridhi (F1)



- Indeterminate F₁ hybrid, developed through heterosis breeding.
- Fruit: Fruits are borne in cluster (8-10), round, red, weight (40-50 g), firm, TSS 5.0-6.0oB, and contain high pulp.
- Resistant to bacterial wilt and early blight disease.
- Maturity: First harvest 55-60 days after sowing.
- Average yield: 90-100 t/ha.
- Recommended for round the year cultivation in Jharkhand, Bihar & adjoining areas.
- Released through IVRC 2004
- Developer: A. K. Singh, R.S. Pan, Mathura Rai, V.S.R. Krishna Prasad, J.P. Sharma and S. Kumar

16. Tomato hybrid Swarna Sampada (F1)



- Round red fruits, firm
- Resistant to bacterial wilt & early blight
- Determinate F1 hybrid, developed through heterosis breeding
- Resistant to bacterial wilt & early blight.
- Fruit: Round, red, weight (120-130 g), firm
- TSS 4.5-5.0B, acidity 0.35-0.40% and contain high pulp
- Average yield: 100-105 t/ha
- Recommended for cultivation in Punjab, Uttaranchal, Jharkhand, Bihar and U.P.
- Released through CVRC Gazette notification No 1422 dt. 28.11.06.

Developer: A. K. Singh, R.S. Pan, Mathura Rai, V.S.R. Krishna Prasad, J.P. Sharma and S. Kumar

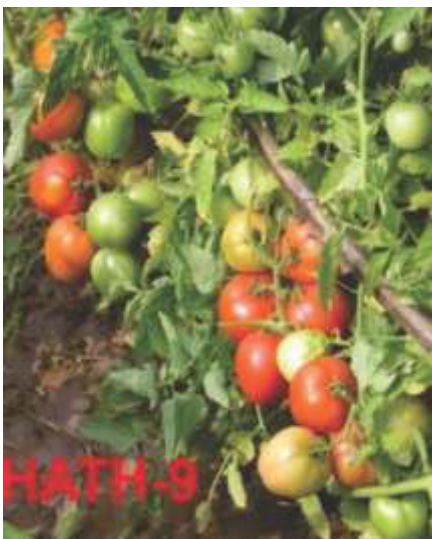
17. Tomato hybrid Swarna Vijaya



- Round red fruits
- Resistant to bacterial wilt & early blight
- Determinate F1 hybrid, developed through heterosis breeding.
- Fruit: Weight (80-90 g), round, red, firm with TSS 4.5- 5.0B and acidity (0.35-0.40 %) and born in cluster of 6-8
- Resistant to bacterial wilt and early blight.
- Maturity: First harvest 55-60 days after sowing.
- Average yield: 100-105 t/ha
- Recommended for cultivation in in Jharkhand, Bihar H.P., J&K and Uttarakhand.
- Released through CVRC Gazette No. 999 dt.18.07.2008

Developer: A. K. Singh, R.S. Pan, J.P. Sharma and S. Kumar

18. Tomato hybrid Swarna Deepti (F1)



- Determinate F₁ hybrid, developed through heterosis breeding
 - Fruit: Round, deep red colour, weight (120-130 g), with TSS 4-5B, and acidity (0.35-0.40 %)
 - Born in cluster of 4-5, Suitable for table & processing
 - Resistant to bacterial wilt and early blight disease
 - Time of sowing: August-September
 - Spacing: 60 cm x 40 cm
 - Seed rate: 125-150 g/ha
 - Maturity: First harvest 60-65 days after transplanting
 - Average yield: 100-105 t/ha
 - Recommended for Jharkhand & Bihar and adjoining areas.
 - Released through IVRC 2011
- Developer: A. K. Singh, R.S. Pan, J.P. Sharma and S. Kumar*

19. Tomato hybrid Swarna Anmol (F1)



- Swarna Anmol was developed by heterosis breeding.
 - Fruits are round, red, with light green shoulder and borne in clusters of 5-6.
 - Fruit weight 60-70 g, TSS 4.5-5.0o brix, acidity 0.30-0.35% and ascorbic acid 40-42 mg/100 g fruit 87.
 - Swarna Anmol is indeterminate in growth habit (5.0-5.5 m), high yielding (160-180 t/ha), resistant to bacterial wilt and can be cultivated round the year
 - It recorded 110% over the check GS-600.
 - Recommended for protected cultivation in Jharkhand, Bihar and adjoining areas where bacterial wilt is a problem.
 - Released through SVRC, 2015
- Developer: A.K.Singh, R.S. Pan, P.Bhavana, S. Maurya, A.K.Jha, J.S.Choudhary, J.P.Sharma and S. Kumar*

20. Tomato variety Swarna Kanchan



- Fruits are oblong, red with less seed, more pulp and borne in clusters of 4-5.
 - High yielding (50-55t/ha)
 - Suitable for processing, Resistant to bacterial wilt
 - Recommended for cultivation in Jharkhand, Bihar and adjoining areas
 - Released through SVRC, 2015
- Developer: A.K.Singh, R.S. Pan, P.Bhavana, S. Maurya, A.K.Jha, J.S.Choudhary, J.P.Sharma and S. Kumar*

21. Tomato variety Swarna Ratan



- Promising cherry type variety.
 - Fruits are very small (15-20g), round, red
 - Born in clusters of 10-12.
 - High yielding (50-60t/ha).
 - Resistant to bacterial wilt.
 - Recommended for cultivation in Jharkhand, Bihar and adjoining areas
 - Released through SVRC, 2015
- Developer: A.K.Singh, R.S. Pan, P.Bhavana, S. Maurya, A.K.Jha, J.S.Choudhary, J.P.Sharma and S. Kumar*

22. Tomato variety Swarna Prakash



- Resistant to bacterial wilt under natural field condition (88.5% plant survival)
 - Determinate growth habit plant height (75-80cm)
 - Flowering starts in 25-30 days after planting
 - Slightly flattened fruits with attractive dark red colour at maturity
 - Avg fruit weight: 90-100g
 - Fruit length: 4.0-4.5cm, Fruit diameter: 4.5-5.0cm
 - Fruits/plant: 25-30,
 - Avg fruit yield/plant: 2.5-3.0kg
 - High yielding 45-50t/ha (34.2% superior than local check)
 - Recommended for cultivation in Jharkhand, Bihar and adjoining areas
 - Released through CVRC, Gazette No. 1296 dated 14.03.2024
- Developer: P. Bhavana, A.K.Singh, S. Maurya, J.S.Choudhary*

23. Chilli variety Swarna Praphulya



- Swarna Praphulya was developed through pureline selection from local germplasm.
- Plant is vigorous with 90-100 cm plant height and resistant to bacterial wilt under natural field conditions.
- Average yield: 20-25 t/ha
- Fruits are long (6.0-6.5 cm), pungent, dark green and dark red when ripe.
- Recommended for cultivation in Jharkhand, Bihar and adjoining areas
- Released through SVRC 2015
Developer: A.K.Singh, R.S. Pan, P.Bhavana, S. Maurya, A.K.Jha, J.S.Choudhary, J.P.Sharma and S. Kumar

24. Chilli variety Swarna Tejaswi



- Less pungent dark red ripe fruit suitable for pickle.
- Resistant to bacterial wilt
- Fruits long, average yield (20-25t/ha)
- Recommended for cultivation in Jharkhand, Bihar and adjoining areas
- Released through SVRC, 2015
Developer: A.K.Singh, R.S. Pan, P.Bhavana, S. Maurya, A.K.Jha, J.S.Choudhary, J.P.Sharma and S. Kumar

25. Chilli variety Swarna Arohi



- Resistant to bacterial wilt under natural field **variety** condition (89.5% plant survival)
- High yielding 20-22t/ha (28.6% superior than KA-2)
- Recommended for cultivation in Jharkhand, Bihar and adjoining areas
- Plant height: 90-100cm
- Days to flowering: 45-50 days
- Dark green upright fruits having good source of vitamin A & C
- High pungency at green chilli & red ripe stage
- Avg. fruit weight: 2.5-3.0g, fruit length: 6.0-6.5cm, fruit dia.: 0.7-0.8cm
- Fruits/plant: 500-600
- Avg fruit yield/plant: 1.0-1.5 kg
- Released through CVRC, Gazette No. 1296 dated 14.03.2024
Developer: A.K.Singh, P.Bhavana, R.S. Pan, S. Maurya, J.S.Choudhary

26. Chilli variety Swarna Apurva



- Resistant to bacterial wilt under natural field condition (87% plant survival)
- High yielding 20-25t/ha (45.4% superior than KA-2)
- Recommended for cultivation in Jharkhand, Bihar and adjoining areas
- Plant height: 80-90cm
- Days to flowering: 35-40 days
- Dark green fruits having good source of vitamin A & C
- High pungency at green chilli & red ripe stage
- Avg. fruit weight: 3.0-3.5g, fruit length: 7.0-7.5cm, fruit dia.: 0.7-0.8cm
- Resistant to bacterial wilt
- Fruits/plant: 400-500 • Avg fruit yield/plant: 1.2-1.7 kg
- Released through CVRC, Gazette No. 1296 dated 14.03.2024

Developer: A.K.Singh, P.Bhavana, R.S. Pan, S. Maurya, J.S.Choudhary

27. Capsicum variety Swarna Atulya



- Swarna Atulya was developed through pureline selection from EC-596749 collected from world vegetable centre Taiwan through NBPGR.
- Fruits (120-130 g) yellow coloured at maturity
- Suitable for *kharif* and *rabi* season cultivation.
- Yield: 40-45 t/ha
- It is tolerant to powdery mildew.
- Recommended for cultivation in Jharkhand, Bihar and adjoining areas.
- Released by SVRC 2015

Developer: A.K.Singh, R.S. Pan, P.Bhavana, S. Maurya, A.K.Jha, J.S.Choudhary, J.P.Sharma and S. Kumar

28. Cucumber variety Swarna Poorna



- Fruit: Cylindrical long in shape, medium size (300 g), light green colour with no placental hollowness
- Tolerant to powdery mildew
- Time of sowing: July-August
- Spacing: 2 m x 0.5 m
- Seed rate: 600-700 g/ha
- Maturity: First harvest 55-60 days after sowing
- Average yield: 30-35 t/ha
- Recommended for Bihar, Jharkhand, Orissa, Uttar Pradesh and Pradesh.
- Released through CVRC Gazette notification No 398 dt.25.04.06.

Developer: V.S.R. Krishna Prasad, D.P.Singh, R.S. Pan, Mathura Rai and A.K.Singh

29. Cucumber variety Swarna Sheetal



- Developed through hybridization followed by pedigree and recurrent selection.
- Fruit: Cylindrical long in shape, medium size (250 g), greenish white in colour with no placental hollowness
- Tolerant to powdery mildew
- Time of sowing: February-March
- Spacing: 2 m x 0.5 m
- Seed rate: 600-700 g/ha
- Maturity: First harvest 60-65 days after sowing,
- Average yield: 25-30 t/ha
- Recommended for Bihar, Jharkhand, Uttar Pradesh, Maharashtra, Delhi, Andhra Pradesh, Himachal Pradesh and Kerala
- Released through CVRC Gazette notification No 1422 dt. 28.11.06

Developer: V.S.R. Krishna Prasad, D.P.Singh, Mathura Rai and R.S. Pan

30. Cucumber variety Swarna Ageti



- Fruit: Cylindrical long in shape, medium size (250 g), greenish white in colour with no placental hollowness
- Tolerant to powdery mildew.
- Time of sowing: February-March
- Spacing: 2 m x 0.5 m
- Seed rate: 600-700 g/ha
- Maturity: First harvest 60-65 days after sowing,
- Average yield: 25-30 t/ha
- Recommended for Bihar, Jharkhand, Uttar Pradesh, Maharashtra, Delhi, Andhra Pradesh, Himachal Pradesh and Kerala
- Released through CVRC Gazette notification No 1422 dt. 28.11.06

Developer: V.S.R. Krishna Prasad, D.P.Singh, R.S. Pan and Mathura Rai

31. Pointed gourd variety Swarna Rekha



- Developed through clonal selection.
- Fruit: Elongated in shape, striped green, contain soft seed
- Time of planting: February (rooted plant) September (vine cutting)
- Spacing: 1 m x 1 m
- No. of plant/ha : 10,000
- Average yield : 15-20 t/ha
- Recommended for Jharkhand, Bihar, Orissa, West Bengal and Eastern Uttar Pradesh
- Released through CVRC Gazette notification No 1422 dt. 28.11.06

Developer: V.S.R. Krishna Prasad and D.P.Singh

32. Pointed gourd variety Swarna Alaukik



- Developed through clonal selection.
- Fruit: Elongated in shape, light greenish in colour, suitable for table and sweet preparation
- Time of planting: February (rooted plant) September (vine cutting)
- Spacing: 1 m x 1 m
- No. of plant/ha : 10,000
- Average yield : 20-25 t/ha
- Recommended for Jharkhand, Bihar, Orissa, West Bengal and Eastern Uttar Pradesh
- Released through CVRC Gazette notification No 1422 dt. 28.11.06

Developer: V.S.R. Krishna Prasad and D.P. Singh

33. Pointed gourd variety Swarna Suruchi



- Developed through clonal selection.
- Fruit: Oval in shape having blunt end on both side, light greenish in colour, suitable for table and sweet preparation
- Time of planting: February (rooted plant) September (vine cutting)
- Spacing: 1 m x 1 m
- No. of plant/ha : 10,000
- Average yield : 25-30 t/ha
- Recommended for Jharkhand, Bihar, Orissa, West Bengal and Eastern Uttar Pradesh
- Released by IVRC 2011

Developer: A. K. Singh, R.S. Pan, J.P. Sharma and S. Kumar

34. Ridge gourd variety Swarna Manjari



- Developed through hybridization followed by selection.
- Fruit: Elongated in shape, medium size, weight (175 g), highly ridged, greenish colour, pulp soft and contain less fibre
- Tolerant to powdery mildew
- Time of sowing: June-July and February-March
- Spacing: 2 m x 0.5 m
- Seed rate: 2.0-2.5 kg/ha
- Maturity: First harvest 65-70 days after sowing
- Average yield: 18-20 t/ha
- Recommended for Jharkhand, Bihar, Orissa, Tamil Nadu, Maharashtra and Andhra Pradesh
- Released through CVRC Gazette notification No 1422 dt. 28.11.06.

Developer: V.S.R. Krishna Prasad, D.P.Singh, Mathura Rai and R.S. Pan

35. Ridge gourd variety Swarna Uphar



- Developed through hybridization followed by pedigree selection.
- Fruit: Elongated in shape, medium size, weight (200 g), long ridged at edible stage, pulp soft and contain less fibre.
- Time of sowing: June-July and February-March
- Spacing: 2 m x 0.5 m
- Seed rate: 2.0-2.5 kg/ha
- Maturity: First harvest 65-70 days after sowing
- Average yield: 20-30 t/ha
- Recommended for Jharkhand, Bihar and adjoining areas
- Released through CVRC Gazette notification No 1422 dt. 28.11.06

Developer: V.S.R. Krishna Prasad, R.S. Pan, Mathura Rai, A.K. Singh and J.P.Sharma

36. Ridge gourd variety Swarna Sawani (*satputia*)



- Swarna Sawani was developed through pureline selection from local collection.
- Plant is vigorous with 3-4m vine length early flowering and fruiting and suitable for rainy season crop.
- Swarna Sawani (20-25t/ha) shows its superiority with 42% increase over local check.
- Recommended for cultivation in Jharkhand, Bihar and adjoining areas
- It is tolerant to powdery mildew and downy mildew.
- Fruits (35-45g) borne in clusters with 6-8 fruits per cluster.
- Released by SVRC 2015

Developer: P.Bhavana, A.K.Singh, R.S. Pan, S. Maurya, A.K.Jha, J.S.Choudhary, J.P.Sharma and S. Kumar

37. Sponge gourd variety Swarna Prabha



- Fruit: Medium length (20-25 cm), weight (150-200 g), light greenish colour, pulp soft and contain less fibre
- Average yield: 20-25 t/ha
- Tolerant to powdery, downy mildew & resistant to leaf minor under field condition
- Recommended for cultivation in U.P., Jharkhand & Bihar.
- Released from CVRC Gazette notification No 398 dt:25.4.06

Developer: A. K. Singh, R.S. Pan, Mathura Rai, V.S.R. Krishna Prasad, J.P. Sharma and S. Kumar

38. Bottle gourd variety Swarna Sneha



- Swarna Sneha was developed through pureline selection from IC284939, collected from NBPGR, New Delhi.
- Plant is vigorous with 4-5m vine length early flowering and fruiting and suitable for rainy season crop.
- Swarna Sneha (50-55t/ha) shows its superiority with 40% increase over local check (Arka Bahar).
- Recommended for cultivation in Jharkhand, Bihar and adjoining areas
- It is tolerant to powdery mildew and downy mildew.
- Fruits are long (30-35cm length), light green and fruit weight 900-1000g.
- Released by SVRC, 2015

Developer: A.K.Singh, R.S. Pan, P.Bhavana, S. Maurya, A.K.Jha, J.S.Choudhary, J.P.Sharma and S. Kumar

39. Bitter gourd variety Swarna Yamini



- Developed through hybridization followed by pedigree selection.
- Plant is vigorous with 2.5-3.0m vine length early flowering and fruiting and suitable for both rainy and summer seasons.
- Swarna Yamini (20t/ha) shows its superiority with 49% increase over local check (Arka Harit).
- Recommended for cultivation in Jharkhand, Bihar and adjoining areas
- It is tolerant to powdery mildew and downy mildew.
- Fruits (65-70g) are dark green with deep tubercles.
- Released through SVRC, 2015

Developer: P.Bhavana, A.K.Singh, R.S. Pan, S. Maurya, A.K.Jha, J.S.Choudhary, J.P.Sharma and S. Kumar

40. Pumpkin variety Swarna Amrit



- Developed through pure line selection.
- The fruits become ready for first harvest after 90-100 days after sowing.
- Fruits round and dark green.
- Average fruit weight 2.5-3.0 kg.
- Yield potential ranges from 40-50 t/ha
- Recommended for cultivation in Himachal Pradesh, Uttarakhand, J&K, Bihar & Jharkhand
- Identified for release through CVRC, during 27th group meeting AICRP (VC) held at TNAU, Coimbatore, 12-15, Feb.09 for cultivation in Zone-I.

Developer: A.K.Singh, R. S.Pan, J. P. Sharma and S. Kumar

41. Garden pea variety Swarna Amar



- Developed through pure line selection
- Pod: Dark green, concave with acute apex having more than 50% recovery of shelled dark green peas
- Mature dried seeds are wrinkled green
- Resistant to powdery mildew disease,
- Time of sowing: September-October
- Seed rate: 75-80 kg/ha
- Maturity: First picking 80-90 days after sowing
- Average fresh pod yield: 20-25 t/ha
- Recommended for Jharkhand and Bihar
- Released by IVRC 2004

Developer: R.S.Pan, A.K.Singh, S.Kumar, J.P.Sharma, Mathura Rai, V.S.R.K. Prasad and Bikash Das

42. Garden pea variety Swarna Mukti



- Developed through hybridisation followed by pedigree selection.
- Pod: Mildly concave, obtuse apexed, long, light green pods. Shelled peas are light green and sweet in taste with very good cooking quality
- Resistant to powdery mildew disease
- Time of sowing: September-October
- Seed rate: 75-80 kg/ha
- Maturity: First picking 80-90 days after sowing
- Average fresh pod yield: 20-25 t/ha
- Recommended for Jharkhand, Bihar and Rajasthan.
- Released by CVRC (Gazette Notification No. 1422 dt 28.11.2006)

Developer: R.S. Pan, A.K. Singh, S. Kumar, J.P. Sharma, Mathura Rai, Bikash Das and V.S.R.K. Prasad

43. Snow pea variety Swarna Tripti



- Pod: Fibreless and very flat; the whole pod is sweet & edible
 - Resistant to powdery mildew
 - Average fresh pod yield: 240-280 q/ha
 - Recommended for Jharkhand, Bihar & West Bengal
 - Released by CVRC (Gazette No. 999 dt 18.07.2008).
- Developer: R.S.Pan, A.K.Singh, S.Kumar and J.P.Sharma*

44. French bean (Bush type) variety Swarna Priya



- Pod: Flat, green, fleshy having good cooking quality.
 - Dried seeds are bold and maroon in colour, suitable for rajma preparation.
 - Time of sowing: Second fortnight of September
 - Spacing: 45 cm x 15 cm, Seed rate: 75-80 kg/ha
 - Maturity: First harvest 50-55 days after sowing
 - Average yield: 12-14 t/ha
 - Recommended for cultivation in Jharkhand, Sikkim, Meghalaya, Manipur, Nagaland, Mizoram, Tripura, Arunachal Pradesh, Western Madhya Pradesh, Maharashtra and Andaman and Nicobar Islands.
 - Released by CVRC (Gazette No 655 dt:01.06.2007)
- Developer: R.S.Pan, V.S.R Krishna Prasad, Mathura Rai and A.B.Pal*

45. French bean (Pole type) variety Swarna Lata



- Pod: Round, fleshy and stringless with good cooking quality
 - Time of sowing: Second fortnight of June and September
 - Spacing: 100 cm x 15 cm
 - Seed rate: 22-25 kg/ha
 - Maturity: First harvest 55-60 days after sowing
 - Average yield: 12-14 t/ha
 - Recommended for cultivation in Jharkhand, Jammu & Kashmir, Himachal Pradesh and Uttaranchal
 - Released by CVRC (Gazette notification No. 655 dt:01.06.20007)
- Developer: R.S.Pan, V.S.R Krishna Prasad, Mathura Rai and A.B.Pal*

46. Cowpea (Bush type) variety Swarna Mukut



- Developed through hybridisation followed by pedigree selection.
- Pod: Straight round, light green pod (20-25 cm).
- Mature dried seeds are kidney shape and yellowish brown.
- Under field conditions, the variety is least infected by cowpea mosaic viral disease and pod borer infestation,
- Time of sowing: February-March and June-July
- Seed rate: 25-30 kg/ha,
- Maturity: First harvest 45-50 days after sowing,
- Average fresh pod yield: 12-15 t/ha
- Recommended for Jharkhand, Bihar, West Bengal and Odisha
- Released by IVRC 2011

Developer: R.S.Pan, A.K.Singh, S.Kumar and J.P.Sharma Mathura Rai, Bikash Das and V.S.R .K. Prasad

47. Cowpea variety Swarna Sweta



- Pod: Medium long (30-35 cm), white, straight, round & fleshy pods having very good cooking quality
- Resistant to mosaic viruses and rust and tolerant to pod borer under field condition,
- Time of sowing: February-March and June-July
- Seed rate: 5-6 kg/ha
- Maturity: First harvest 50-55 days after sowing
- Average fresh pod yield: 25-30 t/ha
- Recommended for Jharkhand and Bihar.
- Released by IVRC 2004

Developer: R.S.Pan, A.K.Singh, J.P.Sharma, S.Kumar, Mathura Rai and V.S.R.K. Prasad

**48. Cowpea (Pole type) variety
Swana Harita**



- Dark green, very long (50-60 cm), straight, round and fleshy
- Mature seeds are light brown, elongated and kidney shaped
- Excellent cooking quality;
- Tolerant to mosaic viruses and rust
- Fresh pod yield: 30-35 t/ha
- Released by CVRC (Gazette No. 999 dt 18.07.2008)
- Recommended for cultivation in Jharkhand and Bihar

Developer: R.S.Pan, A.K.Singh, J.P.Sharma, S.Kumar, Mathura Rai and V.S.R.K.Prasad

**49. Cowpea (Pole type) variety
Swarna Suphala**



- Straight light green pod (30-35 cm) with bulged appearance of seeds
- Resistant to rust and cowpea mosaic viruses under field condition
- Fresh pod yield: 21-25 t/ha
- Released by CVRC Gazette No.1422 dt. 28.11.06
- Recommended for cultivation in Jharkhand and Bihar

Developer: R.S.Pan, A.K.Singh, S.Kumar, J.P.Sharma, Mathura Rai and V.S.R.K. Prasad

**50. Lablab bean (Pole type) variety
Swarna Utkrisht**



- Pod: Straight, flat, green & fleshy pods (10-12 cm) having very good cooking quality
- Tolerant to anthracnose, mosaic viruses and pod borer under field condition
- Average fresh pod yield: 35-40 t/ha
- Recommended for cultivation in U.P., Jharkhand, Punjab & Bihar
- Released by CVRC (Gazette notification No 1422 dt: 28.11.2006)

Developer: R.S.Pan, A.K.Singh, J.P.Sharma, S.Kumar, Mathura Rai and V.S.R.K. Prasad

51. Vegetable soybean variety Swarna Vasundhara



- Pod: 2 & 3 seeded; > 50% recovery of fresh green seeds
- Good cooking quality and taste
- First harvest 75-80 days after sowing.
- Fresh pod yield: 15-20 t/ha
- Recommended for cultivation in Jharkhand, Bihar, West Bengal and Orissa.
- Released by CVRC (Gazette No. 999 dt 18.07.08)
Developer: R.S.Pan, A.K.Singh, S.Kumar and J.P. Sharma

52. Broad bean variety Swarna Safal



- Successful winter vegetable crop. Ready for 1st harvest in 89-94 days after sowing.
- Pods green, round and 5-6 cm long, least infested by leaf eating insects and chocolate spot.
- Fresh pod yield 20-25t/ha
- Released by SVRC, Govt. of Jharkhand (Gazette No. 2878 dt 07.12.2016)
Developer: R.S.Pan, A.K.Singh, Bikas Das, S. K. Naik, S. Maurya, J.P.Sharma and S.Kumar

53. Lima bean (Pole type) variety Swarna Poshan



- Successful winter vegetable legume. Ready for 1st harvest of green pods in 90-100 days after sowing.
- Cooked unripe seeds are very good in taste.
- Pod weight 6.0g with 3-4 seeds/pod.
- Fresh pod yield 12-15 t/ha
- Released through SVRC, Govt. of Jharkhand for cultivation in Jharkhand (Gazette No. 2878 dt 07.12.2016)
Developer: R.S.Pan, A.K.Singh, Bikas Das, S. Maurya, J.P.Sharma and S.Kumar

54. Aromatic vegetable soybean variety Swarna Sugandha



- The edible shelled fresh green beans are bold, sweet and emit fragrance similar to basmati rice during boiling/ cooking
- It is an early, short duration (crop duration 75 days), low input demanding rainfed kharif crop variety. Green pods become ready for 1st harvest in 60-65 days after sowing
- Green pod yield 13-14 t/ha in 75-78 days of crop duration.
- The shelled bold bright green seeds are rich in protein (11.28g/100g).
- Released by IVRC 2004

Developer: R.S.Pan, Meenu Kumari, A.K.Singh, V.K. Yadav, S.K.Naik, A.K.Jha and J.S.Choudhary

55. Lablab bean variety Swarna Rituvar



- Photo-insensitive, Off-season
- Pod: Flat, creamy white & fleshy pods (8-10 cm) having very good cooking quality
- Mature seeds are black in colour, Tolerant to anthracnose and pod borer under field condition
- Seed rate: 8-10 kg/ha
- Maturity: First harvest 75-80 days after sowing
- Average fresh pod yield: 12- 15 t/ha
- Recommended for Jharkhand, Bihar, west Bengal & Orissa
- Released by IVRC 2011

Developer: R.S.Pan, A.K.Singh, S.Kumar and J.P.Sharma

56. Lablab bean variety Swarna Nidhi



- It is a photo-insensitive variety and sowing during 2nd fortnight of May will ensure harvest of off-season produce during July-September and the same crop may continue upto spring season
- Green pods become ready for 1st harvest at 60-65days after sowing
- Off-season crop yield potential is 18-20 t/ha
- Total green pod yield 35-38 t/ha in a period of 180 days
- Released by IVRC 2024

Developer: R.S.Pan, Meenu Kumari, A.K.Singh, V.K. Yadav, S.K.Naik, A.K.Jha and J.S.Choudhary

57. Leaf amaranth variety
Swarna Raktim



- Promising multicut variety with red coloured stems and leaves.
- Suitable for summer and rainy season cultivation, ready for 1st harvest in 30-35 days after sowing.
- Recommended for cultivation in Jharkhand, Bihar and adjoining areas
- Average yield 25-30t/ha
- Released by SVRC 2015, Govt. of Jharkhand
Developer: R.S.Pan, A.K.Singh, Bikas Das, S. K. Naik, J.P.Sharma and S.Kumar

58. Leaf amaranth variety
Swarna Suparna



- The variety is suitable for summer and rainy season cultivation.
- Greens of this multi-cut variety become ready for 1st cutting at 30-35 days after sowing
- Its green coloured tender stems and leaves have been highly accepted by the consumers as a relished cooked leafy vegetable.
- Tender leaves and stems are good source of phosphorus, manganese and potassium.
- Yield: 20-21 t/ha (more than 30% increment in yield over the check)
- Recommended for cultivation in Jharkhand, Bihar and adjoining areas
- Released by IVRC 2024
Developer: R.S.Pan, Meenu Kumari, A.K.Singh, V.K. Yadav, S.K.Naik, A.K.Jha and J.S.Choudhary

59. French bean variety
Swarna Sangram



- Suitable for kharif, rabi and summer season cultivation
- Growth habit is determinate type (bush) and early for maturity
- The tender dark green pods (14-15 cm long and round) are having very good cooking quality and consumer preference
- It is resistant to rust and tolerant to anthracnose and angular leaf spot under field conditions of Jharkhand
- Yield 6.5-7.0 t/ha in 75-80 days of crop duration.
- Recommended for cultivation in Jharkhand, Bihar and adjoining areas
- Released through IVRC 2024
Developer: Meenu Kumari, R.S.Pan, A.K.Jha, J.S.Choudhary and Reshma Shinde

60. Lablab bean variety Swarna Vishist



- High-yielding, early maturing bush-type variety of Lablab bean, developed through single plant selection, with a yield potential of 17-18 t/ha,
- It showed significant yield advantage (11.76 %) over check variety Arka Sambhram.
- It is an early-maturing variety, with 50% flowering in 43 days and a maturity period of 75-85 days.
- The pods are highly nutritious, containing 23.74% protein on dry weight basis and 460 mg/100 g phosphorus.
- The pods are 10.88 cm long, light green, slightly curved, and excellent cooking qualities.
- Under field conditions, the genotype is moderately resistant to pest like aphids, pod borer (*Helicoverpa armigera*), and disease like collar rot. Its dwarf growth habit eliminates the need for staking, making it highly preferred by farmers in Bihar for cost savings.
- Recommended for cultivation in Bihar and adjoining areas
- Released through IVRC 2024

Developer: Shubha Kumari, A.K. Choudhary, A. K. Dubey, R.S. Pan. Kirti Saurabh, Santosh Kumar, Md.Monobrullah, Anirban Mukherjee, Rakesh Kumar, Ujjwal Kumar, Sanjeev Kumar, Anup Das

61. Lablab bean variety Swarna Sampurna



- It is a high-yielding bush-type Lablab bean developed from single plant selection with a yield potential of 16-17t/ha.
- It showed significant yield advantage (6.45%) over check variety Arka Sambhram.
- It is an early maturing variety, with 50% flowering in 41 days and maturity in 75-80 days suitable for mechanical harvesting.
- The pods are nutrient-rich, containing 21.64% protein in dry weight basis, 7.35 mg iron, and 3.65 mg zinc per 100 g.
- The pods are small, light green, and curved, with excellent cooking qualities.
- Under field conditions, the variety shows moderate resistance to aphids, pod borer and collar rot.
- It is a preferred choice for Bihar farmers due to its dwarf growth habit that eliminates the need for staking
- Recommended for cultivation in Bihar and adjoining areas
- Released through IVRC 2024

Developer: Shubha Kumari, A.K. Choudhary, A. K. Dubey, R.S. Pan. Kirti Saurabh, Santosh Kumar, Md.Monobrullah, Anirban Mukherjee, Rakesh Kumar, Ujjwal Kumar, Sanjeev Kumar, Anup Das

Chapter-4

High Yielding varieties of Fruits



Major traits

1. Litchi Variety Swarna Roopa



- Developed through clonal selection
- Fruit: Attractive deep red in colour, contains high pulp (75%), small seed and TSS 19°B
- Resistant to fruit cracking
- Mid late in maturity by 25th May
- Time of planting: July-August
- Spacing: 10 m x 10 m
- No. of plant/ha: 100
- Fruiting period: January-June
- Fruit maturity: May-June
- Average yield: 80-100 kg/tree
- Recommended for Bihar, Jharkhand, Uttaranchal and West Bengal
- Released through IVRC 1996

Developer: H.P Singh, I.S Yadav and N.N. Reddy

2. Litchi variety Swarna Madhu



- It is small seeded regular bearing variety having fruit weight ranged from 20-23g
- Yield 32-35 kg/plant under rainfed condition, pulp recovery >74%, TSS>18°B and acidity 0.35%.
- The variety have high juice recovery (>45%).
- The variety is moderately resistant to seed borer.
- Recommended for cultivation in Jharkhand
- Released through CVRC-Gazette No. 1296 dated 14.03.2024

Developer: Bikash Das, M.K.Dhakar, J.S. Choudhary

3. Jack fruit variety Swarna Manohar



- Fruit: Attractive skin colour, uniform in shape, high quality fragrant pulp, sweet and firm flake.
- Highly nutritive with natural sugars and fragrance, TSS– 18.00B, acidity – 0.09%, Total sugar 8.33%.
- Suitable for table purpose
- Fruit maturity: Early,
- Average fruit weight: 13.7 kg, Spacing: 10 m x 10 m
- Average yield: 548 kg/tree
- Recommended for Jharkhand and adjoining areas
- **Released by IVRC 2004**

Developer: Vishal Nath, Mathura Rai, Bikash Das and S.Kumar

4. Jack fruit Variety Swarna Poorti



- Fruit: Attractive light green colour, roundish uniform shape
- Highly nutritive, TSS– 18.00B, acidity – 0.14%, Total sugar – 7.46%
- Suitable for vegetable purpose
- Average fruit weight : 4.20 kg
- Recommended for Jharkhand and adjoining areas
- Fruit maturity – Late
- Spacing : 10 m x 10 m
- Average yield – 120.0 kg/tree
- **Released by IVRC 2004**

Developer: Vishal Nath, Bikash Das, Mathura Rai and S.Kumar

5. Bael Variety Swarna Vasudha



- It is a medium vigorous, regular bearing variety having fruit weight ranging from 1100g to 1800g
- Yield 42-45 kg/plant under rainfed condition, pulp recovery >80%, TSS >40°B
- The variety has low seed content (<2%) with thin shell (<2mm).
- The plant is semi vigorous and recommended for High Density Planting (6m x 6m).
- Recommended for cultivation in Jharkhand
- Released by CVRC, 2024

Developer: Bikash Das, Mahesh K. Dhakar, J.S. Choudhary, Vishal Nath and Dr Mathura Rai

6. Mulberry Variety Swarna Rasrani



- Plant height ranges from 3.5m-4.0 m and have spreading growth habit.
- It has truncate type leaves, acuminate leaf apex, serrated leaf margin, ovate leaf shape and short petiole length.
- Fruits are red coloured, pendulous and cluster bearing.
- It is precocious in bearing and start bearing in 3rd year.
- Fruit weight ranges from 4.5-6.0 g, fruit width: 8-10 mm and length: 8-9 cm.
- Fruit ripen in 35-45 days from fruit set.
- TSS is more than 22°B and acidity less than 0.5%.
- The yield is high (30-35 kg/plant).
- It is suitable for table and processing purpose (Drying, squash and jam, etc.)
- Recommended for cultivation in Jharkhand
- Released by IVRC, 2024

Developer: Mahesh K. Dhakar, Bikas Das, J.S. Choudhary and Dharmjeet Kerwar

Chapter-5

Other Improved varieties (Chickpea, Makhana & Faba bean)



Swarna Lakshami (DBGC 3): A high yielding chickpea variety

Period of development	: 2012-2023
Developers	: AK Choudhary, IS Singh, Santosh Kumar, Narayan Bhakta, Kumari Shubha
Year of release/notification	: 2024
Recommended states	: North East Plain Zone (Central and Eastern Uttar Pradesh, Bihar, Jharkhand, West Bengal and Assam)
Breeding method	: Pedigree Method
Suitable ecology	: Timely sown, Irrigated condition, Rabi season
Duration (days)	: 129 days
Yield potential (q/ha)	: 17.50
Characteristics of the variety	: 'DBGC 3' (Swarna Lakshami) is a high-yielding desi chickpea genotype developed from ICC 13124 × WR 315, combining drought tolerance and Fusarium wilt resistance. It recorded an average yield of 1750 kg/ha in AICRP trials (NEPZ) with a 26.90% yield advantage over 'PBG 9'. The variety has high protein content (20.04%), 46.25 ppm Zn, and a superior dal recovery ratio (>0.98). It flowers in 77 days and matures in 129 days, matching 'BG 3043'. Seeds have excellent grain traits with a 100-seed weight of 21.27 g, ensuring consumer preference. It is resistant to Fusarium wilt and moderately resistant to dry root rot and collar rot. Its pod borer tolerance is comparable to 'BG 3043' and aligns with 'ICCL 86111' for pod damage.



Proposed stakeholders	: Farmers, KVKs, NGO, NSC, State Seed Corporations
Impact	: DAC indent for BSP-1: 15.0 q (2024-25)

Swarna Vaidehi: First ever variety of Makhana

Period of development	: 2008-2012
Developers	: Lokendra Kumar; VK Gupta, Mohd. Idris, UR Sangle
Year of release/notification	: 2013
Recommended states	: Bihar, Assam, Chhattisgarh and Odisha
Breeding method	: Pure line Selection
Suitable ecology	: Field and pond condition
Duration (days)	: 240 days (140 days-Nursery, 100 day- Field)
Yield potential (q/ha)	: 2.8–3.0 t/ha
Characteristics of the variety	: Swarna Vaidehi exhibits a remarkable productivity of over 3.0 t/ha in farmers' fields, registering a 46% higher yield than local cultivars. Its superior performance makes it an excellent choice for enhancing farm profitability. Beyond yield, it is nutritionally rich, containing essential micronutrients like iron, zinc, and calcium, along with a well-balanced profile of essential amino acids, contributing to better human nutrition. Adapted to diverse agro-climatic conditions, it demonstrates resilience to biotic and abiotic stresses, ensuring stable production. With its high yield potential, superior nutritional quality, and climate adaptability, Swarna Vaidehi stands as a promising cultivar for sustainable agricultural practices.



Proposed stakeholders	: Farmers, KVKs, NGO, NSC, State Seed Corporations, Makhana Industries
Impact	: The varietal development has opened up the scope of Makhana cultivation in more than 6.0 lakh ha area in North Bihar alone.

Swarna Gaurav: Faba bean variety

Period of development	: 2011-14
Developers	: AK Singh, BP Bhatt, S Kumar, PK Sundaram, IS Singh, RS Pan, UR Sangle
Year of release/notification	: 2021
Recommended states	: Irrigated ecologies of Bihar
Breeding method	: Pure line selection
Suitable ecology	: Timely sown, Irrigated condition, Rabi season
Duration (days)	: 120-125 days
Yield potential (t/ha)	: 5.5-6
Characteristics of the variety	: Developed variety “Swarna Gaurav” is nutritionally superior over existing cultivar and national check as well as containing very less amount of anti-nutritional factor like tannin and phytate; a major hurdle in the cultivation of such an excellent crop. This variety attains height of 77- 105 cm, plant type is bushy. It is a medium duration cultivar matures in 120-125 days, whereas the check variety takes 130-140 days. It starts bearing pod at the height of 7.5 cm from the base. The first picking of green pod can be done after 90-95 days after sowing. The seed yield potential of this variety is 5.0 to 5.5 t/ ha. This cultivar contains significantly higher (13.49%) dietary fiber and 31.12% protein. The major breakthrough is the staggering low content of ant-nutritional factor tannin and phytate. Both factor were significantly lower than the check variety i.e. Vikrant. The sweetness of the mature seeds is 10.34 TSS. The developed variety is also rich in minerals like iron, manganese and zinc as compare to check variety vikrant. Not only has these it also contained very good amount minerals particular phosphorus (0.154%) and iron (2420mg/kg).It was noticed that the length of seeds (mm) 8.47 ± 0.50 , width (mm) 6.30 ± 0.36 and thickness (mm) 5.51 ± 0.33 .



Proposed stakeholders	: Farmers, KVKs, NGO, NSC, State Seed Corporations
Impact	:

Swarna Suraksha: Faba bean variety

Period of development	: 2011-2014
Developers	: A.K. Singh, B.P. Bhatt, S. Kumar, P.K. Sundaram, I.S. Singh, R.S. Pan, U.R. Sangle
Year of release/notification	: 2021
Recommended states	: Rainfed ecosystem of Bihar
Breeding method	: Pure line selection
Suitable ecology	: Timely sown, Rainfed condition, Rabi season
Duration (days)	: 100-115 days
Yield potential (t/ha)	: 3-4.3
Characteristics of the variety	: Developed variety is nutritionally superior over existing cultivar and national check as well as containing very less amount of anti-nutritional factor like tannin and phytate; a major hurdle in the cultivation of such an excellent crop. This variety attains height of 70- 90 cm, plant type is bushy. It is a medium duration cultivar matures in 110-115 days. It starts bearing pod at the height of 5.0 cm from the base. The seed yield potential of this variety is 3.0 and 4.3. t/ ha under rainfed and irrigated conditions. This cultivar contains significantly higher (12.57%) dietary fiber and 30.09% protein. The major breakthrough is the staggering low content of ant-nutritional factor tannin and phytate. Both factor were significantly lower than the check variety i.e. Vikrant. The sweetness of the mature seeds is 10.90 TSS. The developed variety is also rich in minerals like iron, manganese and zinc as compare to check variety vikrant. Not only has these it also contained very good amount minerals particular phosphorus (0.038%) and iron (2445mg/kg). The length of seeds (mm) 8.71 ± 0.66 , width (mm) 6.72 ± 0.39 and thickness (mm) 6.05 ± 0.42 .



Proposed stakeholders	: Farmers, KVKs, NGO, NSC, State Seed Corporations
Impact	:

