ICAR RCER : 25 Years of Glorious Journey of Innovation and Excellence



ICAR Research Complex for Eastern Region

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

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ICAR RCER: 25 Years of Glorious Journey of Innovation and Excellence

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Rachana Dubey and Anirban Mukherjee

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ICAR-RCER: 25 Years of Glorious Journey

शिवराज सिंह चौहान
SHIVRAJ SINGH CHOUHAN

कृषि एवं किसान कल्याण और
ग्रामीण विकास मंत्री
भारत सरकार
कृषि भवन, नई दिल्ली

Minister of Agriculture & Farmers Welfare
and Rural Development
Government of India
Krishi Bhawan, New Delhi



MESSAGE

It is heartening to know that the ICAR-Research Complex for Eastern Region, Patna has completed 25 years of dedicated and illustrious service to the Nation and celebrating its Silver Jubilee during February 20-22, 2025. The institute has done commendable work in the field of agricultural research and development benefitting millions of farmers of Eastern India.

I am glad to learn that crop varieties of rice, pulses, vegetables, fruits and makhana developed by the institute is highly popular among farmers of the region and cover a significant area. This institute has also developed and validated several technologies like Integrated Farming System (IFS) models, sustainable intensification of rice-wheat cropping system, rice fallow management, characterization and registration of indigenous animal breeds, land use models for efficient utilization of soil and water, policies for empowering farmers etc. While our past achievements has been impressive, we have to face future challenge of ensuring food and nutritional security to rising population in a sustainable manner without harming our ecosystem.

I am happy to know that the institute is publishing a Book on "*ICAR RCER: 25 Years of Glorious Journey of Innovation and Excellence*". The book contains the glorious achievements of the institute during last 25 years and roadmap for future agricultural development in eastern region. I congratulate the entire team of scientists and other staff of the institute on its Silver Jubilee celebration. I am confident that this document will be highly useful to researchers, academicians, students, planners and policy makers.

(Shivraj Singh Chouhan)

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Secretary (DARE) &
Director General (ICAR)

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FOREWORD

The 25th Foundation Day celebration of the ICAR-Research Complex for Eastern Region (ICAR-RCER) marks a significant milestone in its journey of transforming agriculture in Eastern India. The accomplishments are impressive and reflect the institute's deep commitment to improving the livelihoods of farmers and promoting sustainable agricultural practices. The development of Integrated Farming System models, sustainable rice-wheat intensification, and innovations like solar energy-based farm machinery are crucial for empowering small and marginal farmers. The work done in promoting climate-resilient agriculture and value chain development for important crops like Makhana is highly commendable too. Additionally, the development of multiple stress-tolerant crop varieties shows a deep understanding of the challenges farmers face and provides them with viable solutions. The outstanding contributions of the institute are the, innovative resource conservation technologies for vegetable farming, characterization and registration of indigenous livestock and duck breeds, FPO based extension models for farmers, promotion of climate resilient agriculture through participatory approach, large scale seed and planting material production of field and horticultural crops. It is gratifying to note that the varieties developed by the Institute like 12 multiple stress tolerant rice, 01 chickpea, 63 high yielding nutrient rich vegetables and 6 high yielding fruit varieties are very popular among the farmers and covers a significant area in the region and beyond. ICAR-RCER is promoting renewable energy solutions, particularly through the development of the Solar Irrigation Pump Sizing (SIPS) Tool, solar energy-based paddy thresher& insect trap, biodegradable planting pots among many others are playing an important role in empowering farmers to adopt green and efficient technologies. The institute is also leading the way in cutting-edge research and pioneering groundbreaking innovations like multiple use of water models, agrivoltaic systems, C-farming and futuristic farm models development among other advancements.

To commemorate its 25th Foundation Day, Institute is bringing out a memoir publication entitled "***ICAR RCER: 25 Years of Glorious Journey of Innovation and Excellence***". I hope that this publication will offer valuable insights and learning which will be useful in preparing policies and strategies for next 25 years to address the challenges of climate change, resource constraints, and environmental sustainability reflecting the institute's commitment in achieving national vision of **Viksit Bharat by 2047**.

I extend my best wishes for the **grand success** of the **Silver Jubilee celebrations** and the institute's continued journey of excellence and innovations.

(Himanshu Pathak)

Dated the 11th February, 2025
New Delhi

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A Walk Through 25 Glorious Years

Rachana Dubey, Abhay Kumar, Anup Das, Sarfaraj Ahmad,
Anirban Mukherjee and Arti Kumari

Background

The history of the ICAR-Research Complex for Eastern Region, Patna, reflects a dynamic period of leadership and innovation in Natural Resource Management and sustainable agri-food system. Initially established as the Directorate of Water Management Research (DWMR) at Rahuri on October 22, 1990, the institution underwent significant development under the leadership of Dr. R K Rajput until October 31, 1996. Dr. R K Rajput established the foundations for a groundbreaking research institute. During his tenure, key initiatives were established to solve pressing issues in agricultural water management. His vision and commitment fostered an environment that promoted both research and sustainable practices in water use, setting the stage for future progress. After Dr. Rajput, the leadership transitioned to Dr. T N Choudhary on November, and sustainable water management in agriculture.

The ICAR Research Complex for Eastern Region (ICAR RCER) has its origin in erstwhile DWMR. It came into existence on 22 February 2001, after the merger of DWMR, Patna; Central Horticultural Experiment Station, Ranchi and Central Tobacco Research Station, Pusa, Samastipur**.** Unlike other institutes of ICAR, this Institute was neither a commodity based nor theme-oriented Institute but was mandated to conduct research in all the disciplines of Agriculture and Allied Sciences. Therefore, the name for the Institute was coined as "ICAR Research Complex for Eastern Region (ICAR RCER) with its headquarter at Patna, Bihar. The institute was founded to enhance research capabilities and lay the groundwork for greater agricultural sustainability and productivity in eastern India, using a broad framework to comprehensively handle a range of agricultural concerns related to crop husbandry, horticulture, fisheries, livestock and poultry, agro-processing, socioeconomic factors, and the management of land and water resources.



Fig. 1.1. ICAR RCER main campus cum lab building

Das A, Kumar A , Naik SK, Kumar P, Mali SS, Dubey R. and Mukherjee A. (2025).
ICAR RCER: 25 Years of Glorious Journey of Innovation and Excellence. ICAR RCER, Patna



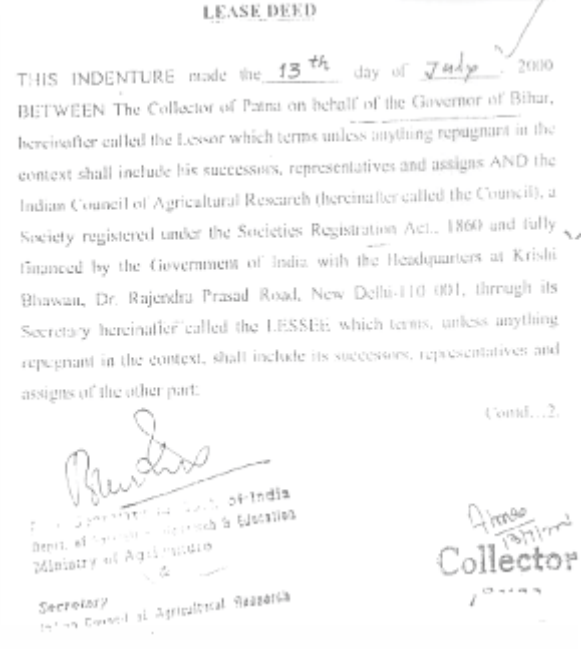
Fig. 1.2. ICAR RCER Serving the farming needs of seven states of India

Initially, the institute had five research programs viz.

- Land, Water, Environment, and Engineering Research Programme (LWEERP), Patna
- Crop Research Programme (CRP), Pusa
- Horticulture and Agro-Forestry Research Programme (HARP) Ranchi
- Livestock and Fishery Improvement and Management Programme (LFIMP), Patna and
- Socio Economic and Extension Research Programme (SEERP), Patna

Later, The National Research Centre on Makhana,Darbhanga also came under the administrative and financial supervision of the Research Complex under the approved Xth Plan. To address research issues and develop technologies pertinent to the existing biophysical and socioeconomic environment in eastern India, the Complex has developed into a multicommodity and multi-disciplinary institutional framework with a mandate to serve the agricultural issues of eastern Uttar Pradesh (UP), Bihar, West Bengal, Odisha, Jharkhand, and Chhattisgarh; later, Assam was added.

The foundation stone of the institute was laid on 29th March 2001 by Shri Nitish Kumar, then Honorable Union Agriculture Minister in the presence of Dr. RS Paroda, Secretary DARE and DG ICAR, Late Ghulam Sarwar, Honorable Agriculture Minister Govt. of Bihar, Late Navin Kishore Sinha, Hon'ble MLA, Dr. S. R Singh, Director ICAR RCER and other dignitaries.



LEASE DEED

THIS INDENTURE made the 13th day of July 2000 BETWEEN The Collector of Patna on behalf of the Governor of Bihar, hereinafter called the Lessor which terms unless anything repugnant in the context shall include his successors, representatives and assigns AND the Indian Council of Agricultural Research (hereinafter called the Council), a Society registered under the Societies Registration Act., 1860 and fully financed by the Government of India with the Headquarters at Krishi Bhawan, Dr. Rajendra Prasad Road, New Delhi-110 001, through its Secretary hereinafter called the LESSEE, which terms, unless anything repugnant in the context, shall include its successors, representatives and assigns of the other part.

Contd...2.

Secretary

Collector

Fig. 1.3. A glimpse of lease agreement executed for establishment of Research Complex at Patna



Fig. 1.4. Shri Nitish Kumar, Honorable Union Agriculture Minister, laying the foundation stone of ICAR RCER, Patna on 29th March 2001

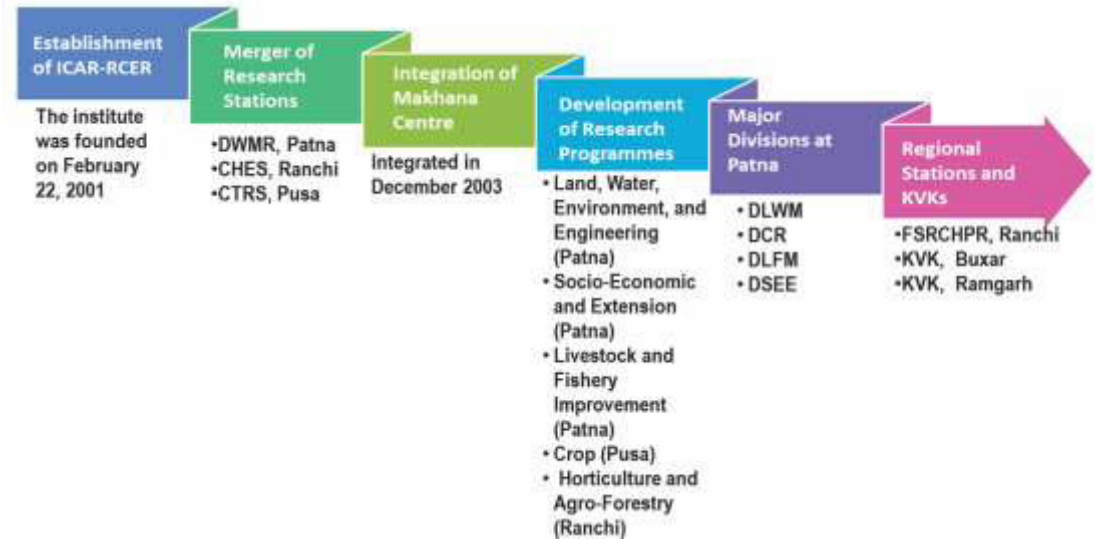


Fig. 1.5. Shri Sharad Pawar Honorable Union Minister of Agriculture Inaugurating office cum lab building of ICAR RCER on 16th October 2006.

The construction of the administrative building was completed in 2006. On, the occasion of World Food Day and Millennium Development Goal, 16th October 2006 the new office cum lab building of ICAR Research Complex for Eastern Region Patna was dedicated to the nation in the memory of Babu Jagjivan Ram by Shri Sharad Pawar, then Honorable Union Minister of Agriculture, Consumer Affairs, Food and Public Distribution in the presence of Shri Nitish Kumar, Honorable Chief Minister of Bihar; Shri Lalu Prasad Yadav, Honorable Union Minister of Railway and Smt. Shri Meera Kumar, Honorable Union Minister of Social Justice, Shri Narendra Sigh, Honorable Agriculture Minister of Bihar, Dr. Mangala Rai, Secretary DARE and DG ICAR; Dr. J S Samra, DDG (NRM), ICAR and Director of the institute Dr. A K Sikka. Shri Sharad Pawar, Honorable Union Minister of Agriculture emphasized that the new institute would cater the needs of farmers of eastern India and stressed on to boost secondary income of farmers through dairy and aquaculture.

Major Divisions

Presently, the institute has 4 (four) divisions at its headquarters in Patna namely, Division of Land and Water Management (DLWM), Division of Crop Research (DCR), Division of Livestock and Fishery Management (DLFM), and the Division of Socioeconomics & Extension (DSEE).



Sanction Strength

ICAR RCER presently have one research center viz Farming System Research Centre for Hill and Plateau Region (FSRCHPR), Plandu, Ranchi. The Darbhanga-based Research Center for Makhana was part of ICAR RCER, Patna until May 14, 2023. The institute also operates two Krishi Vigyan Kendras (KVKs), located at Buxar in Bihar, and Ramgarh in Jharkhand.

Table 1.1 Status of staff positions

Position	Sanctioned	In position	Vacant
Director	01	01	-
Head of the Department	05	04	01
Principal Scientist	02	02	-
Senior Scientist	15	07	08
Scientist	57	50	07
Technical	61	43	17
Administrative	46	29	16
Supporting	61	25	32

Table 1.2 Present farm location and area under the institute including KVK

Name	State	Farm Location	Area (Acre)
ICAR Research Complex for Eastern Region, Patna	Bihar	Main campus and Sabajpura Farm	86.57
Farming System Research Centre for Hill and Plateau Region, Ranchi	Jharkhand	Farm-I, Plandu Farm-II, Churu Old Nursey Farm	426.0
Krishi Vigyan Kendra, Buxar	Bihar	Lalganj, Buxar,	25.0
Krishi Vigyan Kendra, Ramgarh	Jharkhand	Mandu Farm, Ramgarh	19.4



Farming System Research Centre for Hill and Plateau Region, Ranchi



KVK, Buxar



KVK, Ramgarh

Mandate of the Institute

Since its inception, the institute has worked to address the agricultural requirements of farmers in Eastern India, with the following mandates:

- To undertake strategic and adaptive research for efficient integrated management of natural resources
- To enhance productivity of agricultural production systems comprising of field and horticultural crops, aquatic crops like Makhana, agro-forestry, livestock, and fisheries in different agro-ecological zones of the Eastern region.

Later the institute adapted a broad-based approach to address diverse agricultural issues related to water and land resource management, crop husbandry, horticulture and agroforestry, livestock and fisheries management, aquatic crops, socio-economic and extension research as well as development programs in a holistic and integrated manner for promoting research capability in order to enhance production and productivity potential, which lead to some modification in the mandate which was done after the approval from second Quinquennial Review Team (QRT) during the year 2012 and the revised mandate was:

1. *Strategic and adaptive research for efficient integrated management of natural resources to enhance productivity of agricultural production systems in Eastern region.*
2. *Transform low productivity-high potential Eastern region into high productivity region for food, nutritional and livelihood security.*
3. *Utilization of seasonally waterlogged and perennial water bodies for multiple uses of water.*
4. *Promote network and consortia research in the Eastern region.*

Fourth QRT (2018-2023) recommended to be updated the fourth mandate to include 'teaching' as one of the institute's key activities and the mandate was revised as:

4. *Promote network and consortia research, education and technology transfer in the eastern region.*

Directors in Office

List of Directors along with their office tenure, who guided the research, training and development of the Institute during the twenty-five years is given below



Dr. S R Singh
(22/02/2001 to 06/05/2002)



Dr. A K Sikka
(12/07/2002 to 01/11/2007)



Dr. M A Khan
(05/05/2008 to 31/12/2010)



Dr. B P Bhatt
(01/01/2011 to 01/10/2020)



Dr. Anup Das
(06/02/2023 to till date)

Sl. No.	NAME	FROM	TO
1.	Dr. R.K. Batta (Acting)	02/11/2007	04/05/2008
2.	Dr. Ujjwal Kumar (Acting)	01/10/2020	08/03/2022
3.	Dr. A. Upadhyaya (Acting)	09/03/2022	05/02/2023

Research Achievement

Over the past 25 years, ICAR-RCER Patna has developed a comprehensive suite of natural resource management (NRM) technologies, including improved crop, vegetable, and fruit varieties, as well as multiple stress-tolerant varieties. The institute has also pioneered water smart farming models, improved animal and fisheries interventions, technology upscaling, and policy frameworks to enhance agricultural sustainability and farmer livelihoods across Eastern India.

Farming system models for sustainable crop intensification

The institute has developed innovative Integrated Farming System (IFS) models tailored to the needs of small and marginal farmers. To increase farmers' income, generate employment, and improve soil health through resource recycling, these models optimize resource use by integrating crops, livestock, and fisheries, enhancing productivity and sustainability

Table 1.3 Integrated farming system and land use models developed

Model	Numbers
Integrated fish livestock model	06
IFS model for rainfed ecologies	01
Horti-based IFS model	01
Pond based IFS model	01
Half-acre, one acre and two-acre IFS model	03
Rice-fish-vegetable farming system model	01
Homestead farming system (1 and 2 Katha) model	02
Multiple use of water model	01
Tribal farming systems	08
Integrated natural farming system (INFS)	01
Integrated organic farming system (IOFS)	01
Multitier land use models (Mango and Litchi-based)	02
Agro-forestry model for rehabilitation of coal mine affected areas	01
Nutri garden model	01
Total	**30**

- A half-acre IFS model has been developed, incorporating crops, livestock (buffalo), and backyard fishery/duckery. Out of the total 2000 m^2 area, 1400 m^2 was allocated to crops such as rice, wheat, and vegetables, while the remaining area was utilized for pisciculture integrated with ducks. The model generated a net return of ₹ 48,650/-annually and created employment opportunities equivalent to 156 man-days per year.
- One-acre IFS model combining crops, goats, poultry, and mushrooms yielded a net return of ₹ 1,15,000 with 324 man-days of annual employment, three times higher than the Rice-Wheat system. Recycling farm resources added 44 kg nitrogen, 29.5 kg phosphorus, and 31.2 kg potash to the soil, equivalent to 93 kg urea, 184 kg SSP, and 52 kg MOP. The system was energy-efficient, with a total energy output of 2,17,548 MJ.

- A two-acre IFS model, incorporating agri-horti crops, two milch cattle, and fish-cumduck integration for upland and lowland conditions, generated a net return of ₹ 2,10,000 and 535 man-days of annual employment. Recycling farm resources added 56.5 kg nitrogen, 39.6 kg phosphorus, and 42.7 kg potash to the soil, equivalent to 118 kg urea, 247 kg SSP, and 42.7 kg MOP.
- A rice-fish-vegetable farming system was developed for low-land ecosystems, with a central refuge covering 10% of the area and fish stocked at 10,000 yearlings/ha. Fish productivity reached 1.23 t/ha with a 78% recovery rate. Net monetary gains from ricefish integration ranged from ₹ 51,000–64,500/ha, significantly higher than ₹ 20,000–30,000/ha from rice alone. In waterlogged conditions, integrating fish, livestock, ducks, and horticulture yielded an average income of ₹ 3,10,000/ha.
- A multitier horticulture system with large-canopy fruit trees (mango, litchi, aonla, jackfruit) spaced at 10 m x 10 m, dwarf fruit species (guava, lime, lemon) as fillers at 5 m x 5 m, and understorey crops (French bean, groundnut, cowpea) enhanced upland productivity. A 10-year-old system achieved 12.0 t/ha REY, with benefit-cost ratios of 2.01, 1.89, and 1.90 for mango, litchi, and Aonla, respectively. Adoption increased cumulative net income during the first five years from ₹ 20,000/ha to ₹ 1,13,000/ha.
- A technology for restoring seasonally waterlogged areas was developed using raised and sunken bed methods of cultivation. Trenches (1.5-2.0 m deep) were prepared, and the excavated soil was used for pasture production, integrating 15 Black Bengal goats. Fish yearlings (10,000/ha) were stocked in the trenches, yielding 2.2 t/ha with a 93% recovery rate. The system produced 82 t/ha of pasture (Para grass), generating a total income of ₹ 1,06,000/ha and a cost-benefit ratio of 1.87.
- Six integrated fish-livestock farming models were developed: Fish-cum-cattle, Fishcum-poultry, Fish-cum-duck, Fish-cum-pig, Fish-cum-goat, and Fish-cum-buffalo. The stocking density for fish was standardized at 10,000 yearlings/ha, compared to the previous recommendation of 8,000 fingerlings/ha. Livestock stocking densities per hectare of water area were set as 6 cattle, 4 buffalo, 60 goats, 40 pigs, 500 ducks, and 450 poultry. The highest net monetary return of ₹ 6,20,000/ha was observed in the cattle-fish system, followed by ₹ 4,10,000/ha from poultry-fish integration.
- The technology developed for greening rice-fallow areas in eastern India focuses on crop intensification through strategic management, including short duration drought tolerant rice, winter crops such as grain pulses (chickpea, lentil) and oilseeds (mustard, safflower). The study analyzed three rice establishment methods (ZTDSR, CTDSR, TPR) with residue and no residue management, showing increased system productivity from 3.5 to 5.13 t/ha. Zero-tillage Direct Seeded Rice (ZTDSR) improved yields of winter crops, reduced energy use by 23.3%, and increased net returns by 14.3%. ZTDSR also lowered carbon footprints by 2.8%, making it a sustainable and ecofriendly system for improving productivity and reducing environmental impact.
- Conservation agriculture-based rice-wheat-moong system (minimum till rice, ZT wheat and ZT moong bean under residue retention) increased system productivity by 30%, improved soil health and reduced greenhouse gas emission by 7-10%.

Varietal development (Field & Horticultural crops):

- The institute has developed and released 12 multiple stress tolerant improved variety of rice viz. 'Swarna Shreya', 'Swarna Samriddhi Dhan', 'Swarna Shakti Dhan', 'Swarna Sukha Dhan', 'Swarna Unnat Dhan', 'Swarna Shusk Dhan', 'Swarna Purvi Dhan-1', 'Swarna Purvi Dhan-2', 'Swarna Purvi Dhan-3', 'Swarna Purvi Dhan-4' and 'Swarna Purvi Dhan-5' with a yield potential of 4.5-5.5 t/ha. These varieties cover more than 5 lakh ha area in the eastern region.
- Institute has developed and released 63 improved varieties of different vegetables through IVRC, SVRC and CVRC viz. Swarna Pratibha (Brinjal), tomato 'Swarna Lalima' Swarna Sampada 'Swarna Anmol' (protected cultivation), 'Swarna Kanchan' (processing type) and 'Swarna Ratan' (open field condition); chilli 'Swarna Praphulya' and 'Swarna Tejashwi' (pickle purpose); bottle gourd 'Swarna Sneha'; bitter gourd 'Swarna Yamini'; satputia 'Swarna Sawani'; lima/butter bean 'Swarna Poshan' and leaf amaranth 'Swarna Raktim' etc. have been developed and released. These varieties are adopted in majority of eastern states.
- In fruit crops 6 varieties have been developed. In Jackfruit, Swarna Manohar is a superior table variety, while Swarna Poortiis ideal for culinary uses. In Litchi, Swarna Roopa is cracking-resistant, and Swarna Madhu features small seeds and seed borer tolerance. The Bael variety Swarna Vasudha is suited for high-density planting at 5m x 5m spacing, enhancing land use efficiency. Mulberry variety Swarna Rasrani supports both sericulture and fruit production. These varieties promote resilience, sustainability, and profitability for farmers.
- The first ever variety of Makhana, Swarna Vaidehi' developed by the Institute have been released by CVRC. The improved variety has a production potential of 3.0 t/ha compared to the productivity of local cultivars (1.4-1.6 t/ha).
- Two improved varieties of Faba bean have been developed and released for irrigated (Swarna Gaurav) and rainfed (Swarna Suraksha) ecologies with a production potential of 5.5-6.0 t/ha (Swarna Gaurav) and 4.0-5.2 t/ha (Swarna Suraksha), respectively.
- Swarna Laxmi variety of Bengal gram has been released by CVRC is disease resistant and yield potential 1.7 t/ha. Zn - 46.25 ppm, Fe- 53.6 ppm suitable for timely and late sowing condition.
- The institute has signed 41 Memorandums of Understanding for fostering research, academic activities, technology dissemination and entrepreneurship development.
- Institute also incubated 17 startups to promote technology dissemination across various stakeholders.

Livestock & Fisheries

- The institute has established a Murrah buffalo breeding unit to produce quality bulls with high genetic potential for breeding. It has characterized indigenous germplasm such as Kosi buffalo, Seemanchali Sheep, Maithili goat, and Champaran pig for breed registration. Additionally, breed descriptors for Bachaur cattle, Diara buffalo, and Red Purnea cattle have been developed. Indigenous breeds like Red Purnea cattle and Maithili duck have been registered in collaboration with ICAR-NBAGR.
- Area-specific mineral mixtures, like Swarna Min, were developed for livestock in Bihar and Jharkhand.

- The institute has also advanced genetic research with 32 gene sequences registered at NCBI, USA, focused on growth and prolificacy genes of goats. Notably, Bengal goats were identified for their high fecundity rate, with some goats producing quadruplets and quintuplets. AI of improved Murrah germplasm has been employed to enhance the conception rate of non-descript buffalo breeds with a conception rate of 40%.
- The institute has successfully bred two fish species, Labeorohita and Puntius japonicus, on its farm, conducting successful breeding demonstrations at Sonmar Chaur, Sahajadapur village. Additionally, the breeding of Labeobata has been completed with hatching success rates ranging from 39.67% to 84.00%. Ovaprim (0.3 mL/kg for females and 0.1 mL/kg for males) was identified as the most effective breeding hormone for Labeobata. Induced breeding of Magur yielded a 93.16% fertilization rate, 55.10% hatching rate, and 21.55% survival rate from spawn to fry.

Solar energy and farm mechanization

- The institute has developed and demonstrated several solar-powered systems and farm implements/machineries, including solar powered groundwater pump, aerators, livestock washing systems, and humidifiers. Additionally, solar photovoltaic systems for animal shed cleaning, solar water heaters, and street lighting have been implemented.
- The institute has developed ecofriendly solar operated water pumping system, paddy thresher and insect trap. Also developed Solar irrigation pump sizing tool which is adopted by MNRE under PM-KUSUM scheme, Govt of India
- A hand-operated makhana grader prototype with a circular drum and cylindrical bars has been designed for grading based on size (14, 12, 9, 7, and <7 mm).
- A solar-operated fish vending cart prototype and a pedal-operated paddy thresher (40 kg/h capacity) have also been developed, improving efficiency over manual methods (33 kg/h).
- Two Custom Hiring Centers were established at Patna HQs and KVK Buxar respectively.

Social science & policy research

- The institute developed four FPO-based technology delivery models across Eastern India, boosting crop productivity (rice: 18-22%, wheat: 15-25%, green gram: 30-45%) and farmers' income (12-17%). It transferred 16 high-yielding varieties to 789 farmers and scaled 26 more FPOs. Additionally, five FPCs were registered in four states.
- The institute has undertaken several policy-oriented research projects to enhance agricultural development in Eastern India. Key initiatives include the Production and Value Chain Analysis of Makhana, which focuses on optimizing production and market strategies, and the Growth and Instability in Production of Principal Crops, analyzing regional crop dynamics. Additionally, the Impact of e-NAM on Agricultural Marketing assesses the effectiveness of electronic platforms in improving market access, while studies on the transfer and adoption of improved agricultural technologies examine the dissemination of advanced farming techniques. The institute also investigates the status of digital tool utilization in agriculture, food and nutritional security in rural households, and conducts model-based inference on agricultural crops for food security. Besides, the resource incentivization of floodplain wetlands documents vital ecosystem services. These projects collectively contribute to informed policymaking and the promotion of sustainable agricultural practices in the region.

- To reduce poverty in the Eastern Gangetic Plains by making smallholder agriculture more profitable and sustainable a project "Sustainable and resilient farming systems intensification in the Eastern Gangetic Plains (SRFSI)" was done in collaboration with CIMMYT. The major focus was on improving water and labor productivity in wheat cultivation. The scientific intervention resulted in a 42% increase in water productivity and 36% improvement in labor productivity under zero tillage.
- The Climate Resilient Agriculture Program, initiated in 10 villages of Gaya and Buxar districts, has successfully covered 10,924 acres of farmer fields since 2019, with an annual expansion of 2,936 acres. Zero tillage (ZT) for rabi crops has been widely adopted, achieving near-total implementation (100%), resulting in a significant increase in cropping intensity from 200% to 300%. The program has fostered the development of 12,000 climate-smart farmers, demonstrating the effective integration of climateresilient practices and sustainable agricultural techniques, significantly enhancing productivity and resilience in the region.
- The institute has launched innovative extension models, including the Participatory Research Application for Year-Round Income and Agricultural Sustainability (PRAYAS) and the Zero Hunger Zero Technology Gap Village (ZHZTG) program, benefitting resource-poor farmers by disseminating advanced agricultural technologies across Eastern India. About 12000 farmers (mostly belonging to weaker section) and 300 farmers benefitted under PRAYAS & ZHGTD, respectively with 20 to 30% enhancement in annual income.
- The institute has been playing an important role in Skill and capacity building of farmers as well as other stakeholders. Till date more than 5 Lakh farmers and stakeholders are trained through different institute programmes.

Important Events Organised

The institute is actively engaged in a wide range of teaching, research, and extension activities. As one of the leading ICAR institutes in the eastern region, it has collaborated with state universities, the state agriculture department, and other stakeholders to host a number of noteworthy events over the years. The following are some of the most notable moments:

- An Agri Business Camp was jointly organized by ICAR RCER, Patna, ZTM-BPD Unit (East Zone), NIRJAFT, Kolkata and Agri Business Incubation Programme, ICRISAT, Hyderabad in collaboration with Jharkhand Chamber of Commerce and Industries (FJCCI) and Jharkhand Small Industries Association (JSIA) on 14th December 2012 with the objective to appraise the investors, entrepreneurs and potential investors of Jharkhand about available technologies generated at different ICAR institutes in eastern zone for facilitating the process of commercialization of technologies. During the meeting, MOU was signed for the commercialization of "Swarna Vijaya" tomato variety, developed by the Institute.
- Workshop on Networking of Agricultural Research in Eastern Region during 18-19 May 2004. *In this workshop a decision was taken for initiating newsletter for R & D activities of the institute*.
- The institute organized three regional committee meetings in 2006, 2012 and 2016. XVIII Meeting of ICAR Regional Committee (No. IV) in 2006; XXI Meeting of ICAR Regional Committee (No. IV) in 2012 and XXIII ICAR Regional Committee MeetingIV in 2016 attended by State Agriculture Ministers, DG; DDGs and Director's of various ICAR institutes located in Jharkhand, Bihar and Uttar Pradesh.



Fig. 1.6. Dr. T Mahapatra, Secretary DARE and DG ICAR during XVIII Meeting of ICAR Regional Committee at ICAR RCER Patna during 26-27 August 2006

- **Agri Summit-2013:** A Step Towards Second Green Revolution, was inaugurated by Sh. Narendra Singh, Hon'ble Agriculture Minister, Govt. of Bihar on April 8, 2013 at ICAR RCER, Patna. It was attended by Dr. R S Paroda, Chairman, Haryana Kisan Ayog and former DG, ICAR; Sh. Niraj Kumar Babloo, MLA, Bihar Legislative Assembly; Sh. Alok Kumar Sinha, Agriculture Production Commissioner, Govt. of Bihar; Dr. A K Singh, Vice Chancellor, Rajmata Vijayaraje Sindhiya University, Gwalior; Dr. H S Gupta, Director, IARI, New Delhi; various representatives of State Govts from all the eastern states of the country, representatives of ICAR institutes of around 27 institutions of eastern region, Dr. B P Bhatt, Director, and all the scientists of ICAR RCER, Patna. The summit was organized to discuss necessary measures for bringing second green revolution from eastern states of the country.



Fig. 1.7. Agri-Summit: A Step towards Second Green Revolution, was inaugurated by Sh. Narendra Singh, Hon'ble Agriculture Minister, Govt. of Bihar on 8 April, 2013 at ICAR RCER, Patna.

- **Showcasing of Agricultural Technologies from Seven states of Eastern India:**

Showcasing of "Agricultural Technologies 2013" was inaugurated by Dr. Mangala Rai, Agricultural Advisor to Chief Minister, Govt. of Bihar at ICAR RCER, Patna, on 6th December 2014. In the two-day programme (6-7th December, 2013) various institutes working for the farming community showcased their activities, latest technologies and products.



Fig. 1.8. Dr. Mangala Rai, Agricultural Advisor to Chief Minister, GoB for agricultural technologies showcasing at ICAR-RCER, Patna

- **87th ICAR Foundation Day and 9th KVK National Conference:** In the history of ICAR, it was the rare occasion when ICAR foundation day was celebrated outside ICAR, New Delhi. The ICAR-RCER, Patna at Gandhi Maidan, Patna, Bihar organized the ICAR 87th Foundation Day Award Ceremony and 9th National KVK Conference. The program was inaugurated by Shri Narendra Modi, Hon'ble Prime Minister of India on 25th July 2015. The Prime Minister launched ICAR schemes: Farmer First, ARYA, Student Ready and Mera Gaon Mera Gaurav and conferred awards to outstanding SAUs/ICAR institutions.



Fig. 1.9. Shri Narendra Modi, Hon'ble Prime Minister of India at ICAR 87th Foundation Day Award Ceremony and 9th National KVK Conference at Patna on 25th July 2015

- Her Excellency **Smt. Droupadi Murmu**, Hon'ble Governor of Jharkhand visited ICAR RCER, Research Centre Ranchi on 9th September 2016. The Hon'ble Governor expressed her happiness regarding the activities of the center. She emphasized the need for a close association between resource-poor farmers and the institutions.



Fig. 1.10. Smt. Droupadi Murmu, Hon'ble Governor of Jharkhand visited ICAR RCER, Research Centre Ranchi on 9th September 2016

- The institute organized the ICAR Zonal Sports Tournament for Eastern Zone twice (2012 and 2017) where a total of 16 institutes participated in various events and around 430 participants were present.



Fig. 1.11. ICAR Zonal Sports meet, 13-16 November, 2017

- **Second Green Revolution Meet:** The institute organized the Second Green Revolution Meet on 27 June, 2016. The meeting was Chaired by Shri Radha Mohan Singh, Hon'ble Union Minister of Agriculture & Farmers Welfare, Govt. of India. It was attended by the Directors and scientists of the ICAR institutes, SAUs, CGIAR institutes and State Government Officials of the Eastern States.



Fig. 1.12. Shri Radha Mohan Singh, Hon'ble Union Minister of Agriculture & Farmers Welfare addressing Second green revolution meet at ICAR RCER Patna on 27th June 2016

- **State level agriculture Fair-cum-Farmers Scientists interaction** meet during 13-15th April, 2018 was organized by ICARRCER. Shri Radha Mohan Singh, Hon'ble Union Minister of Agriculture & Farmers Welfare, Govt. of India graced the occasion as Chief Guest and Shri Prem Kumar, Hon'ble Minister of Tourism, Govt. of Bihar attended the inaugural function as Guest of Honour.
- **Agri-Expo** 2012 and 2018 was organized by the institute to showcase the latest technological developments in the field of agriculture. Apart from ICAR institutes and Agril universities many private companies like Bayer, John Deere, Jain irrigation, Escort etc. also participated through their stalls.
- **Bihar State Coordination Committee Meeting for Doubling Farmers' Income by 2022:** ICAR RCER organized Bihar State Coordination Committee Meeting for Doubling Farmers' Income by 2022. Dr. N Saravana Kumar, Agriculture Secretary Govt of Bihar chaired by State Coordination Committee Meeting on 23 March 2017.
- **Visit of Secretary DARE and DG ICAR:** Dr. Himanshu Pathak, Hon'ble Secretary, DARE and DG, ICAR, visited ICAR-Research Complex for Eastern Region, Patna on 27th Feb, 2023. Dr. Pathak interacted with all the Scientists, Administrative and Technical staffs of the institute. Director of the institute briefed about the progress and future course of action made by the institute. Honorable DG, ICAR appreciated the effort made by the institute and congratulated Scientists and other staff for the achievements.



Fig. 1.13. Dr. Himanshu Pathak, Hon'ble Secretary, DARE and DG, ICAR, visited ICAR-RCER, Patna on 27th February 2023.

- **Establishment of Himanshu Pathak Mother Block:** Dr. Himanshu Pathak, Secretary DARE and DG ICAR, visited the Ranchi centre on 6th September. Litchi mother block was established after the name of Hon'ble DG, ICAR, Dr. H Pathak. Dr. Pathak planted a sapling of **litchi variety "Swarna Madhu"** which marked the inauguration of plantation program for establishment of Mother Block of the variety developed by the centre on 20th September 2023. Swarna Madhu is a small-seeded and seed-borertolerant variety. It has yield potential of 50-60 kg/plant under rainfed conditions.

- **Mango Festival:** On 7 June 2023, a grand Mango Festival-cum-Farmers Fair was organized at Farming System Research Center for Hill and Plateau Region, Ranchi. The chief guest of the function, The Hon'ble Governor of Jharkhand Shri C.P. Radhakrishnan inaugurated the program. On this occasion, Dr. S K Chaudhari, DDG-NRM, ICAR, New Delhi, Shri Abubakkar Siddikh, Secretary, Department of Agriculture, Animal Husbandry and Cooperation, Government of Jharkhand, Ranchi and many distinguished guests were present. More than 350 farmers from the eastern states of the country participated in this event.



Fig. 1.14. The Hon'ble Governor of Jharkhand Shri C.P. Radhakrishnan during the Mango festival at Ranchi Centre of ICAR RCER on 7th June 2023

- **Inauguration of Administrative building and Hi-tech Nursery at KVK Ramgarh :** KVK Ramgarh marked a significant milestone on October 31st 2023, with the inaugura-tion of its new administrative building. The ceremony was graced virtually by Chief Guest Dr. Himanshu Pathak, Secretary, DARE and DG, ICAR, New Delhi, along with guests of Honour Dr. S K Chaudhari, DDG (NRM), ICAR, New Delhi, and Dr. U S Gautam, DDG (Agricultural Extension), ICAR, New Delhi.



Fig. 1.15. Inauguration of Administrative building and Hi-tech Nursery at KVK Ramgarh on 31 October 2023

- **Farmer-Scientist Interaction and Agri-Exhibition:** A 'Farmer Scientist Interaction and Agri-Exhibition' meet was organised on 16th December 2023 at Ranchi centre of the institute. Shree Arjun Munda, Hon'ble Minister of Agriculture and Farmers' Welfare and Minister of Tribal Affairs was the chief guest of the function. More than 250 farmers from the eastern states of the country participated in this event.



Fig. 1.16. Shree Arjun Munda, Hon'ble Minister of Tribal Affairs and Minister of Agriculture and Farmers' Welfare in Agri Exhibition at Ranchi centre

- **Interaction with Dr. Mangala Rai, former Secretary, DARE and DG ICAR:** Dr. Mangala Rai interacted with Scientists on World Food Day (16 October), 2023, Dr. Rai highlighted on the pertinent issues of water use efficiency in India as our country has 17% of world population and holding only 4.2% fresh water resources. and urged the scientists to unite in a collaborative effort, focusing on enhancing factor productivity at the grassroots level in agriculture and emphasized on agricultural intensification.



Fig. 1.17. Dr. Mangala Rai, former Secretary DARE and DG ICAR interacted with Scientists on World Food Day, 16 October 2023

- **Rice Transplantation Day Celebrated:** ICAR RCER, Patna celebrated Paddy Transplantation Day with great zeal at Sabjpura Farm on 3rd July 2023. On this occasion, the Director of the Institute, Dr. Anup Das, thanking the farming community, said that farmers are our food providers and life cannot be imagined without food. Our laborer family also support and work hard like transplanting paddy, due to which the whole country gets food. The main objective of celebrating this day was to get recognition for their hard work. More than 100 participants including scientists, employees of the institute and farmers from nearby areas participated in the program.



Fig 1.18. Rice transplanting day at Sabajpura farm, ICARRCER Patna on 3rd July 2023

- **'Ek Ped Maa Ke Naam' Plant 4 Mother :** With a goal of expanding sustainable lifestyle practices in the Eastern region of India, ICAR-RCER organized a tree plantation event under Global Campaign #'Ek Ped Maa Ke Naam' #Plant 4 Mother# during 2024 to spread the importance of trees for ecosystem conservation. More than 6000 multipurpose trees were planted at Headquarter Patna, Ranchi centre, both KVKs (Buxar and Ramgarh) and in farmer's field.



Fig. 1.19. 'Ek Ped Maa Ke Naam' 'Plant 4 Mother' during 2024

- **Visit of High level IRRI, BMGF team to ICAR RCER Patna:** An interaction meeting of scientists from International Rice Research Institute (IRRI), Philippines and Bill & Melinda Gates Foundation (BMGF), Washington, USA with team of scientists from ICAR RCER, Patna was organized on issue of "Direct Seeded Rice" on 24th September 2024. It was attended by high level officials like Dr. Gary Atlin, Senior Program Officer, BMGF-India, Dr. Sankalp Bhosale, Research Leader-Product Development & Varietal Development, IRRI, Philippines. The participants appreciated the 11 Climate resilient rice varieties developed by the institute for its wider adoption by the farmers of the eastern region.



Fig. 1.20. BMGF and IRRI Team at ICAR RCER Patna on 24th September 2024

- **ICAR-Industry Meet:** To bridge the gap between ICAR institutes and Agricultural Entrepreneurs in the eastern region of India ICAR RCER held industry meet in Patna on September 24, 2024. Ten MoUs were signed during the meet.More than 35 entrepreneurs from Bihar, Jharkhand, Chhattisgarh and Maharashtra participated in the meet and had an interaction with the scientists belonging to various agricultural disciplines.



Fig. 1.21. ICAR Industry Met at ICAR RCER Patna on 24th September 2024

- **Tribal Farmers' Conclave:** ICAR RCER Patna hosted a remarkable Farmer's fair cum-Tribal Farmers' Conclave during 21-23 Feb 2024 bringing together over 500 participants from tribal communities (Santhal, Munda, Oraon, Gond and others) and other marginalized groups across the seven states of eastern India. The



Fie. 1.22. Tribal Conclave at ICAR RCER Patna during 21-23 February 2024

event celebrated the rich tapestry of tribal culture, traditional practices, and sustainability initiatives. It served as a vibrant platform for showcasing indigenous knowledge, exchanging innovative ideas, sharing time-tested methods, and promoting unique tribal products. The conclave highlighted the invaluable contributions of tribal communities to sustainable development while fostering collaboration and mutual learning among diverse stakeholders.

- **Rice-Fallow Workshop:** A two-day national workshop on "Strategies and Approaches for Greening Rice Fallow Areas" was organized at ICAR Research Complex for Eastern Region, Patna, Bihar during 3- 4 January, 2025. The workshop aimed to design strategies and approaches for managing rice fallow areas while building a module for sustainable crop intensification. The Chief Guest, Dr. SK Chaudhari, DDG, NRM ICAR, stressed the urgent need to adopt an integrated & multidisciplinary approach to address the challenges faced by small and marginal farmers in rice fallow areas. Dr. Chaudhari urged the adoption of innovative resource conservation technologies like minimal soil disturbances, residue management, and control in rice fallows.



Fig. 1.23. Dr. S. K. Chaudhari, DDG (NRM) and other dignitaries during National Workshop on greening rice fallow areas.

In addition to these, significant events such as World Soil Day, World Environment Day, Water Day, Swachata Pakhwada, Hindi Pakhwada, Republic Day, Independence Day and others are organized by the institute from time to time. Additionally, to share our technology with the farming community, we regularly host national webinars, seminars, and agricultural fairs.



Fig. 1.24. Dr. Anup Das and team ICAR RCER During Swachata Pakhwada, 2024



Fig. 1.25. Republic Day Celebration 2025 at ICAR RCER, Patna



Fig. 1.26. Hindi Pakhwada at ICAR RCER during 14-29 September 2024

Institute Foundation Day Celebrations

Since Inception Institute celebrated 24 foundation days on 22 February every year and going to celebrate its 25th foundation day.



Fig. 1.27. Dr. S. R. Singh, Dr. M. A. Khan, Director of the institute, Foundation Day 2012



Fig. 1.28. Dr. Mangala Rai, former Secretary, DARE, DG (ICAR) Foundatino Day 2013



Fig. 1.29. Padma Shri Shri Chandi Prasad Bhatt, Founder, Chipko Andolan Foundation Day 2014



Fig. 1.30. Dr. H. S. Gupta, DG, BISA Foundation Day 2015



Fig. 1.31. Shri Radhamohan Singh, Union Minister of Agriculture and Farmers Welfare, Govt. of



Fig. 1.32. Smt. Draupadi Murmu, Her Excellency Hon'ble Governor of Jharkhand, Foundation Day 2017



Fig. 1.33. Shri Radhamohan Singh, Union Minister of Agriculture and Farmers Welfare Govt. of India, Foundation Day 2018



Fig. 1.34. Dr. Panjab Singh, former Secy (DARE) and DG (ICAR) Foundation Day 2020



Fig. 1.35. Dr. Anjani Kumar, ATARI, Patna. Foundation Day 2021



Fig. 1.36. Dr. Rameshwar Singh, V.C, BASU, Patna Foundation Day 2022



Fig. 1.37. Dr. N. Saravana Kumar, Secretary Agriculture, Govt. of Bihar Foundation Day 2023



Fig. 1.38. Shri RV Arleker, His Excellency Hon'ble Governor of Bihar, Foundation Day 2024

Visit of Thinkers and Policy Makers in Agricultural Sciences

Several dignitaries, including those from Cornell University, IRRI Philippines and India, CIMMYT Mexico and India, DFID UK, and others, have visited the institute on a variety of occasions. However, the institute always treasures a few events and occasions down memory lane, such as meeting with Bharat Ratna Dr. A P J Abdul Kalam (2000), the Honorable PM (2015), Shri Chandi Prasad Bhatt (2014), the Padmabhusan and Magsayaya award winner, the Honorable Governor of Jharkhand (2016, 2017), and Bihar (2024), the Honorable Minister of Agricul-ture and Farmers Welfare (2023, 2016), and the Honorable Minister of State for Agriculture and Farmers Welfare (2023). In addition to this, the institute has had the good fortune to have periodical visits of Secretary DARE and DG ICAR and DDG's of various subject matters. Few of the glimpses are shown below:



Fig 1.39. Bharat Ratna Dr. A.P.J. Abdul Kalam, Principal Scientific Adviser to Govt. of India visited Directorate of Water Management Research Patna on 22 October 2000



Fig. 1.40. Dr. Mangala Rai, Secretary DARE and DG ICAR laid the foundation stone of ICAR RCER KVK Buxar on 23 December year 2007



Fig. 1.41. BMGF Founder Bill Gates and his team during field visit at Sabajpura farm ICARRCEF on 4th April 2010.



Fig. 1.42 Shri Narendra Singh Tomar, Hon'ble Minister of Agriculture & Farmers Welfare, Govt. of India visited RoCM in Darbhanga on 28 February, 2023

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Fig. 1.45. Dr. Himanshu Pathak, Secretary DARE and DG ICAR interacting with Staff of RCER on 27 February 2023



Fig 1.44. Dr. R S Paroda Former Secretary DARE and DG ICAR and Chairman TAAS during interaction with scientist at RCER Patna on 2 March 2017



Fig. 1.46. Dr. S Ayyappan, Secretary DARE & DG ICAR on 05 May 2014 at Ranchi center



Fig. 1.47. Dr. S K Chaudhari, DDG (NRM) visiting stalls during 24 Foundation Day



Fig. 1.48. Dr. Gurbachan Singh, Chairman, ASRB visited to the institute on 05 May, 2016



Fig. 1.49. Shri Chhabilendra Roul, AS (DARE) & Secy. (ICAR) visited ICAR RCER on 14 July, 2017



Fig. 1.50. DG, CIMMYT Dr. Martin Kropff and Dr AK Joshi CIMMYT, South Asia, at ICAR RCER on 09 October, 2018



Fig. 1.51. Shri Kailash Chaudhary, Hon'ble MoS, DAFW, Govt. of India visiting Natural Farming trials in Patna on 18 February 2023



Fig.1.52. Secretary, Agriculture GoB interacting with scientist and visited research activities/ facilities of ICAR RCER on 5 July 2023



Fig. 1.53. Dr. A K Singh, Ex DDG (NRM) and Hon'ble VC RVSKVV Gwalior inaugurating Baghbani Paudhshala at ICAR RCER on 11 June 2024.



Fig.1.54. Dr. U S Gautam, DDG, AE visiting Technology gallery in Swarna e Vatika on 22 January, 2025

Institute Technology Management Unit (ITMU)

The ITMU of ICAR RCER, is engaged in commercializing and forming public private partnership through signing of MoUs/ MoAs as per ICAR guidelines for intellectual property management and technology transfer /commercialization. For collaboration in research, academic excellence, technology dissemination, entrepreneurship development etc. Institute has been signing MoU and MoAs with central and state organizations/ universities/ enterprenurs/ startups, business firms etc. So far institute has signed 41 MoUs and MoAs and promoted developed 17 entrepreneurs.



Fig.1.55.Signing of MoUs during Industry Meet 2024 at ICAR RCER Patna on 24.09.2024



Fig.1.56. MoA signed with a-IDEA, Centre for Agri-Innovation, ICAR-NAARM, on 23rd August 2023



Fig.1.57. MoA signed with M/s Pararth Community Farm Livelihood Development Gumla, Jharkhand on 30.01.2024



Fig.1.58. Signing of MoUs with M/s Phal Udyog Nursery on 19.12.2023

Collaborations

The institute is working in close collaboration with many international and national institutes and other government Stakeholders on various aspects.

Table 1.4. Active Collaboration of the institute with other organizations

Institute/Organization	Area of Collaboration
IRRI	Drought & submergence tolerance, DSR varieties
CIMMYT	Conservation Agriculture, GHG emission
BISA & ICRISAT	Climate resilient agriculture & Water budgeting
IWMI	Solar applications in agriculture
ACIAR	Improving dry season irrigation in EGP
NABARD	Impact evaluation of Watershed projects

NHM	• Commercial production of custard apples • Production of bio-control agents • Mushroom spawn production
Grant Thronton Bharat	•Improved vegetable production technologies
DBT	•Value chain of high value fruits and vegetables •Participatory action research
IFFCO	Evaluation of nano DAP & nano Urea
Govt. of Bihar	Climate resilient agriculture, Mushroom Spawn production
Govt. of Jharkhand	IFS, MUW, Mushroom, planting materials
NASF/DST/SERB	Impact of climate change, technology simulation
GBRC	Providing infra and experimentation facilities for research

Training Abroad by Scientists

Many scientists of the institute visited the foreign countries for enhancing their skills in their subject matter, table 1.4 shows the journey from 2001-2024 for the same.

Table 1.5 Number of scientists visited abroad and major aspects

Country	Major aspects	No. of scientists visited
USA	Pressurized Irrigation, Open Education, and Open Data	08
UK	OPTALL and LATGA packages for optimal irrigation allocation, Natural resource management	12
Philippines	Characterization of physiological responses of drought tolerant and drought susceptible genotypes, Phenotyping for Abiotic stresses and GHG Emissions in Rice Systems.	06
Nepal	Dissemination of Stress Tolerant Varieties in South Asia, Solar pump sizing tool	07
Netherland	Value chain on farmers producer varieties	01
Sri Lanka	Sustainable water management at a spatial scale	04
Australia	Food system innovation; multispectral and thermal drone imagery to assess water stress	02
Bangladesh	Intervention on economics in agriculture	03
Italy	Securing Food and Nutritional Security through Subtropical Fruits	01

Turkey	CIMMYT-Turkiye's Soil & Root Health Training	02
Mexico	Innovation in Agri-food Systems	03
Netherlands, Belgium, Germany and Switzerland	Effective Organizational Leadership for Senior Officers	02



Fig.1.59. Dr. Rachana Dubey in GHG training at IRRI, Philippines in 2024



Fig.1.60. Dr. S S Mali working with multispectral drones at University of Queensland, Australia, 2024

Major Awards

ICAR RCER has bagged many prestigious honors given to individuals, groups, and groups, and works that have significantly contributed to a particular field. These honors often reflect excellence, innovation, or service.

Table 1.6 Major National Awards bagged by the institute

Name of the Award	Year	Recipient(s)
Rafi Ahmed Kidwai Awar	1999-2000	Dr. S.R. Singh
M.S. Swaminathan National Award	2015-2017	Dr. B.P. Bhatt
Dr. Rajendra Prasad Puraskar	2016	Dr. B.P. Bhatt
Fellow of National Academy of Agricultural Sciences	2019	Dr. A.K. Singh
Ganesh Shankar Vidyarti	2014-15	Akshay Kheti (Institute Hindi magazine)
Rajbhasha Second Prize for effective implementation of official language policy in A region by Ministry of Home Affairs, GoI	2021-22	FSRCHPR, Ranchi

Monitoring and Review Committees

Quinquennial Review Team (QRT)

ICAR-RCER, Patna, underwent a substantial transformation from 2001 to 2025, with four QRTs finalizing strategic directions that shaped its research agenda with changing agricultural scenarios. QRT basically reviews the functioning and progress of each ICAR institute every five years, assessing their research achievements, relevance, and effectiveness, and providing recommendations to improve their operations and future strategies; essentially acting as a mechanism for accountability and transparency within the ICAR system.

QRT Period/Committee	QRT Period/Committee
2001-2005 **Dr. SM Virmani, Chairman** Dr. R M Pandey, Member Dr. A P Mishra, Member Dr. S H Ahmad, Member Dr. Dinesh Marothia, Member Dr. M S Gill, Member Dr. R K Batta, Member-Secretary	**2006-2011** **Dr. RP Singh, Chairman** Dr. N Sarangi, Members Dr. Gautam Goswami, Members Dr. I S Singh, Members Dr. K N Tiwari, Members Dr. S S Randhawa, Members Dr. N Parsuraman, Members Dr. R D Singh, Member Secretary
2012-2017 **Dr. AN Mukhopadhayay, Chairman** Dr. VV Sadamate, Member Dr. P K Mahapatra, Member Dr. Kusumakar Sharma, Member Dr. K K Satapathy, Member Dr. Kamal Sarma, Member Secretary	**2018-2023** Dr. SK Chakrabarti, Chairman Dr. A K Patra, Member Dr. Chandrahas, Member Dr. Sudhir Raizada, Member Dr. Anjani Kumar, Member Dr. Kamal Sarma, Member Secretary



Fig.1.61. Dr. R P Singh, Chairman, 2nd QRT interacting with staff



Fig.1.62. Dr. A N Mukhopadhyay, Chairman 3rd QRT interacting with staff



Fig.1.63. Dr. S K Chakrabarti, Chairman 4th QRT interacting with staff in Patn



Fig.1.64. Dr. S K Chakrabarti, Chairman 4th QRT interacting with staff of RC Ranchi

Institute Research Council (IRC)

IRC is the highest body for monitoring of research projects of the institute consisting of Director as chairman and all the scientist as members. Two meetings of IRC are held annually which reviews the progress of individual projects as well as to take up new projects as per the demand of the council or institute requirement to work on frontiers areas.

The Complex has conducted research programs since 2001 under the following seven themes:

1. *Resource appraisal and inventorization: Inventorize natural (including environmental) resources by use of modern state-of-the-art tools for planning research and development projects and for monitoring the impacts of improved technologies.*
2. *Plant genetic resource management and improvement of field, horticultural and aquatic crops*
3. *Improved production technologies for field, horticultural and aquatic crops*
4. *Integrated land and water management.*
5. *Livestock and fishery improvement and management*
6. *Development of need-based farming system models for different eco-systems*
7. *Socio-economics, technology transfer and HRD*

From 2011 to 2023, the research programmes of the Complex were reorganized to **six themes:**

1. *Farming System Research including Climate Resilient Agriculture*
2. *Genetic Resource Management and Improvement of Field, Horticultural and Aquatic crops*
3. *Improved Production and Protection Technologies for Agri-Horti Crops*
4. *Integrated Land & Water Management*
5. *Livestock & Fisheries Management*
6. *Socio-Economics, Extension and Policy Research*

During IRC 2024, the research programmes of the Complex have been reorganized under five themes:

- **Theme I** — Farming System Research including Climate Resilient Agriculture
- **ThemeII** — Genetic Resource Management and Improved Productio Technologies
- **Theme III** — Natural Resource Management for Enhancing Land & Water Productivity
- **Theme IV** — Livestock and Fisheries Management
- **ThemeV** — SocioEconomics, Extension and Policy Research



Fig.1.65. Dr. P K Ghosh, Director ICAR-NIBSM, Chief Guest for IRC 2024

Since 2001, the institute has implemented 287 in-house projects, 18 foreign-funded projects, and 58 externally funded projects (Fig. 1.66 and 1.67).

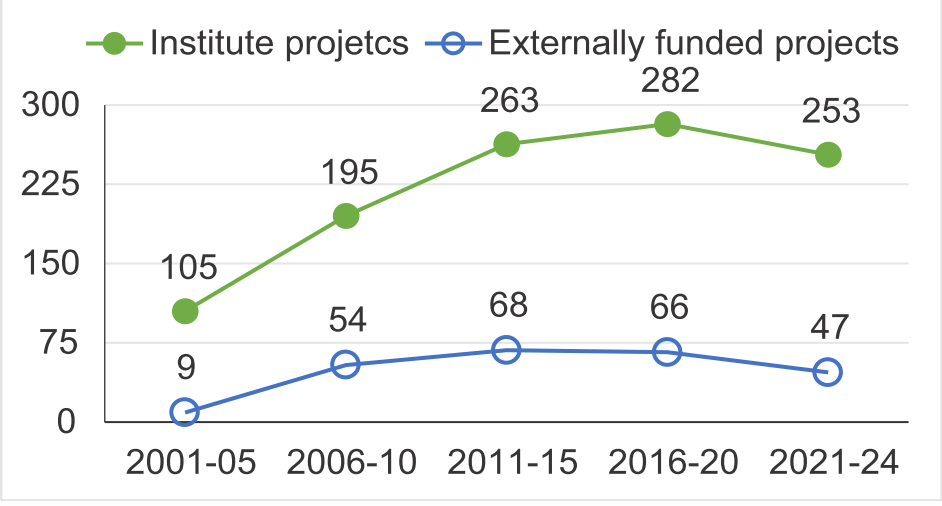

Fig.1.66. Number of Institute and Externally funded projects in the institute

Research Publications

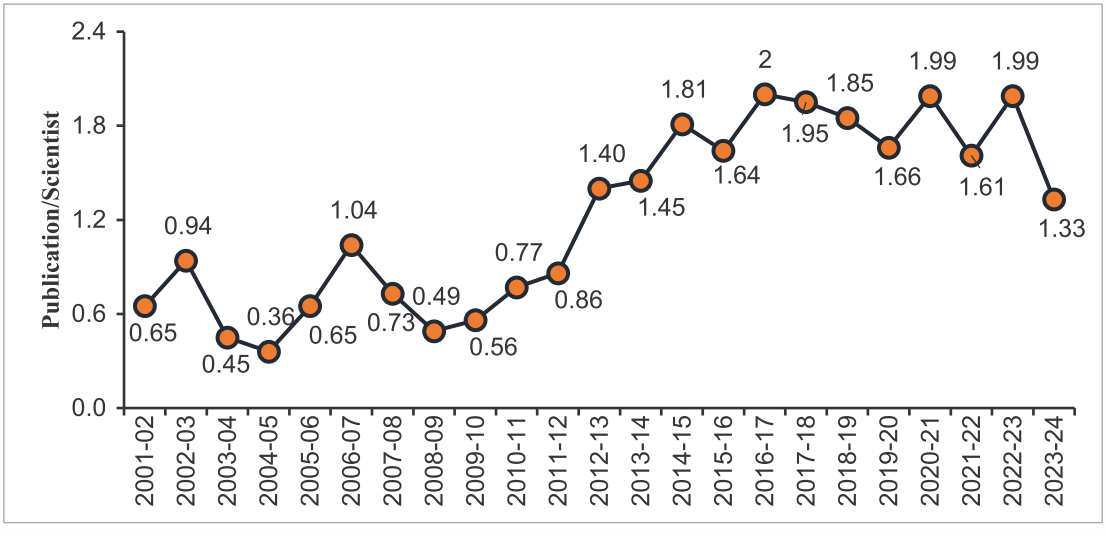

Fig.1.67. Research Publication per scientist of the institute

New Initiatives

Several new initiatives have been undertaken for achieving mandates of the Institute in changing scenarios and for enhancing productivity in research, administration as well as efforts to keep the campus vibrant and energy efficient.

Research Initiatives

- Emphasis on solar energy based farming
- Integrated natural (INFS) and organic farming (IOFS)
- Digital agriculture like drone, decision support tool etc
- Ecosystem services by indigenous livestock species and Diara farming system
- Environmental monitoring of heavy metal and microplastic in food chain system
- Carbon credit potential for farmers of eastern India
- Climate resilient models for small holder dairy production system
- Zero hunger technology gap village through innovative approach
- "Holistic GHG Emission Measurement"
- Establishment of horticulture planting materials production unit (for timely access to high-quality planting materials)
- Plantation of multiple purposes tree species in the institute
- Homestead Farming System (1 and 2 Kattha) for marginal farmers and semi urban area

Emphasis on Science and innovation

Weekly scientific seminar : From 2023, the institute began holding a weekly scientific seminar to showcase and discuss global scientific advance events and ideas. These seiminars acted as platform for sharing knowledge, fostering collaboration, and receiving feedback from peers.

- **Institute innovation cell:** To foster intellectual curiosity, support creative ideas, and provide ideas a place to thrive, the Institute Innovation Cell was founded in 2023.During its founding year, the Cell called for Young Scientist Innovation Project Proposals, allowing young scientists under 40 to present their creative ideas. Two innovative projects were chosen for funding for the first year, and if they are successful, they can be turned into a project. The cell is also engaged in promoting innovation through interaction, meeting, eminent personalities interaction with scientists and students etc.



Fig.1.68. Glimpse of Institute Innovation cell meeting of ICAR-RCER, Patna

- **Swarna e- Vatika:** To foster agro ecotourism in the premises A fruit based nutri-garden names as Swarna e-Vatika has been established in the Institute Premises in Patna. Plants were chosen based on their suitability for the local climate and the needs of the local customer. Technology gallery and recreation sites are other important aspects of the vatika. The vatika is named as "Silver Jubilee Park" to commemorate its silver jubilee year.



Fig. 1.69. Swarna e Vatika at ICAR RCER, Patna

- **Swarna Rath:** On January 3, 2025, Dr. SK Chaudhari, DDG (NRM) New Delhi, unveiled the Swarna Rath, an electric vehicle that is part of an institute initiative to further promote ecotourism on campus. The primary goal is to disseminate technologies to the visitors.



Fig.1.70. Inauguration of Swarna Rath by Dr. SK Chaudhuri and other dignitaries on 3rd January

Initiative for Eco-friendly Campus

- ✓ Promotion of Solar energy
- ✓ Separate arrangement for disposal of bio-chemical waste.
- ✓ Environment friendly techniques to utilize crop residues, plant waste etc.
- ✓ Recycling of farm waste through vermi-composting
- ✓ Minimizing GHG emission through RCTs, IFS and integrated crop management
- ✓ Plantation of multiple purposes tree species in the institute
- ✓ Rainwater harvesting structures

At the same time with collective efforts the premises was made PLASTIC free campus and clean and green campus.



Fig.1.71. Efforts for clean and green campus

Improved Infrastructures & Facilities



Fig. 1.72. Administrative building inaguration KVK Ramgarh



Fig. 1.73. Inauguration of implement shed KVK Buxer



Fig.1.74. Biofloc unit



Fig.1.75. Rainout shelter

Institute library

The institute library serves as a comprehensive knowledge resource hub, housing 3,074 books across diverse disciplines in agriculture and allied sciences. It supports academic and research excellence by offering 41 Indian and 51 foreign journals and periodicals (up to 2018) on various agricultural topics. Since 2018, it has expanded its digital presence by subscribing to e-journals via the Consortium for e-Resources in Agriculture (CeRA). Equipped with electronic databases like CAB Abstracts and Agricola, the library ensures efficient access to global scientific research. Its rich blend of physical and digital resources fosters advanced learning, innovation, and scholarly pursuits in agriculture.



Fig.1.76. View of library at ICAR RCER, Patna

Museum

The ICAR-RCER Museum, established in 2010, showcases innovative agricultural technologies developed by the institute. It serves as a knowledge hub, promoting technology transfer and educating farmers, researchers, and students on practical agricultural solutions. By exhibiting key advancements in areas like water management, climate resilience, and sustainable farming, the museum bridges the gap between research and field application, fostering agricultural development in eastern India.



Fig.1.78. ICAR RCER Museum to showcase technologies developed by institute

Technologies Certified by the ICAR

Division	Technologies
Crop Science	1. IFS for different ecologies 2. Multitier cropping system for rainfed uplands 3. Sustainable intensification of rice-wheat cropping system 4. Improved agro-techniques for enhancing productivity of millets in eastern India 5. Innovative millet-based climate resilient cropping system for eastern India 6. Technology for sustainable intensification of rice-fallow in Eastern India 7. Climate resilient agriculture practice in rice fallow ecosystems of East India Plateau
Horticulture	8. Carbon stock quantification models for important fruit trees 9. Modified drip fertigation technology for vegetable production 10. Modified drip fertigated mulched planting system for commercial cultivation of vegetable in East India Plateau 11. Tephrosia biomass mulching technology for improving soil health and productivity of fruit orchard 12. Flood prone area identified as fruit hub in Bihar: A policy framework
Animal Science	13. Identification of CCL8 and CXCL10 as early pregnancy biomarker in buffaloes 14. Serological diagnosis (Indirect ELISA) of Theileria annulata using recombinant spm2 antigen
Water Science	15. Solar Irrigation Pump Sizing Tool 16. Design and development of solar-operated hold-on type paddy thresher 17. Low-cost non-weighing lysimeter for assessing nutrient leaching loss
Social Science	18. Seed-based technology delivery model through FPO 19. Policy measures for tenant farmers of Bihar 20. Socioeconomic status scale for farmers of Bihar and Jharkhand 21. Climate resilient model village developed at Gaya and Buxar districts of Bihar 22. Strengthening export potential of farmer producer organizations (FPO) through One District One Product (ODOP): a conceptual model 23. Nutri garden model addressing anemia and hypovitaminosis challenges of Eastern India 24. Model for structural and functional analysis of makhana value chain model

IARI Patna hub

IARI Patna Hub initiated in the academic session 2023-24, with the vision of strengthening agricultural education and research-driven, practical learning under the IARI, New Delhi as part of "Sun, Planet, and Satellite" academic collaboration model developed by the ICAR. ICAR-RCER, Patna acts as a nodal institute of the hub, with ICAR-ATARI Patna, the Central Potato Research Station Patna, and ICAR-NRC on Litchi, Muzaffarpur as coordinating institutes. The IARI Patna Hub offers a range of academic programs across undergraduate, postgraduate, and doctoral levels. Presently the second batch of B.Sc. Agriculture has enrolled totaling the number of students to 37 U.G students and 2 M. Tech. and 4 Ph.D.



Fig.1.79. IARI hub students with Dr. T Mohapatra, Chairman PPV&FRI and Former DG and Secretary ICAR with Dr. D R Singh VC BAU and Dr. Anup Das Director ICAR RCER

ICAR RCER in Media

ICAR-RCER actively connects with the public and the agricultural community through various social media platforms, including Facebook, YouTube, Twitter, and its official website, to share valuable research, innovations, and educational content. The institute's digital outreach continues to grow, with 1,584 followers on Facebook, engaging 469 interactions per post. On YouTube, ICAR-RCER has a strong presence with 6,360 subscribers, 3.69 lakh viewers, and a total watch time of 46,309 hours. The official website has recorded 12,56,739 total page views, attracting 5,79,821 visitors, with an average of 2.16 pages viewed per visit. Meanwhile, on Twitter, the institute has 133 followers and has shared 244 posts to keep stakeholders informed. Through these platforms, ICAR-RCER continues to expand its reach, making scientific advancements more accessible and fostering engagement with the agricultural community. Institute has outreach to various national and local newspaper like The Hindustan, The Prabhat Khabar, Dainik Jagran, Aaj, Rastriya Sahara, Time of India, Hindustan Times and many others. If we talk in numbers then in the year 2024 total media coverage was 1420, while in year 2023 it was 1120, 2022 it was 920 and in 2021 it was 300 and before that the presence was around 200 in most of the years.



Fig.1.80. Glimpses of outreach activities by ICAR-RCER, Patna

Advancing Crop Science: Innovations for Sustainable Agriculture

Sanjeev Kumar, Rakesh Kumar, Santosh Kumar, Saurabh Kumar, Rachana Dubey, Kumari Shubha, Abhishek Kumar, Abhishek Kumar Dubey, A K Choudhary and Narayan Bhakta
Division of Crop Research

Background

The Division of Crop Research (DCR) came into existence on April 1, 2009 at ICAR Research Complex for Eastern Region, Patna evolving from the Crop Research Programme (CRP) situated at Pusa, Samastipur. Crop Research Programme (2001-2009) before its existence at Pusa was part of the Central Tobacco Research Institute, Rajamundry. Since research on crops was one of the major thrust areas of the Complex, the CRP at Pusa was shifted to ICAR RCER main campus and named Division of Crop Research on the recommendations of first QRT (2001-2005) chaired by Dr. S M Virmani.

The Division of Crop Research undertakes strategic and adaptive research aimed at enhancing crop productivity and resilience across the diverse agroclimatic zones of Eastern India mainly focusing on developing location-specific improved production technologies for field and horticultural crops, resource conservation technologies, genetic enhancement of crops, crop protection, climate change mitigation, abiotic stress management, fostering agricultural resilience, and promoting sustainable development. It addresses diverse challenges in crop husbandry, focusing on cereals, pulses, oilseeds, vegetables, and plantation crops.

Dr. S S Singh was the first head of the division, followed by Dr. A R Khan, Dr. Abdul Haris, Dr. J S Mishra, Dr. A K Choudhary, and Dr. Sanjeev Kumar, the current head of the division. The division on its commencement comprised of nine scientists in the field of Agronomy, Plant Pathology, Plant Physiology, Plant Breeding, Soil Science, Entomology, and Agricultural Meteorology, working collaboratively to advance agricultural research and innovation. Presently 11 scientists are working in the division with diverse fields like Agronomy, Plant breeding, Agroforestry, Environmental science, Plant pathology, Agricultural microbiology, Agricultural meteorology and Vegetable science (Table 2.1).

The division has been engaged in 43 institutional research projects and 20 externally funded projects supported by foreign (IRRI, CIMMYT) and national (DST-SERB, DBT, RKVY, NASF) funding agency including AICRPs, driving innovation and progress in agricultural practices across the region. The key research initiatives of the division include evaluating the long-term effects of conservation agriculture practices on the productivity of rice-based production systems, management of rice-fallow areas, development of locationspecific integrated farming system (IFS) models for small and marginal farmers; evaluating and developing rice varieties with improved tolerance to drought and submergence; yield enhancement in pulse and oilseed crops; genetic improvement of vegetable legumes; developing climate-resilient agro-techniques for Nutri-cereals, assessing climate change impacts on crop production, quantification of GHGs and abiotic stress management.

The scientists of the division have developed 11 climate-resilient rice varieties with yield potentials ranging from 4.0 to 6.0 t/ha, most of which are well-suited for extensive areas across Bihar, Jharkhand, Odisha, West Bengal, Uttar Pradesh, Chhattisgarh, Madhya Pradesh, Rajasthan, Haryana, Maharashtra, and Gujarat. They have also developed the high-yielding chickpea variety "Swarna Lakshmi (DBGC-3)," which offers a yield potential of 1.7 q/ha and a protein content exceeding 20%, making it ideal for cultivation in Uttar Pradesh, Bihar, Jharkhand, West Bengal, and Assam. The division has also contributed in developing 10 climate-smart villages (5 in Gaya and 5 in Buxar), and has successfully brought a significant portion of rice-fallow areas into double and triple cropping systems through the persistent efforts of its scientists. The division has developed location specific IFS models for the diverse ecological situations of eastern India through which the income of the farmers increased up to 3-4 times after the adoption of IFS approaches into their farms. The division is actively involved in teaching at IARI Patna Hub, and research guidance/internship support for several reputed national universities/institutes. Moreover, the division is regularly organizing farmers outreach and capacity programmes.

Table 2.1 Heads of the Division of Crop Research

S.No.	Name	Designation	Tenure	
			From	To
1	Dr S S Singh	Head	29/04/2009	21/01/2014
2	Dr. A R Khan	Head (Acting)	22/01/2014	31/03/2014
3	Dr. Abdul Haris	Head (Acting)	01/04/2014	26/11/2014
4	Dr. J S Mishra	Head	27/11/2014	25/11/2020
5	Dr. A K Chaudhary	Head (Acting)	26/11/2014	11/01/2023
6	Dr. Sanjeev Kumar	Head (Acting)	12/01/2023	16/07/2023
7	Dr. Sanjeev Kumar	Head	17/07/2023	Continue

Research Contributions

Pre-establishment year (2001-2009)

The major focus of the CRP (CRP), Pusa was to design tobacco based cropping system and germplasm improvement of tobacco genotypes. The significant achievements of this programme before converting to the Division of Crop Research are given below:

- A chewing tobacco variety "Lichhavi" with a yield potential of 2700 kg/ha with a mean productivity of the crop in north Bihar of 1730 kg/ha was released in 2001.
- A total of 76 germplasm of N. tabacum were maintained during 2005-06 for breeding purposes.
- The tobacco + garlic/coriander intercropping system developed by the institute has spread over 40-50 percent of tobacco cultivated area.
- The continuous cultivation of tobacco since 1963 resulted decline in organic carbon status from 0.55 to 0.46% till 1990.
- Out of several F4 generations grown with 100 plants each, 06 best individual plants were

selected for testing and evaluation under line X tester analysis of chewing tobacco. The advanced breeding lines of rustica tobacco (06) collected from Anand produced significantly highest yield (2821 kg/ha) by line R-12 (c) followed by line AR-87 (2431 kg/ha).

2009 onwards as DCR :

Integrated Farming system

The eastern region has high population pressure and small holding size (0.32-0.88 ha), making the agriculture less profitable. Further, more than 85 percent of the farmers are small and marginal and rice- wheat is the pre-dominant cropping system. The area region diverse agroecosystems viz. rice- fallow area, drought prone area, flood affected area, water logged area etc. due to which either the lands are kept fallow or monoculture/ monocropping is practiced in a large area. For enhancing agricultural productivity and providing better livelihood to the small and marginal farmers' a programme on development of Integrated farming system (IFS) was initiated in the year 2007 and two IFS models (One acre IFS model) by integrating i. Field crops + Hort. + Goat + Poultry + mushroom for midland ecology and ii. Field crops + Hort. + Fish/duck + dairy (Two-acre IFS model) for low land ecology were developed. These developed IFS models enhanced the income by 3-4 times over conventional rice- wheat system with added benefits like more employment, low cost of production, saving of natural resources, green and clean environment. Further, different location specific IFS models were developed (2012-18) viz. Vegetable- based IFS model (Veg. + Backyard fish/duck + goat) for marginal farmers at Vaishali; Livestock- based IFS model (F. Crops + Hort.+ goat + Poultry + mushroom) for irrigated midland/upland situation; Pond- based IFS model (i. F. Crops + Hort.+ Cows + Fish/duck and ii. Makhana based IFS model) for irrigated lowlands at Darbhanga; Pond-based IFS model (F. Crops + Hort. + Fish/duck) for Flood prone areas at Motihari and Orchard/Tree based IFS model (Rice + HD Orchards + Apiculture + Duck + Poultry + Hedge row spp.) for hill and plateau regions at Ranchi and Ramgarh. The developed models have been proved beneficial in aspect of income enhancement (3-4 times), fertilizer economy due to resource recycling (16.5- 28.4 %), additional man-days generation (56- 234 man-days/year) and enhanced organic carbon in soil (12-24%). After 2016, LIN Programme was used for land optimization of different components in the developed IFS models. In the year 2023, Azolla farming, vertical farming and nutri-cum- kitchen garden was added in the developed IFS model to enhance the income of the system and securing nutritional demand of the farm family.



Fig. 2.1. Integrated farming system models at ICAR RCER, Patna

Again, for learning the hidden benefits from IFS, data on carbon sequestration (enhanced by 43.6 %), energy budgeting (output energy were more than 2.1 times over R-W), microbial biomass, GHG emission (-ve Co2 emission in the developed models) etc. were undertaken for the developed IFS models. The developed IFS models have been accepted by Govt. of Bihar and these 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 improved substantially (income increased by 87-352 percent). Till date 52 acres of waste and unutilized lands has been made productive though IFS approach.

Crop diversification in Bihar

A pilot project on crop diversification was initiated in the West Champaran and East Champaran districts of Bihar, aimed at enhancing agricultural productivity, promoting sustainable agriculture, and improving livelihoods in the region. West Champaran was selected for the first phase (2024-25) of the program, covering a total area of 100 hectares during the kharif season of 2024. The project showcased a transformative impact compared to benchmark data, particularly in terms of productivity, resource efficiency, and income enhancement. Traditional cropping systems, such as rice and maize, were replaced or supplemented with diversified crops like maize (Shaktiman-5), soybean (P-1241), pigeon pea (IPA-203), and finger millet (Rajendra Madua-1). Additionally, innovative intercropping systems, such as maize+pigeon pea and pigeon pea+soybean, were introduced, resulting in improved yields and resource-use efficiency.

Maize, soybean, pigeon pea, and finger millet yielded 68.4 q/ha, 24.8 q/ha, 27.8 q/ha, and 21.7 q/ha, respectively in West Champaran. These crops have demonstrated greater profitability and emerged as a high-return alternative to water-intensive rice cultivation, promoting both sustainability and economic viability. These diversified crops have consumed 44.3% less water compared to rice, and increased water use efficiency by 155%, offering an effective solution to water issues. Intercropping systems reduced labor costs by 19.8% through optimized field operations, while efficient soil fertility management decreased fertilizer use by 38-46%. Farmers experienced around 116% increase in average income, driven by the higher yields and market rates of diversified crops.

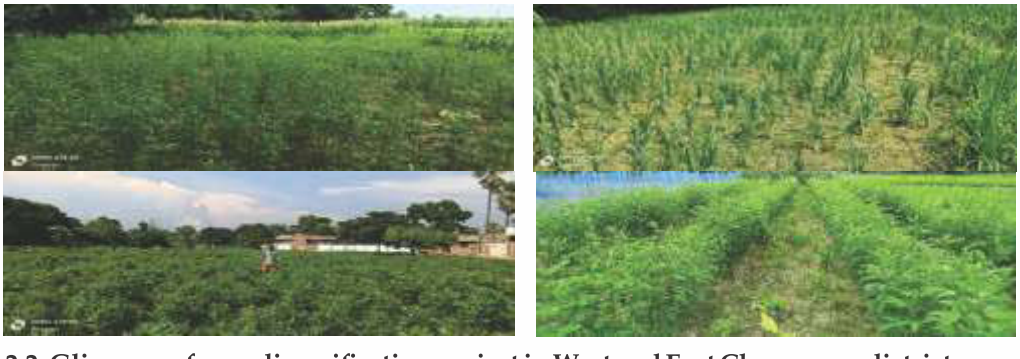

Fig. 2.2. Glimpses of crop diversification project in West and East Champaran districts

Conservation agriculture for sustainable rice-wheat cropping system

Under the Cereal Systems Initiative for South Asia (CSISA), the Division of Crop Research successfully optimized rice-wheat systems through conservation agriculture (CA).

The adoption of the rice-wheat-mungbean system under CA-based practices resulted in 10.8% higher net returns and 14–36% greater system energy productivity compared to conventional tillage. Additionally, CA-based systems reduced weed flora density, soil weed seed banks, and production costs while maintaining similar yields. Soil health improved significantly, with a 46% increase in soil organic carbon and 40% higher carbon stock in the surface layer. The CAbased rice-wheat-mung system outperformed conventional rice-wheat rotations, increasing productivity by 38–53%. However, a major challenge encountered was the emergence of rice mealybug at an epidemic level under long-term direct-seeded rice (ZT-DSR), posing a potential threat to CA-based rice production. To sustain the benefits of conservation agriculture, it is crucial to develop integrated pest management strategies, including weed control, residue management, and crop rotation.

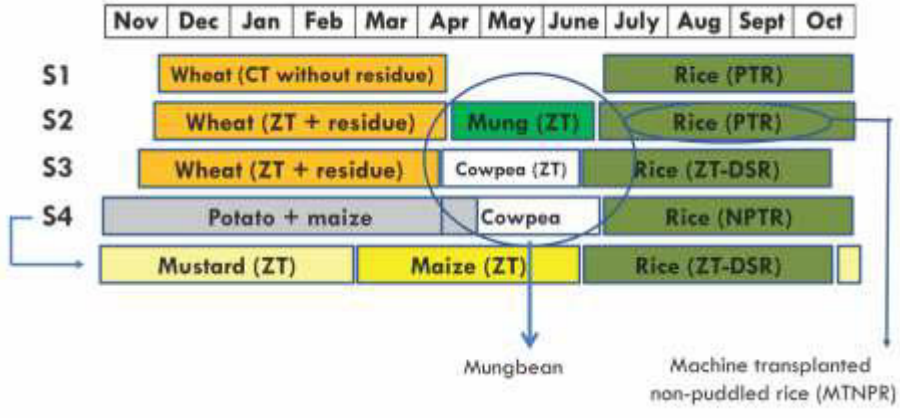

Fig. 2.3. Scenario treatment details with changes during 5th years



Fig. 2.4. Glimpses of CSISA experimentation at Sabajpura farm

Rice fallow management in eastern India

Rice-fallow, a rainfed mono-crop production system practiced over 22.3 m ha in South Asia, is gaining greater attention in recent times for cropping intensification. The main challenges for sustainable intensification of rice-fallow systems are lack of irrigation facility, preponderance of long-duration rice varieties which delay planting of the succeeding winter crops, low residual soil moisture and poor-fiscal status of farmers. The sustainability of ricefallow system is additionally defied by degrading soil quality, falling groundwater table, and polluting environment. Rice-fallow areas of eastern India have the potential for agricultural intensification by inclusion of a second crop after rice through strategic crop management In this

context, various experiments on rice fallow management were initiated during 2015-2016 with respect to suitable cultivars of rice, oilseeds/pulses, tillage-cum crop establishment and residue management and nutrient management practices for improving productivity of ricefallow in rainfed ecosystems of eastern region. The major achievement of this experimentation are as follow:

- Lentil/lathyrus sown in utera crop establishment (10-12 days before rice harvesting) had 30-45% more crop yields and WUE (20-25%). Utera led to less emission of greenhouse gas(GHG) & low global warming potential (GWP). Short/medium duration rice cv. Swarna Shreya/Naveen/Lalat (120-125 days) during kharif followed by chickpea, lentil, lathyrus, safflower in winter have been identified as a potential cropping system. Crop productivity of ZT/CTDSR was less (25-30%) than transplanted puddled rice (TPR) during kharif but yield of all the winter crops were higher (20-30%) in ZT/CTDSR, thereby improved overall system productivity. Soil crack volume was higher (2.6-3.3 times) under TPR in comparison to ZT/CTDSR. More earthworm's diversity was observed in soil under ZT/CTDSR (CA/pCA) as compared to TPR.
- Lentil sown under utera crop establishment along with seed priming+microbial treatment+ 2% urea at branching+2% DAP at flowering+0.5% KNO3 at podding had the maximum crop yield (2.07 t/ha). Utera had higher B: C ratio and energy ratio compared to CT/ZT.
- Pusa Masoor 5, Pusa Vaibhav, IPL 81, HUL 57, Arun & DPL 15 were found stable & promising cultivars under ZT & residual moisture condition. Linseed cvs. Uma and RLC 143 were found promising under ZT and limited moisture condition after rice.



Fig. 2.5. CA experiemnt under rice fallow at Sabajpura farm

Rice-fallow management flagship program

Under the Rice-Fallow Management Flagship Program, the institute successfully demonstrated climate-resilient agricultural practices to utilize rice fallow lands in Gaya district, Bihar. The introduction of high-yielding varieties (HYVs) of pigeon pea (IPA-203) in upland fields and raised bunds showed excellent performance under rainfed conditions, encouraging farmers to adopt this high-value crop. Short-duration pulses and oilseeds, including lentil (IPL 220), chickpea (GNG 2299), and mustard (DRMR 150-35), were successfully cultivated on residual soil moisture during the rabi season, achieving grain yields of 1.77 t/ha (pigeon pea), 1.14 t/ha (lentil), 1.57 t/ha (chickpea), and 1.08–1.14 t/ha (mustard). The adoption of direct seeded rice (DSR) with Swarna Shreya resulted in better resource efficiency, early harvesting, and

timely winter crop sowing, gaining strong acceptance among farmers. Conservation agriculture (CA)-based practices, including zero tillage, residue retention, seed priming, and foliar nutrient application, contributed to improved productivity. The participatory approach, involving farmers and government departments, proved effective in greening rice fallow areas, ensuring better land utilization and higher farm incomes.



Fig. 2.6. Interventions in rice fallow area in Gaya

Millets based crop diversification

Millets are highly nutritious, highly resilient to harsh growing conditions and require minimal input thus, could play a vital role for food & nutritional security in climate change scenario. Ten millet based diverse cropping systems were evaluated for their adoption in eastern India. Millet-based production systems reduced input cost (43-69%) and sometimes doubled farmers' income. The most productive cropping system in terms of system rice equivalent yield (SREY) was obtained with maize cob–pigeon pea (ZT) (22.3 t/ha) followed by sorghum fodder-mustard (ZT)–urd bean (ZT) (18.5 t/ha). Similarly, in terms of economic feasibility, most profitable cropping system was maize cob–pigeon pea (₹ 25,5272/ha) followed by sorghum fodder-mustard–urd bean system (₹17,8059/ha). Millet-based system reduced C-input (172%) and improved energy ratio (61%) compared to cereal-based system. Thus, inclusion of millets in existing production system improved the energy productivity, system productivity, economic efficiency in diverse agro-ecological zone of eastern India. Hence, the existing rice-wheat cropping system may be diversified with substitution of climateresilient millet-based production systems, which are more productive, resource use-efficient, energy-cum-carbon-efficient, and low emitter of GHGs. This production technology has been widely adopted in rainfed ecologies of Bihar for diversification of existing cropping system under Climate Resilient Agriculture (CRA) Program in all 38 districts of Bihar. Under CRA Program (GoB), ICAR RCER Patna has covered more than 500 ha area with millet-based production system during last 5-years in drought prone district of Bihar.



Fig. 2.7. Jowar-mustard-urad based cropping system

Agro-techniques for millets production in eastern India

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)] and 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 the tested major millets, Bajra & Ragi & Barnyard among minor nutri-cereals identified in terms of crop yields while planted up to 15th July for sustainable millets/climate-resilient system. Among tested cultivars of Bajra cv. Proagro (2.98 t/ha); Ragi cv. RAU-8 (2.29 t/ha) and Barnyard cv. DHMB 93-3 (1.91 t/ha) were identified the potential nutri-cereals cultivars. In case of weed management, application of atrazine@0.5 kg/ha (PE) fb 1 HW (30 DAS) had significantly higher yields. Amongst the nutrient management, application of 75% RDN (IN) & 25% RDN (FYM) had significantly higher yield of Bajra (2.83 t/ha), Ragi (2.25 t/ha) & Sawa (1.54 t/ha) at par with 100% RDN (IN). Thus, standardization of agro-techniques in nutri-cereals help in designing climate resilient cropping system having better energy productivity, system productivity, economic efficiency for eastern India.



Fig. 2.8. Experimental site for standardizing agro-techniques of nutri-cereals

Direct seeded rice cafeteria

A field experiment was initiated during kharif 2023 at ICAR Research Complex for Eastern Region, Patna, Bihar (25°35′ N and 85°05′ E and 51 m above mean sea level) to study the performance of inbred and hybrid rice cultivars under dry-seeded direct seeded conditions (DSR cultivar cafeteria). Altogether, 24-inbred hybrid rice cultivars were evaluated for their production potential. Out of 24 tested inbred/hybrid rice, 11 inbreds and hybrids (Swarna Sherya, Swarna Shakti Dhan, Swarna Unnat Dhan, Swarna Purvi Dhan-3, Swarna Sukha Dhan, CR Dhan 201, CR Dhan 202, PR 126, Arize 6129 Gold, RCPR 68 and RCPR 92) were short duration and remaining 13 [Sarju 52, Swarna Samriddhi Dhan, BPT 5204 (Samba Mahsuri), Arize 6444 Gold, Arize 8433 DT, 27P37 (XRA 37923), 28P67 (XRA 38967), 25P85 (XRA 752PJ6), Sava 134, Sabour Sampanna Dhan, MTU 7029 (Swarna), DRR 56, DRR 64] were medium/long-duration. Seed materials were collected from IRRI South Asia Regional Centre Varanasi, Uttar Pradesh, ICAR RCER Patna, Bihar and from the different private firms. Rice inbred, Swarna Samriddhi Dhan and MTU 7029 (Swarna) were used as Check I & Check II. Crop was sown on 17th June

2023 under conventional-till dry-direct seeded condition following the standard agronomic management practices. Thus, from the above study following significant findings had been drawn

- Among tested inbreds/hybrids which performed better in terms of crop yield having more than 4.0-4.5 t/ha in case of short duration and 5.0-5.5 t/ha in case of medium/long duration one were promoted for its further long-term testing in dry-DSR at various locations.
- In short duration inbreds/hybrids which matured in 115-120 days (4.0-4.5 t/ha) & in case of medium/long-duration line (5.0 -5.5 t/ha) which matured in 135-140 days in dry- DSR production system may be adopted to enhance cropping intensity and overall system productivity of rice-based cropping systems in irrigated agro-ecosystem of Bihar.

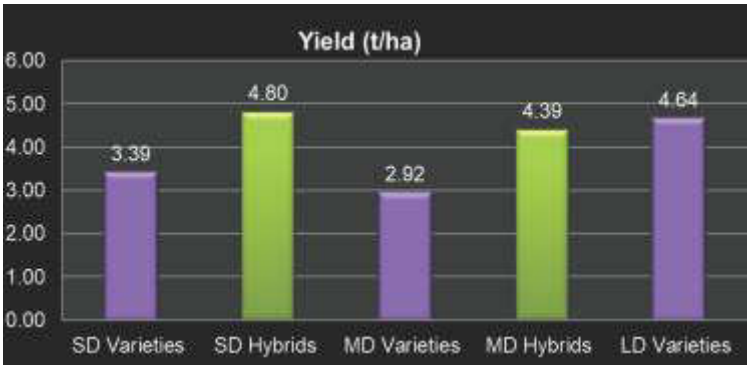

Fig. 2.9. Performance of inbred and hybrid rice cultivars under dry-seeded direct seeded conditions

Improved Rice Based Rainfed Agricultural System (IRRAS)

Keeping the importance of adoption of stress tolerant varieties coupled with best management practices (BMPs) in rainfed ecosystem, a project "Improved Rice Based Rainfed Agricultural System (IRRAS)" was conducted in collaboration with International Rice Research Institute (IRRI), Philippines in 2012 with objective to develop, validate, refine and demonstration best agronomic technologies for improved rice varieties along with complementary crops to increase the productivity and reduce the risk of rice based cropping systems. To achieve the objectives of this project, ten experiments were conducted during 2012-2016. Through this study, identified the promising genotypes (IR 84899B183CRA19-1, CR Dhan 40, Abhishek, IR83387-B-B-40-1, Shusk Samrat, Swarna Sub 1, and IR 83387-B-B-27-4) and best integrated agronomic management practices (suitable rice establishment methods, weed control measures, appropriate seed rate, foliar application of nutrient, seed treatment with Trichoderma strains, suitable wheat sowing time) for rainfed ecology.



Fig. 2.10. Experimental site of IRRAS project at Sabajpura farm

Resource management for cold tolerance in winter maize

Maize hybrid SM9522 was evaluated under three doses of nitrogen: N1 (120 kg N/ha), N2 (150 kg N/ha) and N3 (180 kg N/ha) along with two crop residue managements practices (with crop residue and without crop residue) and two tillage practices (zero tillage and conventional tillage) to study the effect of the management practices on cold tolerance in winter maize. In the experiment, the available above ground biomass @ 0.75 t/ha from the preceding rice crop was retained in the plots with with-residue treatments. The crop was sown on 7th December 2018. During the early vegetative phase, the minimum temperature remained between 5-10°C and the maximum temperature was above 20°C. Hence the effect of cold was very mild which was observed as temporary purple pigmentation in leaves of younger plants. The purple pigmentation of leave disappeared in the month of February when the minimum temperature went above 10°C. The grain yield was the highest (6.16 t/ha) in plots under zero tillage with the retained crop residue from the previous rice crop. However, there was no significant difference between zero tillage over conventional tillage whether with or without residue in terms of grain yield. There was significant difference among the different nitrogen levels in maize crop. N180 has resulted in significant higher grain yield over N120 but it was found at par with N150.

Long-term CA-impact on microbiome health indicators in maize system

A field experiment (2018–2021) evaluated the impacts of tillage and residue management on productivity, energy efficiency, and soil health across three cropping systems: rice-wheat (RW), rice-maize (RM), and rice-chickpea (RC). Three tillage practices-conventional tillage (CT), reduced tillage (RT), and reduced tillage with 30% residue retention (RTR30) were arranged in a randomized block design. The results showed that partial conservation agriculture (pCA) practices significantly enhanced system productivity, with RM under RT achieving the highest yield (12.2 Mg ha^{-1}). RT consistently minimized energy use, while pulses-based systems had the highest energy ratio (3.97). On average, total earthworm counts were 0.92 and 6.5 times higher during rainy and post-rainy seasons in pCA in comparison to CT. Earthworm species diversity was more in pCA-based systems (RT/RTR30) than in CT. In rice-wheat system, maximum bacterial and actinomycetes counts were observed in CT/FP followed by pCA. Maize-based systems under CT had the highest global warming potential, while pulsebased systems had the lowest. The RM system under RTR30 demonstrated the greatest increase in soil organic carbon.

Nitrogen and zinc management in fodder oats

Considering its importance as fodder for eastern region, a field experiment was carried out in split plot design (SPD) during Rabi 2022-23 to evaluate the efficacy of different nitrogen and zinc management practices in fodder oats. Application of whole recommended dose of nitrogen through inorganic fertilizer combined with Zn1 (zinc @ 10 kg/ha through inorganic fertilizer. This combination showed the highest total green fodder yield (36.70 t/ha), total dry matter yield (6.23 t/ha), and significant improvements in fodder quality traits such as total crude protein yield, total ash yield, and total ether extract yield.

Rice breeding for abiotic stresses (drought and submergence)

The challenge of day to day growing water scarcity and frequent occurrence of drought and flood threating food security of the eastern region. Keeping these facts in view, rice breeding programme (drought, aerobic, submergence, multi-stages-drought, multiple stress tolerance) was started in 2010 after establishment of division of crop research in 2009. Division initiated the rice breeding programme and taken lead in development of climate resilient rice varieties at ICAR RCER, Patna.

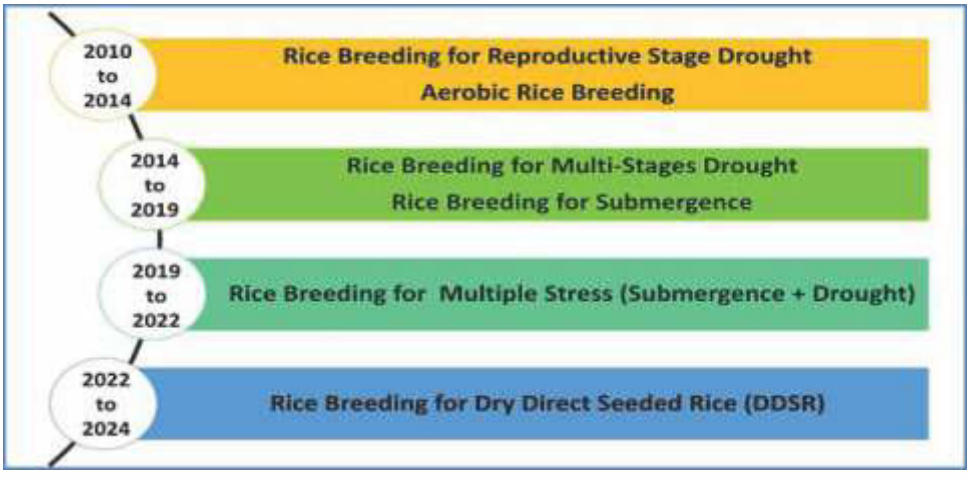

Fig. 2.11. Rice breeding programme at ICAR RCER, Patna

Rice breeding for reproductive stage drought

Drought, particularly at reproductive stage is considered one of the main constraints that limit rice yield in rainfed and poorly irrigated areas of eastern India. A rice breeding programme in collaboration with International Rice Research Institute (IRRI), Philippines (STRASA Project) was initiated in 2011 with the objective to identify suitable rice genotypes/ donor lines having tolerance to drought stress at reproductive stage. One hundred ninety five under STRASA phase II (2011-2014) and five hundred twenty under STRASA phase III (2014-2019) rice genotypes were evaluated during kharif season 2011-2019 under drought stress and non-stress (irrigated) conditions. After on-farm testing (participatory varietal selection) as well as national (AICRP on rice) and state trial, some of the promising genotypes have been released as climate resilient rice varieties (Swarna Shreya, Swarna Samriddhi Dhan, Swarna Shusk Dhan, Swarna Unnat Dhan, Swarna Purvi Dhan 2 and Swarna Purvi Dhan 3).



Fig. 2.12. Evaluation of rice genotypes under drought stress and non-stress condition

Aerobic rice breeding for water limited areas

In order to stabilize rice productivity in the water scarce or water limited areas in eastern India, aerobic rice breeding programme was started in 2011 with the objective to identify suitable lines or varieties for eastern region which perform better under water scarce condition. Two hundred and seventy six rice genotypes comprises of advanced breeding lines and high yielding varieties were evaluated during kharif 2011-2015 under aerobic and irrigated condition. Promising aerobic rice genotypes showing significant yield advantage (16.5-58.11%) over best check varieties were identified. After on-farm testing (participatory varietal selection) as well as national (AICRP on rice) and state trial, some of the promising genotypes have been released as climate resilient aerobic rice varieties (Swarna Shreya, Swarna Shakti Dhan, Swarna Purvi Dhan 1 and Swarna Purvi Dhan 4).



Fig. 2.13. Evaluation of rice genotypes under aerobic condition

Rice breeding for multi-stages drought

In rainfed conditions, the occurrence of drought is not stage specific and can occur at any developmental stage of rice (seedling, vegetative and reproductive) or it can be intermittent drought due to greater temporal variability and long breaks between rainfall events. A rice breeding programme on multi-stage drought was started in 2014 with aim to develop/ or identify new rice genotypes tolerance to multi-stages drought and identify physio-biochemical traits/mechanisms of tolerance to MSD. Forty-four rice genotypes were evaluated under MSD and non-stress (irrigated) conditions during wet season 2014-2018. After on-farm testing as well as national (AICRP on rice) and state trials, some of the promising genotypes have been released as climate resilient rice varieties (Swarna Shreya, Swarna Sukha Dhan, Swarna Purvi Dhan 1 & Swarna Purvi Dhan 5).



Fig. 2.14. Evaluation of rice genotypes under multi-stages drought stress condition

Rice breeding for flood-prone ecology

In order to identify flood tolerant rice, sixteen elite rice genotypes were evaluated for submergence tolerance at active vegetative stage along with Swarna sub1 as tolerant and Swarna as susceptible check. Forty days old crop was completely submerged under 75-100 cm water depth for 21 days during kharif 2016. Observations on post-submergence crop

regeneration revealed that rice genotypes IR09L342, IR10F198, IR11F195 and IR10F365 along with the tolerant checks Swarna sub1 showed more than 70% survival with no stem elongation. Under complete submergence of 3.0 -3.5 m depth for more than 25 days there was complete crop failure. The locations with submergence up to 3 weeks, Swarna sub1 with 25% crop damage produced 4.30 t/ha grain yield and local variety Silky with 40% crop damage could produce grain yield of 3.73 t/ha. In Kishanganj, duration of submergence was for 10-15 days with water depths varying from 1.0 m to 1.5 m. The highest grain yield (5.75 t/ha) was recorded in Swarna sub1 and the lowest in Silky (4.10 t/ha). Similarly, in Katihar also, Swarna sub1 produced the highest grain yield (5.96 t/ha) followed by BB11 (5.22t/ha) and Rajendra Mahsuri (5.03 t/ha). For the rice ecosystem prone to stagnant flooding (semi-deep-water situation) early maturing rice varieties like CR Dhan 401, Sudha, TTB 404 and Vaidehi were found promising in the farmers field when there is rainfall deficit in September

Rice breeding for multiple stress (drought and submergence) tolerance

Most of the popular high-yielding rice varieties being grown in rainfed lowland ecosystem of eastern India, were originally bred for irrigated ecosystems and they are extremely sensitive to submergence and drought conditions, leading to high yield losses every year in regions of their cultivation. Keeping these facts in view, a rice breeding program on multiple stress tolerance was initiated in 2019 with aim to develop or identify new rice genotypes combine tolerance to both drought and submergence stress at different growth stages. Twenty-four rice genotypes were evaluated under multiple stress and non-stress (irrigated) conditions during wet season 2019-2023. One of the promising rice genotypes RCPR 10 has been released in the name of "Swarna Samriddhi Dhan" for irrigated as well as rainfed lowland ecology. This rice variety helping in improving rice productivity of rainfed lowland ecology of eastern India.



Fig. 2.15. Evaluation of rice genotypes under multiple stress condition

Resource remobilization during grain filling under drought

Different mechanisms may contribute to improved resource re-mobilization during grain filling among different donor lines. Rice donar lines having high HI were identified followed by development of four mapping population by using four pair of donor lines having similar days to flowering and biomass but contrasting HI. The identified stable high HI lines (Aus 257 and Wanni Dahanala) may confer mechanisms to improve HI that are independent of drought

response and therefore may be useful for breeding improved rice varieties. One QTL for high HI was detected on chromosome 3 in mapping population. Further, promising advanced breeding lines selected from mapping population along with high yield varieties of eastern and south India were evaluated during wet season 2021-2022 under drought and non-stress condition. The comparison of stem carbohydrate dynamics under drought of selected high-HI lines from the mapping populations with popular rice varieties commonly grown in South and Eastern India was carried out. The results indicated that, the rice variety Swarna Shreya and IR 134118-3-B-RGA-B-RGA-B-RGA-29 showed highest harvest index (HI) and resources remobilization efficiency (ME).



Fig. 2.16. Experimental fields and inspection of rice

Management of low temperature stress in boro rice

A breeding programme on boro rice under NICRA project was initiated for addressing low temperature stress in 2016. Eight rice varieties were sown at four different dates in sets one under open and the other under polytunnels during 2016-17. Among the 4 different date of sowing, seed germination, seedling root and shoot length and vigour was maximum under 15thNovember sowing than other dates of sowings subsequent to 15th November. Among the varieties, there were variations in seed germination and other seedling growth parameters. Gautam recorded maximum germination % and seedling vigour. Nursery raised under poly tunnel resulted in better seed germination and seedling vigour and lesser leaf discolouration than the nursery raised under open condition. In the farmers' fields in Purnia and Kishanganj districts, application of farm yard manure 1.5 kg/m2 in the nursey bed, early morning removal of dew from the leaf tips of the seedling with rope, and frequent irrigation of the nursery bed were effective management practices to mitigate the adverse effect of cold in boro rice nursery. In another experiment, eight promising rice genotypes along with Naveen, IR64, CR Dhan 601 and Chandrama as check varieties were evaluated under late boro season in 2022. Normal boro season is from Oct-Nov to May-Jun. In theis study, nursery seeding was done on 22nd January and transplanting was done on 3rd March in 2022 in order to escape cold injury to seedling during winter months. There was no significant difference in the genotypes for grain yield. Naveen was the highest yielding check variety with grain yield of 6.70 t/ha. CR Dhan 204 (7.07 t/ha) and CR Dhan 203 (6.83 t/ha) are the top two yielding varieties with early maturity with 107 days to flowering.

Rice germplasm for flood-prone ecosystem

One hundred twenty-seven accessions of traditional rice germplasm were collected from the flood prone areas of Assam (North Lakhimpur & Dhemaji), Bihar (Madhubani & Darbhanga) and West Bengal (Malda). The accessions consisted traditional lowland rice, semi deep-water rice, deep-water rice, short grain aromatic rice and glutinous rice. A set of 88 accessions have panicles been deposited in national gene bank at ICAR-NBPGR for long term conservation. Three traditional short grain aromatic rice assessions were given mutagenic treatment for crop improvement.

Evaluation of Toria genotypes for rice fallow

Thirty elite toria genotypes were obtained from ICARDRMR Bharatpur and evaluated during rabi 2021-22 to assess their suitability for rice fallow areas. Fourteen promising genotypes were e further evaluated during rabi 2022-23 and 2023-24. There was no significant difference among the entries with respect to seed yield and maturity duration. The average seed yield and crop duration were 10 q/ha and 92 days respectively. However, DRMR-352 (12.2 q/ha), TS38 (12.0 q/ha) and TS-36 (11.2 q/ha) were found top three genotypes in terms of seed yield.

All India Coordinated Rice Improvement Project (AICRIP)

The division is actively involved in All India Coordinated Rice Improvement Project (AICRIP) since 2011. More than 125 varietal trials of rice (more than 5000 advanced breeding lines along with national, regional and local check varieties) were conducted during 2011-2024 suitable for different ecology of the eastern region. Final data submitted to nodal institute ICAR-IIRR, Hyderabad. Based on their results, promising genotypes were identified and released as variety under different ecology for different states of India.



Fig. 2.17. Evaluation of rice genotypes under national AICRP rice trials at Sabajpura farm of ICAR RCER, Patna

Pulse improvement programme

The Division of Crop Research has made significant strides in genetic improvement of pulses, focusing on developing improved plant types for the cool season and enhancing pigeonpea varieties. Through two institute-funded projects, several improved pulse lines have been developed, contributing to AICRP and State Varietal Trials. These advanced lines, detailed in Table 2.2 exhibit superior traits, including higher yield potential, better adaptability, and resilience to climatic variations, strengthening pulse cultivation in the region.

Table 2.2 Some Improved lines of pulses with special significance

Crop	Plant types/ Lines	Special features
Chickpea	DBGC 1 (IC650180)	A high yielding line of *desi* chickpea having drought tolerance and wilt resistance.
	DBGC 3 (IC650181)	A biofortified (Zn> 42 ppm) line of *desi* chickpea having heat tolerance and wilt resistance; released for cultivation in NEPZ as 'Swarna Lakshami'.
	RCECK 17-4 (IC650182)	A determinate genotype of *kabuli* chickpea with early maturity and high yield.
Lentil	DBGL 105	A high yielding line of lentil having wilt resistance; being evaluated in SVT.
	RCEL 19-1 (IC650183)	A super early line of lentil maturing in about 90 days; could be used as donor for earliness.
Grasspea	RCEGP 16-1	A low ODAP (>0.12%) line with diagnostic white flowers, white seeds and medium seed size (5.5 g/100 seeds).
Pigeonpea	RCEA 14-5 (INGR 20024)	A high yielding "cleisto" line of long duration pigeonpea with no natural outcrossing; registered with NBPGR.

Genetic enhancement of Lablab bean and Yardlong bean

Legumes like lablab bean and yardlong bean are vital for nutritional security, soil fertility, and farmer income but face challenges like low productivity and disease susceptibility. 340 lablab bean and 144 yardlong bean genotypes were evaluated during 2021-2025 with the objectives to identify promising lines with desirable traits such as high yield, disease resistance, and adaptability. Promising seven pole and two bush-type lablab bean lines have been identified. Notable among these were RCPD-1 (extra-early, dwarf, 105-110 pods/plant, photo-insensitive, collar rot tolerant), RCPD-15 (140-145 pods/plant, pole type, anthocyanin-rich, collar rot resistant), and RCPD-16 (extra-early, suitable for rice-fallow areas, dwarf, photo-insensitive, 95-110 pods/plant). Promising genotypes have also been evaluated across four distinct zones of Bihar. In the yardlong bean group, RCPY-1 and RCPY-2 emerged as early-maturing, dwarf, and yellow mosaic disease-resistant genotypes ideal for pre-kharif and kharif seasons. RCPY15, with its long, attractive pods, is also suitable for these seasons. These genotypes offer improved productivity, disease resistance, and adaptability across diverse agro-climatic conditions.



Fig. 2.18. Labab bean trials in fields

Optimizing soil organic carbon stock under different irrigation systems

The most important factors in achieving the goals of doubling agricultural income and bringing about the second green revolution in eastern India are soil health and irrigation water management. Thus, the a project was undertaken to investigate the minimum amount of rabi cover crop biomass that should be removed and recycled to sustain SOC stocks, farm income, and improve water productivity under various micro-irrigation systems which will aid in the restoration of SOC stock in the soil and reduce greenhouse gas emissions. The research was funded by SERB as an Early Career Research Award to Dr. Rachana Dubey during 2019-2023. Meanwhile, through this project and institute support GHG analysis lab was established in the year 2022. Result indicated that drip and sprinkler system had higher grain yield, biomass yield, test weight, number of seeds/pod by 15-25%, 20-28%, 10-12% and 11-20% %, respectively over no irrigation in mustard, chickpea and lentil crop. Meanwhile Global Warming Potential (on 100-year time scale) of surface irrigation was 29-33% and 33-55% more compared to sprinkler and drip irrigation, respectively. Similarly, C-flow ranged from -2.4 to -3.2 t C/ha/year indicating that T4 is the best option where 75% biomass incorporation can give good yield with lesser GHG emission.



Fig. 2.19. GHG sampling and field view under irrigation systems

Heat stress management in wheat



Fig. 2.20. Evaluation of wheat genotypes for heat and drought stress in wheat

Rising global temperature is of significant concern, as metabolic processes which govern agricultural production are temperature dependent. The onset of significantly higher temperatures coincides with the wheat grain-filling stage, particularly in the Indo-Gangetic plains, resulting in terminal heat stress and reduction in yield. Therefore, research for identifying genotypes/varieties of wheat which can tolerate or resist heat stress for eastern region of India was initiated in 2013 by evaluating 30 wheat genotypes. The initial studies indicated that yield was reduced by 18% (in late sown 15 December) to 34% (in very late sown 15 January) conditions as compared to the TS (15 November). Halna, one of the wheat lines studied, displayed extreme heat tolerance among the considered genotypes with the lowest heat susceptibility index for grain yield (HSI < 0.5). Later 17 genotypes (after refining from 30 genotypes) were assessed for drought and heat (Combined) stress tolerance. Heat stress alone caused 37% yield reduction compared to TS sowing while wheat yield can potentially reduce to half (49.3%) when crops face droughts and heat stress simultaneously. The top five promising varieties, namely genotypes Raj 3765, HD 2967; HD 3093, DBW 187, and DBW 14, have been identified as having potential for combined stress in the middle Indo-Gangetic plains area.

Valuing ecosystem services

A significant initial step toward the quantification of ecosystem services in rice practices from MIGP's was initiated by the institute to develop effective responses in collaboration with the key players from governments, local communities, policy, and business. By highlighting these resources' significance and their contributions to the economy and to shared goals like the SDGs, ES valuation aids in improving knowledge of the field ecosystem. The study found that ZTDSR (9583 US$/ha/yr), followed by conventional till DSR (9398 US$ ha/yr), had the highest ES value compared to PTR systems (8767 US$/ha/yr). The cumulative ecosystem value of different rice establishment methods ranged from US$ 8767 to 9583 ha/yr. These results have revealed the benefits of DSR cultivation and ZT and its significance in developing sustainable agriculture in ecologically fragile areas. As we enter the UN Decade of Ecosystem Restoration (2021–2030), there is a renewed push to scale up current ecosystem restoration activities and increase awareness of the value of environmental conservation. Our findings can help policymakers to formulate payment for ecosystem services (PES) and appropriately incentivize the farmers to adopt sustainable agriculture practices.

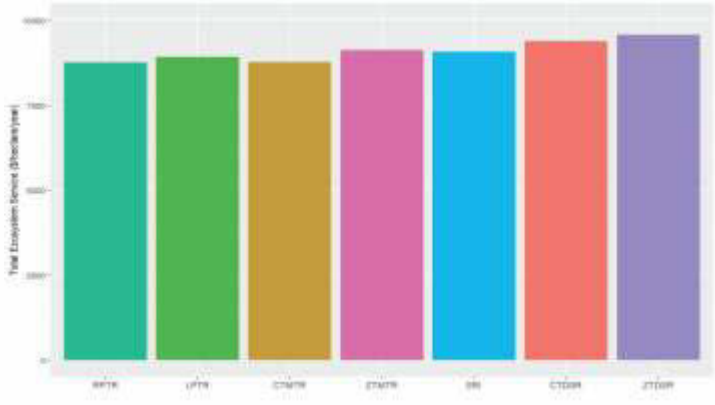

Fig. 2.21. Economic valuation of ecosystem services (US$/ha/yr) under different rice establishment methods

Soil organic carbon stocks under agroforestry systems

Considering the importance of agroforestry practices in terms of carbon sequestration, a study was undertaken in the Vaishali district of Bihar, India, to assess the effect of various agroforestry systems (AFS) on the distribution of different pools of soil organic carbon, carbon stocking and soil microbial activity. The mean (0–45 cm) total organic carbon (TOC) in different AFS ranged from 5.55 to 6.64 Mg C/ha, with the highest under poplar-based AFS (PB-AFS). Across the AFS studied, the C stocks (0–45 cm) varied from 36.24 (mango-based AFS) to 41.43 Mg C/ha (PB-AFS). Basal respiration was also the highest under PB-AFS (0.54 µg CO2-C/g/h), followed by TB-AFS (0.50 µg CO2-C/g/h) in 0–15 cm depth.

Agroforestry interventions for sustainable farming system

A study was conducted in Motihari (West Champaran), Bihar for enhancing productivity and resilience through agroforestry systems. Over 10,000 horticultural and agroforestry species were planted across 110 acres in different agroforestry systems, including mango, guava, litchi, and jackfruit-based agri-horticultural systems, as well as teak, mahogany, sissoo, simal, and gamhar-based agri-silvicultural systems. Simal demonstrated exceptional growth, reaching a height of 6.71 m, a trunk circumference of 149.22 cm, and canopy spread of 3.11 m under no intercrop conditions. Among mango-based systems, the Langra cultivar intercropped with maize recorded the largest canopy spread (3.68 m) and a substantial trunk circumference (132.14 cm). Teak, particularly in border plantations, exhibited notable growth, with a 71.19% increase in trunk diameter and a 27.86% increase in height, affirming its adaptability in diverse systems. Crop yields benefited significantly from agroforestry integration. Turmeric emerged as the most productive intercrop, with yields increasing from 7.53 t/ha in 2017-18 to 8.24 t/ha in 2020-21 under mango-based systems. Paddy and maize also performed well, with the highest paddy yield (4.37 t/ha) recorded in Mango + Guava + Teak (border plantation) based systems and consistent maize yields of 5.25 t/ha in Guava-based systems. Mango-turmeric systems demonstrated the highest productivity, achieving a Rice Equivalent Yield (REY) of 27.47 t/ha by 2020-21. Other systems, such as Mango + Teak and Mango + Gamhar, also showed consistent improvements in REY, reaching 7.10 t/ha and 7.12 t/ha, respectively.

Development of nutri-garden model

The Nutri Garden Model is designed as a low-cost, backyard vegetable garden aimed at improving the nutritional intake of rural households by focusing on iron and vitamin-rich vegetables. This model, developed and validated at ICAR-RCER, Patna, during 2019-2023, to fulfill the recommendations of Indian Council of Medical Research for vegetable intake (200g fruit vegetables, 50g leafy vegetables, and 50g root vegetables daily). Key cropping patterns includes:

- Pea-Red Amaranth-YLB: Highest in energy (23,892 Kcal), protein (1,849.9 g), and fat (143.2 g), also rich in iron and Vitamin B (thiamine: 58.55 mg, riboflavin: 68.52 mg, niacin: 653.7 mg).
- Carrot-Bottle gourd-Water spinach: Highest in Vitamin A (1,876,380 IU).
- Cauliflower-YLB-Poi: Highest in Vitamin C (20,888 mg).

This model supports a 100 m² area for households with 4 members, focusing on nutritional requirements rather than taste preferences. Rural women and school students, poor households facing nutritional deficiencies in Bihar and West Bengal, Policymakers aiming to implement cost-effective nutritional solutions for underprivileged communities



Fig. 2.22. Establishment of nutri-garden at ICAR RCER, Patna

Plant Protection

Isolation and characterization of potential biocontrol agent



Fig. 2.23. Trichoderma isolate

In eastern India, soil-borne diseases pose a serious threat to agricultural crops. Diseases, like wilt and root rot, cause considerable losses to crops like lentils and chickpeas. In severe conditions, total crop loss has also been observed. Trichoderma has been proven to be potential means of management of soil borne diseases. Keeping these things in view, project was undertaken for isolation of potential native Trichoderma isolate during 2018-2022. Soil from rhizospheric zone of different crops/plants from 60 different locations from Patna and adjoining areas ware collected. Ninteen Trichoderma spp. were isolated and these isolates were characterized based on growth, suppression of pathogenic fungi in dual culture, siderophore production and suppression of root complex diseases in chickpea and lentil. Out of 19 Isolates, 2 isolates were found to be most effective. Based on ITS sequencing, Trichoderma isolate was identified as Trichoderma harzianum.

Disease prediction in Yardlong bean using machine learning

The production of Yardlong bean crop is often challenged by several biotic stressors, among which viral infections are major limitations causing yield losses ranging from 10-100%. Plants affected by Yellow Mosaic Disease (YMD) exhibit reduced flower and pod production, with malformed pods and the yield loss can potentially reach 100%. Screening of germplasm for finding resistant genotypes and predicting yellow mosaic severity using machine learning models is the major component for yield loss reduction. One hundred forty-three yardlong bean genotypes were screened for yellow mosaic disease reaction during. Out of 143 genotypes screened, 3, 18, 18, 17, 34 and 53 genotypes were found to be immune, resistant, moderately resistant, moderately susceptible, susceptible and highly susceptible categories respectively. Visible imaging coupled with machine learning models were also evaluated for Predicting yellow mosaic disease severity in Yardlong bean.



Fig. 2.24. Yardlong bean showing immune and highly susceptible reaction

Characterization of phytoplasma associated with lentil and chickpea phyllody

Phytoplasma diseases can cause severe yield losses in vegetable, oilseed, fruit and pulse crops. Floral virescence, phyllody and extensive proliferation of the branches in chickpea and lentil genotypes were observed at ICAR RCER, Patna experimental field during 2018-19. Samples from symptomatic plants were analysed for pathogen associated with the disease. The extracted DNA was used as template in nested PCR assay by utilizing primer pairs, P1/P7 and R16F2n/R16R2 for 16S rRNA gene. Blast analysis of sequences revealed that sequence was related with Candidatus Phytoplasma asteris related strain (16SrI-B). The 16S rRNA gene sequences from the symptomatic plants were deposited in GenBank.

Thirteen chickpea genotypes were screened against chickpea phyllody under irrigated and rainfed conditions with heat stress. Genotypes varied in their response against the disease. Most of the genotypes viz. Pusa 256, Pusa 547, Pusa 372, DBGC 3, Pusa 1103, Pusa 3043, DBGC4 and GNG1581 were showing resistance under irrigated as well as rainfed conditions, however genotypes ICC 4958 and JG 14 were highly resistant to phyllody under both the conditions. DBGC 1, DBGC 2 and KWR 108 were moderately susceptible under irrigated conditions. Samples from periwinkle plants showing extensive proliferation symptoms were also studied and it was found that same group of phytoplasma was associated with periwinkle plant which indicates that periwinkle plant may serve as off season reservoir of phytoplasma.



Fig. 2.25. Phyllody and extensive proliferation of the branches in chickpea, lentil and periwinkle

Management and false smut using alteration in sowing date

Rice false smut has long been considered a minor disease, but recently it occurred frequently and emerged as a major disease in rice production. Management of false smut through modification in sowing date may serve as ecofriendly, economical and effective method for disease management. In this regard an experiment was conducted during 2022-2024 with six rice genotypes viz., IR11F195, IR09L 342, Moudhamini, Swarna Shreya and Swarna Samridhi and Swarna which were sown at five different dates starting from 21 may at 15 days interval each. Disease severity for different date of sowing in the all the rice genotypes were recorded. Disease incidence for false smut was different for all the five genotypes with maximum in Moudhamini. Low false smut severity was observed in timely sown condition without significant yield reduction.

Screening of chickpea genotypes against root rot incidence

Root rot is a major problem in chickpea in eastern India. Twelve varieties of chickpea were screened for root rot incidence under irrigated and rainfed conditions. None of the genotypes were resistant to root rot and variable degree of disease incidence could be observed. Overall, high incidence of root rot was observed under irrigated condition (41.65%) as compared to rainfed conditions (35.15%). Under irrigated condition, root rot incidence varied from 26.2 % to 54.1% while under rainfed conditions it was from 22.1% to 49.6%. Highest disease incidence was observed in ICC 4958 (52.8%) and Pusa 547 (49.6%) under irrigated and rainfed conditions, respectively.

Microbial interventions for arsenic management in paddy

Arsenic (As) is a toxic metalloid that affects around 200 million people globally. Exploration of arsenic resistant plant growth-promoting rhizobacteria (PGPR) is an environment-friendly approach that holds promise for both plant growth promotion and arsenic amelioration in food grains. Indigenous arsenic resistant PGPRs were isolated from arsenic contaminated regions of Bihar and West Bengal for arsenic management in paddy. Five isolates have been characterized for plant growth promoting potential and taxonomically identified through complete 16S rRNA gene sequencing. The whole-genome sequencing (WGS) of these isolated are also being performed for their complete characterization. Moreover, high-yielding paddy varieties (HYPVs) are more sensitive to As accumulation in grains and their rhizosphere microbiome is

not well studied in the middle Indo-Gangetic Plains of Bihar. The Rhizosphere microbiome of three inbreed paddy varieties (MTU7029, IR64, and BPT5204) and one hybrid variety (Arize 6444 Gold) grown in arsenic-contaminated middle IGP was studied through metagenomics. Overall taxonomic analysis revealed that Proteobacteria (16.3-23.6%), Chloroflexi (13.9-22.6%), Actinobacteriota (3.7-16.6%), Acidobacteriota (6.5-11.8%), Bacteroidota (6.3-12.3%), Patescibacteria (2.4-10.3%), Verrucomicrobiota (1.7-7.3%), Planctomycetota (2.6-7.7%), and Firmicutes (0.8-8.7%) were dominant bacterial phyla, which together constituted 84.5-88.1% of the bacterial phyla in HYPVs. Gammaproteobacteria (10.8-15.9%), Anaerolineae (4.7-18.1%), Alphaproteobacteria (4.8-11.3%), Bacteroidia (4.7-9.6%), Actinobacteria (1.1-8.0%) and Verrucomicrobiae (1.4-7.1%) were dominant bacterial classes.

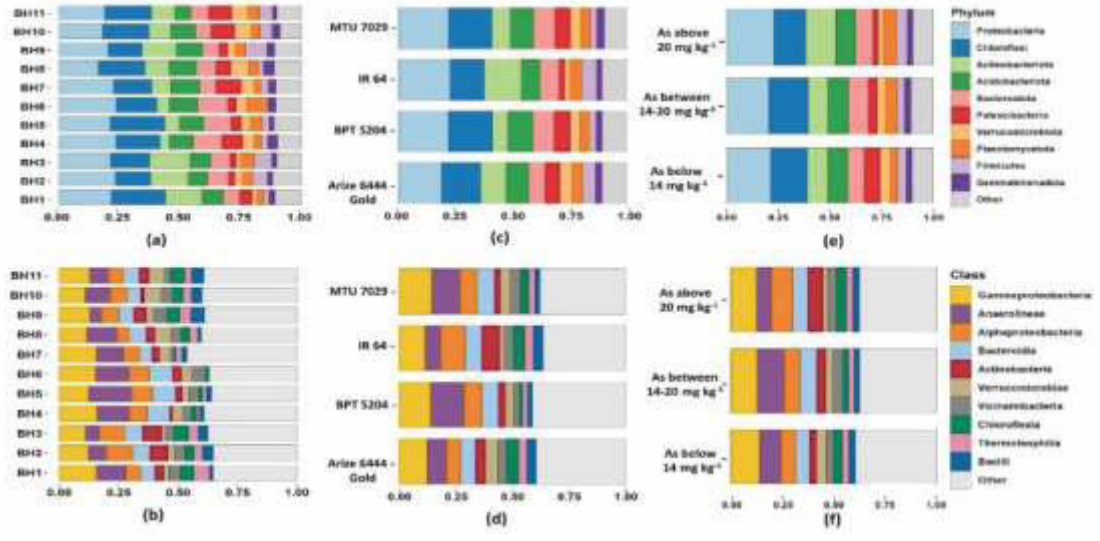

Fig. 2.26.Microbial community composition at HYPVs rhizosphere, (a) and (d): relative abundance at phylum and class level in different sites (BH1-BH11), respectively; (b) and (e): relative abundance at phylum and class level in different HYPVs, respectively; (c) and (f): relative abundance at phylum and class level in different soil arsenic levels, respectively.

Evaluation of rice and wheat genotypes for natural farming condition

Evaluation of rice and wheat genotypes under natural farming condition has been initiated during 2023. In first year, 60 rice and 27 wheat genotypes were evaluated with objective to identify high yielding genotypes (rice & wheat) suitable for natural farming condition. The average grain yield of 3.15 t/ha (1.788-4.313 t/ha) and 2.087 t/ha (1.35-3.19 t/ha) of rice and wheat experiments, respectively. Promising rice



Fig. 2.27. Evaluation of rice genotypes under natural farming

(Swarna Purvi Dhan 2, IR 14L 362, Swarna Shreya, IR 95781-15-1-1-4, IR 97030-7-2-2-2) and wheat (HD 2046, PBW 826, HD 3386, DBW 222, HD 2987) genotypes have been identified.

Crop improvement in finger millet for eastern India

Finger millet is an important nutricereal having great promises for small and marginal farmers of dryland areas in eastern India. In order to identify suitable genotypes of finger millet, one hundred forty-two accessions of finger millets obtained from ICRISAT, Hyderabad were evaluated for grain yield other traits. Initially, the genotypes IE667 (4.30 t/ha), IE546 (3.33 t/ha), IE 224 (2.80 t/ha) are found promising for seed yield. In collaboration with ICAR-IIMR, Hyderabad, another 46 improved varieties of finger millets have also been evaluated among which the genotypes R-23-3035 (3.06 t/ha), R-23-3054 (2.50 t/ha), R-23-3052 (2.49 t/ha), R23-3044 (2.04 t/ha) and R-23-3064 (1.97 t/ha) have been found to be promising. These entries will be further evaluated to ascertain their worth.

Enhancing the potential of grass pea as a nutritious green leafy vegetable

A new initiative was started as to explore the potential of Grass Pea as a nutritious green leafy vegetable, particularly for drought-prone rice fallow systems. The project focuses on two key aspects: first, the characterization of diverse Grass Pea lines to evaluate BOAA (β-N-OxalylL-α,β-diaminopropionic acid) content in leaves, For this eighteen lines has been evaluated for horticultural important leafy traits. Second, a comprehensive nutritional profiling of these lines will be conducted to assess their suitability as green leafy vegetables, emphasizing their contribution to food security and sustainability in water-scarce regions.



Fig. 2.28. Evaluation of Grass Pea

Rainout shelter facility

A Rainout shelter at ICAR-RCER was set up in 2023 with objective to evaluating advanced breeding lines as well as released varieties of cereals and other crops under controlled water stress (drought) condition. It creates controlled conditions that allow researchers to accurately simulate drought while comparing crop responses under stressed and irrigated scenarios. This setup enables a detailed understanding of how different growth stages-pre-flowering, flowering, and grain filling react to drought stress.



Fig. 2.29. Evaluation of rice genotypes for multi-stages drought tolerance under rainout shelter

Vertical farming above IFS pond banks

In October 2023, a vertical farming initiative was taken above pond banks to maximize space and enhance crop productivity. This approach of vertical intensification, allows for efficient use of vertical space while benefiting from the proximity to water resources. The first crop cultivated was Lablab bean during the rabi season, chosen for its resilience and ability to enrich soil through nitrogen fixation. Following this, Bottle gourd was planted in the summer, utilizing the vertical structure to support its climbing vines and ensuring optimal growth. This method offers several advantages, including space efficiency, effective water management, improved soil health through crop rotation, and sustainable practices.



Establishment of horticulture planting materials production unit

Horticulture planting materials production unit established in 2024 with objective to improve the availability of high-quality planting materials for farmers in Bihar. The unit is designed to address challenges related to the timely supply of reliable and affordable planting materials, which are critical for improving crop productivity and ensuring sustainable agricultural practices. The unit specializes in producing a diverse range of planting materials tailored for early and off-season cultivation. It includes vegetable seedlings such as sponge gourd (Luffa cylindrica), bottle gourd (Lagenaria siceraria), tomato (Solanum lycopersicum), cabbage (Brassica oleracea var. capitata), and cauliflower (Brassica oleracea var. botrytis) etc. Additionally, fruit saplings like lemon (Citrus limon) and bael (Aegle marmelos), along with various tree saplings, are propagated and distributed. These planting materials are supplied to farmers, research institutions, and other stakeholders to enhance horticultural productivity and ensure access to superior genetic resources.

Development of agroforestry models for seasonally water logged agro-ecosystem

To restore and promote the efficient use of natural resources in waterlogged areas, an agroforestry intervention was initiated in July 2023. A total of 288 saplings, including 72 each of Arjun, Mahogany, Kadamb, and Jamun, were planted over a one-hectare area at the Sabajpura farm of the institute. The experiment was laid out in a Randomized Block Design (RBD) with nine treatments, replicated thrice, including sole tree planting, trees with intercrops (rice and lentil), and sole cropping. The trees were planted at a spacing of 8m x 4m, with a plot size of 32m x 12m, accommodating 12 trees per plot. In the initial phase, the plantation has been successfully established, and the intercropping experiment is currently ongoing.



Fig. 2.31. Agroforestry for restoring seasonally waterlogged areas

Development of Nutri-cum-kitchen garden for small farm holders

A Nutri-cum- kitchen garden model for an area of 50 m2 was established in which seasonal vegetables and condiments were grown annually viz. Kharif: cucumber, bottle gourd, brinjal, red spinach etc.; Rabi: spinach, radish, mustard sag, turnip, carrot, broccoli, coriander, fenugreek, fennel, cumin, garlic and Summer: bottle gourd, bitter gourd, red spinach, onion, bhindi etc. The developed Nutri- garden is able to support a family size of 5-6 and also provided an income of ₹ 3,300/- per annum. This Nutricum- kitchen garden model is helpful for the poor family who can't afford to buy vegetables on regular basis by providing fresh green vegetables.



Fig. 2.32. Nutri-cum kitchen garden

Pilot Project on Crop diversification

Rice- wheat is the dominant cropping system of whole eastern India which is now became less profitable due to many reasons viz: small land





Fig. 3.33. Maize crop Fig. 3.34. Soybean intercropped with maize

holding, diminishing rain fall and lack of assured irrigation, unavailability of labour etc. Since rice is high water demanding crop and due to diminishing patter of rainfall from past 10 years now it is difficult to grow rice in a large area of East and West Champaran districts of Bihar and there is need to diversify the cropping system with some other alternate crops having lesser water requirement viz. soybean, maize, pigeon pea, ragi, turmeric etc. Keeping above points in view, a programme named "Pilot Project on Crop Diversification", funded by The Ministry of Agriculture and Farmers' Welfare, New Delhi was initiated and implemented since 2023 in 200 ha of land with an objective to replace rice with some other high value crops with less water demand. For, this 4 nos. of capacity building programmes were conducted for the farmers and Agril. Extension Functionaries in both the districts in which 105 no. of farmers and 45 nos. of Agril. Extension Functionaries were trained for carrying out crop diversification programme in their respective areas and Crops like maize, pigeon pea, ragi and soybean were grown in the rice fields (100 ha) in the farmers' fields of Baikunthawa, Rulhi, Sanbaria and Dubauliya clusters of Bettiah district in West Champaran. The performance of all the alternate crops were found excellent and it was observed that after diversification, the production was increased by 46 percent, income enhanced by 116 percent with a B:C ratio of 2.3 over the rice crop during kharif season. The diversified system has curtailed the water requirement by 38-46 percent and WUE increased by 50-58 percent over the rice crop. Farmers of the area were satisfied with the interventions and ready to carry out this diversification programme in continuation.

Village-level Carbon Budgeting through Climate Resilient interventions

Villages are the focal centers for altering the country's growth trajectory and achieving Viksit Bharat by 2050. Promotion of agroecological methods in agriculture is critical in building a roadmap for rural empowerment with guaranteed sustainability goals. Agriculture is the backbone of Bihar's economy, with 79% of the state's population engaged in agricultural activities, which exceeds the national average (NitiAayog, 2021). India's Nationally Determined Contribution (2022) aims to follow a climate-friendly and greener route to reduce the emissions intensity of its GDP by 45 percent by 2030, compared to 2005 levels. As a result, the institute initiated a study on the impact of climate resilient agricultural practices in August 2024, with quantification in terms of greenhouse gas emissions (CO_2e) currently underway.

Weather-Based Agriculture Advisory System

A new project initiated for farmers in Bihar's Patna and Buxar districts to build a Weather Based Agriculture Advisory System, which would provide farmers with timely weather information and warnings. Progressive farmers, known as Mausam Mitras, were hired to help bridge the gap between services and the farming community. Awareness campaigns and field activities in Simra and Gopalpur villages emphasized the significance of these services in mitigating weather-related risks and improving decision making. A poll found that 100% of farmers needed weather forecasts, 95% needed irrigation assistance, 92% needed pest and disease control advice, and 90% wanted fertilizer recommendations. The collected data was digitized for study, and it influenced the creation of targeted alerts. This effort lays the way for resilient and sustainable agriculture, incorporating.

Technologies Developed

Development of climate resilient varieties

Eastern states account for 27.26 million ha rice area, out of which nearly 3.92 million ha rice area are prone to frequent floods/submergence and 4.28 mha are prone to drought. Rice productivity in these drought or submergence prone areas is low and unstable. Most of the current high-yielding varieties of rice grown in rainfed areas were bred for irrigated ecosystems and are they highly susceptible to drought or submergence situations as well as major biotic stresses. Keeping these facts in view, the rice breeding program was started in 2010 with the objective to develop rice varieties that are climate resilient suitable for the agroecology of Eastern India. Since inception of rice breeding programme at ICAR RCER, Patna, eleven climate resilient rice varieties (Swarna Shreya, Swarna Shakti Dhan, Swarna Samriddhi Dhan, Swarna Unnat Dhan, Swarna Sukha Dhan, Swarna Shusk Dhan, Swarna Purvi Dhan 1, Swarna Purvi Dhan 2, Swarna Purvi Dhan 3, Swarna Purvi Dhan 4 and Swarna Purvi Dhan 5) have been developed. Out of these varieties, Swarna Samriddhi Dhan is tolerant to multiple stress (drought and submergence). Most of these varieties are also suitable for water limited irrigated and DSR condition. The salient feature of these varieties is given below in a tabular form.



Fig. 3.35. Varietal evaluation under field conditions

Table 2.3. Characteristics and suitability areas of the varieties developed

Name of Rice varieties	Duration (Days)	Ecology/ Areas	Yield Potential (t/ha)	Year of release/ notified	Recommended states
Swarna Shreya	115-120	Aerobic	4.50-5.00	2016	Bihar, Chhattisgarh, & Madhya Pradesh
Swarna Shakti Dhan	115-120	Aerobic	4.50-5.00	2020	Bihar, Jharkhand, OD, Haryana. CH, Gujrat & MH
Swarna Samriddhi Dhan	135-140	Irrigated & rainfed shallow lowland	5.50-6.00	2021	Bihar
Swarna Unnat Dhan	115-120	Irrigated	5.00-5.50	2021	Bihar, Odisha, West Bengal, Madhya Pradesh and MH

Swarna Sukha Dhan	110-115	Rainfed upland to midland	4.00-4.50	2021	Jharkhand and Uttar Pradesh
Swarna Purvi Dhan 3	115-120	Irrigated ecology	5.00-5.50	2022	Bihar, U.P., Haryana, Rajasthan, MH
Swarna Shusk Dhan	110-115	Rainfed upland to midland	4.00-4.50	2023	Uttar Pradesh
Swarna Purvi Dhan 1	115-120	Aerobic	4.50-5.00	2023	Jharkhand
Swarna Purvi Dhan 2	115-120	Irrigated ecology	5.00-5.50	2023	Jharkhand
Swarna Purvi Dhan 4	115-120	Aerobic	4.50-5.00	2024	Bihar, JH, Haryana, & Gujarat
Swarna Purvi Dhan 5	110-115	Rainfed upland to midland	4.00-4.50	2024	Bihar, Jharkhand & West Bengal

Development of chick pea variety 'Swarna Lakshami (DBGC 3)'

The variety Swarna Lakshami (DBGC 3) has been recently notified [S.O. 1560 (E), Dated: March 26, 2024] for cultivation in the entire north east plain zone (NEPZ) comprising states of UP, Bihar, Jharkhand, WB and Assam. It has been derived from a cross, 'ICC 13124' × 'WR 315', following pedigree method of advancement of segregating generations. This variety derives desirable characteristics such as drought tolerance, earliness, seed size and high reproductive capacity from the genotype 'ICC 13124', whereas it owes its wilt resistant characteristic to its other parent 'WR 315'. These attributes make it suitable for planting under both rainfed as well as irrigated conditions. 'Swarna Lakshami' has shown an overall yield advantage of 26.90, 13.20 and 17.29 percents over 'PBG 9', 'BG 3043' and 'GNG 2207' (check varieties cultivated in the NEPZ), respectively. It provides 1.8-2.0 t/ha (with a potential yield of 2.8 t/h) under timely sown irrigated condition with recommended package of practices. Its mean days to 50% flowering (77 days) and maturity duration (129 days) are matching with the check variety 'BG 3043'. Double flowers/peduncle (double pods/peduncle) is the main diagnostic feature of this variety. It has an excellent grain color, size and shape, and is likely to fetch consumers' preference in the NEPZ. Its average 100-seed weight is 21.27 g. Seeds of the 'Swarna Lakshami' contain high protein content (20.86%), which is higher than that of most of the check varieties such as 'BG 3043', 'GNG 2207' and 'GCP 105'. Its seeds are significantly superior in Zn content (46.25 ppm) to all the checks. The Fe content (53.6 ppm) of seeds is also comparable to most of the check varieties (BG 3043, GCP 105 and KPG 59). It is resistant to wilt and moderately resistant to dry root rot and collar rot. The variety is tolerant to heat stress, and provides satisfactory yield (>1.5 t/ha) in late sown condition. In addition, it has shown higher Percentage Dal Recovery and Recovery Ratio than most of the check varieties.



Fig. 2.36. Swarn Lakshmi under field conditions

Teaching, Extension and Capacity Building

Teaching and research guidance

Currently, 38 undergraduate students (BSc Agriculture Hons), 2 postgraduate students, and 6 PhD students (3 in Soil and Water Conservation Engineering and 3 in Agronomy) are pursuing their studies at the IARI Patna Hub. The Division of Crop Research has also provided internship and hands-on training to 63 students across various research areas (Fig. 4.36). Additionally, two students from AN College, Patna, completed their M.Sc. dissertations in microbiology (2022–24), while one student from Central University of Haryana and one from CCSU, Meerut, are currently working on their M.Sc. dissertations in microbiology and plant pathology, respectively.

The scientists of the Division of Crop Research (DCR) teach 16 courses, covering a wide range of subjects including crop physiology, genetics, agronomy, plant breeding, microbiology, biotechnology, and sustainable farming practices. These courses include both fundamental subjects and skill enhancement programs, such as Seed Production and Testing Technology and Mushroom Production Technology, designed to enhance students' practical knowledge and employability.

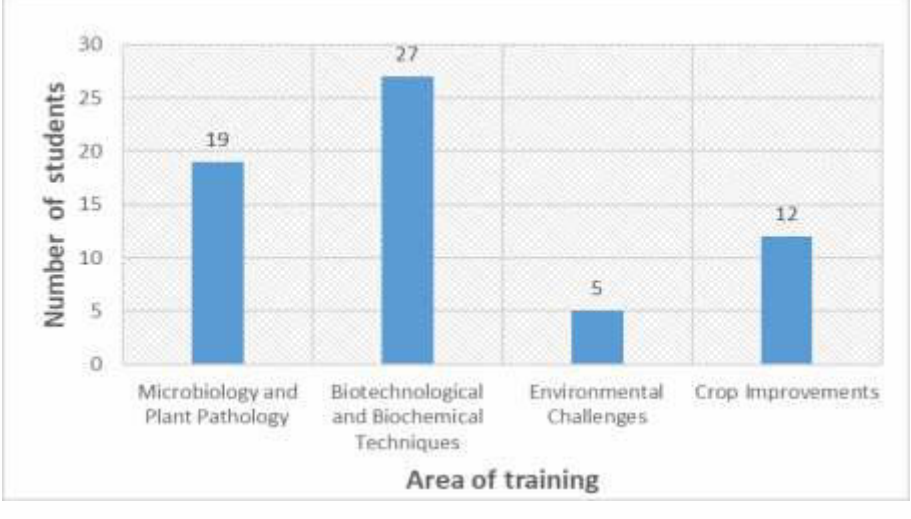

Fig. 2.37. Area of internship/hands on training and number of students attended.

Technology dissemination

High yielding Climate Resilient Rice Varieties

The Division of Crop Research has successfully promoted climate-resilient rice varieties across Bihar, Jharkhand, and other eastern states through on-farm trials and demonstrations. Between 2017 and 2024, ICAR-RCER, Patna conducted FLDs on nine rice varieties across 586 farmers' fields (including 89 women farmers), covering 219.8 hectares. The demonstrated varieties showed a yield advantage of 8.3% to 27.1% over local checks, with early maturity, high yield potential, good grain quality, and tolerance to drought and pests. Farmers expressed high satisfaction, highlighting the potential of these varieties in addressing water scarcity and improving farm incomes.



Fig. 2.38. Performance of climate resilient rice varieties in Farmers Field

Adoption/impact of the technologies

Out of 11 climate-resilient rice varieties, 9 varieties are under active seed chain programme and cover more than 4 lakh hectare rice area in eastern India. More than 900 quintals of quality seed of these rice varieties have been produced and provided to central and state government agencies, KVKs, NGO and farmers as per their demand and indent. Additionally, approximately 140 tons of seed of these varieties were also produced by the FPO-based seed production model and supplied to the farmers. These varieties are performing well in the states of Bihar, Jharkhand, Uttar Pradesh, Odisha, Telangana, Madhya Pradesh, Chhattisgarh, and West Bengal.



Fig. 2.39. Adoption of the rice varieties developed by ICAR RCER, Patna

Climate-Resilient Villages under CRA in Bihar

Under the Jal-Jeevan-Haryali Program, ICAR-RCER, Patna developed 10 ClimateResilient Villages (CRVs) in Gaya and Buxar districts in collaboration with the Government of Bihar. Between 2019 and 2020, 145 acres in three villages were cultivated with zero tillage (ZT) wheat and lentil, benefiting 138 farmers. Following its success, the program was expanded statewide, covering 618 acres across five villages in Buxar and benefiting 883 farmers with improved wheat, chickpea, lentil, and mustard varieties. Additionally, two climate smart model villages were established in Jharkhand and Chhattisgarh, while in Patna, conservation agriculture practices were adopted over 90 acres, and wheat seed production was facilitated under the Seed Village Scheme. Farmers also formed the Patliputra Farmers Producer Company Limited to strengthen seed production initiatives. The project demonstrated resource conservation technologies (RCTs), emphasizing soil testing, expert guidance, and climate-resilient seed distribution, significantly improving crop yields and climate adaptation strategies.



Fig. 2.40. Components of CRA in Bihar

Zero-Tillage technology

Under the CRA project, key climate-resilient technologies were demonstrated to enhance productivity and sustainability. In Gaya (2020), Zero-Tillage (ZT) wheat and lentil were introduced on 144.5 acres, yielding 4.15 t/ha wheat (18% higher than conventional methods) with ₹51,476/ha net returns (50% higher). ZT mung was demonstrated on 45 acres, achieving 0.85 t/ha yield (16% higher) and ₹33,200/ha net returns (36% higher). Additionally, climate resilient cropping systems (rice, maize, pigeonpea, bajra) were introduced on 170 hectares, benefiting 220 farmers. Encouraged by these results, the program was expanded to Buxar in rabi 2020, covering 618 acres across five villages, benefiting 849 farmers through the distribution of quality seeds of wheat, chickpea, lentil, and mustard.

Conservation Agriculture

Extension activities under Conservation Agriculture (CA) practices were carried out in Chene (Jharkhand) and Kondora (Chhattisgarh) from 2019–21, demonstrating Zero-Tillage (ZT) rice and winter cropping systems. The adoption of ZT direct-seeded rice (ZTDSR) with mulch significantly increased summer crop yields (28.7%). In the Eastern Indo-Gangetic Plains, ZT based crop rotations improved wheat and rice yields while enhancing soil health and reducing greenhouse gas emissions. These technologies have been adopted over 2.5 lakh hectares, with potential expansion to 50% of wheat-growing areas by 2030. Resource conservation technologies (RCTs), including short-duration rice varieties, ZT-seeding of winter crops, and farm ponds, successfully addressed soil moisture and biotic constraints, improving productivity and profitability.



Fig. 2.41. Advancements in Conservation Agriculture Practice

Integrated Farming Systems models

The developed IFS models have been accepted by Govt. of Bihar and these 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 (increased income by 87-352 percent). Till date 52 acres of waste and unutilized lands has been made productive though IFS

approach. Food and nutritional security of small and marginal farmers have been strengthened with these IFS models.



Fig. 2.42. IFS models established at Farmers Field

Table 2.4. Climate resilient IFS models at farmers' fields

IFS model	Components	Area	System Income (Av.)	Income (Rice-Wheat)	Fert. Saving (%)	Add. emp. over R-W system	Location
Vegetable-based	Veg. + Backyard fish/duck + goat	2000m^2 (1/2 acre)	52,000-58,000	15,000-18000	24.5	56	Chakramdas Vaishali
Livestock-based	F. Crops + Hort.+ goat + Poultry + mushroom	4000m^2	80,000-1,10,000	30,000-35,000	22.7	135	ICAR-RCER, Patna &. Nalanda dist.
Pond- based (lowland)	F. Crops + Hort.+ Cows + Fish/duck	8000m^2	1,50,000-2,18,000	60,000-70,000	28.4	234	ICAR-RCER, Patna & Nalanda
Pond-based (Flood prone)	F. Crops + Hort. + Fish/duck	8000m^2	1,28,000-1,48,000	42,000-50,000	16.5	148	Motihari

Nutri-Garden

Nutri-Garden initiative in Chotka Dhakaich, Buxar, Bihar aimed to address the food and nutritional security through community-driven vegetable cultivation. Using PRA tools, gaps in dietary diversity and agricultural practices were identified. Nutri-garden kits containing seeds for 14 nutrient-rich vegetables like spinach (iron, 5.65 kg yield), cauliflower (vitamin C, 10 kg),

and tomato (vitamin C, 7 kg) were distributed to 26 families. These gardens provided fresh, diverse vegetables, significantly improving nutrition, especially for women and children. Households reduced their dependence on market vegetables, saving 20-30% of monthly food costs.



Fig. 2.43. Nutri Garden models established at farmers Field

Agroforestry for farmers livelihood improvement

A participatory agroforestry trial (2017–2020) in Motihari, Bihar demonstrated the benefits of the Mango + Turmeric system in improving farmers' livelihoods. Over four years, the system enhanced soil fertility, moisture retention, and microclimate, leading to an increase in turmeric yield from 7.53 t/ha (2017-18) to 8.24 t/ha (2020-21). It also achieved the highest Rice Equivalent Yield (REY) of 27.47 t/ha by 2020-21.

This successful model is now being promoted for wider adoption to enhance productivity and farmer income.



Fig. 2.44. Agroforestry interventions in farmers' fields

Participatory lac cultivation

Scientific lac cultivation trials in Banka, Bihar significantly improved lac production and farmer participation. Yields increased from 76 kg (2023) with 25 palas trees to 340 kg (2024) with 200 trees, demonstrating the success of collective efforts and adaptive farming practices. The initiative expanded to four villages, equipping farmers with technical skills to tackle environmental challenges while boosting income. This model has proven effective in enhancing agricultural productivity and promoting sustainable farming in the region.



Fig. 2.45. Participatory Lac Cultivation trials at farmer's field

Quality seed production

The division is producing quality seed of various classes (Breeder seed, Foundation seed, certified seed and TL seeds) of our own varieties of rice (Swarna Shreya, Swarna Shakti Dhan, Swarna Samriddhi Dhan, Swarna Unnat Dhan, Swarna Sukha Dhan, Swarna Shusk Dhan,Swarna Purvi Dhan 1, Swarna Purvi Dhan 2, Swarna Purvi Dhan 3, Swarna Purvi Dhan 4 and Swarna Purvi Dhan 5), and recently released wheat varieties (HD 2967, DBW 187, DBW 303, DBW 222). After establishment of two pulse seed hubs, one each at ICAR RCER, Patna and KVK Buxar, under the NFSM funded project "Creation of Seed hubs for increasing indigenous production of pulses in India", the pulse seed production programme has been going on. Under the aegis of these two pulse seed hubs, quality seed production of pulses varieties, viz., IPA 203, IPA 206 (Pigeonpea), Pusa 547, Pusa 3043, GNG 2207, GNG 2299 (Desi chickpea), Shubra (Kabuli chickpea), HUL 57, IPL 220, IPL 306, Pusa Ageti lentil (Lentil), Samrat, Virat, IPM 2-3, IPM 2-14 etc. (Mungbean), HUDP 15 and DFP-1 (Field pea) have been produced.

Table 2.5. Quality seed production of different crops

Year	Quantity (in ton)		
	Rice	Pulses	Wheat
2017-2018	1.65	57.12	----
2018-2019	2.25	54.52	----
2019-2020	6.15	36.18	----
2020-2021	10.0	18.49	11.0
2021-2022	17.70	36.3	9.5
2022-2023	28.18	44.46	12.0
2023-2024	14.88	37.6	10.0
2024-2025	16.90	Being produced	Being produced
Total	**97.71**	**284.67**	**42.50**

Capacity building

Training Program Organized for various stakeholders

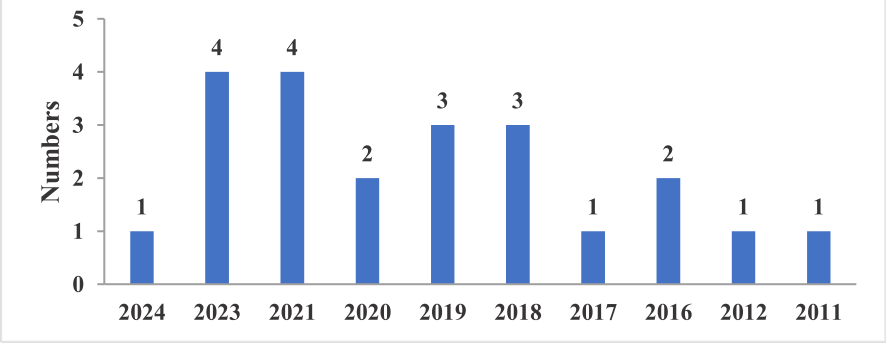

Fig. 2.46. Number of training programs organised

Foreign Deputation and Training

Table 2.6 Details of the foreign visits undertaken by the Scientists of the division

S. No.	Name of scientist	Place/Institute/ country vistied	Research aspect	Duration
1.	Dr. Rachana Dubey	International Rice Research Institute (IRRI), Phillipines	GHG Emissions in Rice Systems	25/11/2024 to 29/11/2024
2	Dr. Saurabh Kumar	Ankara and Eskisehir, Turke	Soil and Root Health	31/03/2024 to 05/04/2024
3	Dr. Rakesh Kumar	CIMMYT, Texaco, Mexico	Innovation in Agri-food Systems	22/11/2023 to 29/11/2023
4	Dr. Santosh Kumar	International Rice Research Institute (IRRI), Los Banos, Phillipines	Drought tolerant and drought susceptible genotypes	24/05/2019 to 05/06/2019
5	Dr. Santosh Kumar	Bangkok, Thailand	4th International Rice Congress	27/10/2014 to 01/11/ 2014
6	Dr. Sanjeev Kumar	International Rice Research Institute (IRRI), Phillipines	Experimental Design and Data analysis	02/02/2014 to - 07/02/2014
7	Dr. Santosh Kumar	International Rice Research Institute (IRRI), Philippines	7th International rice genetics symposium	05/11/2013 to - 08/11/2013
8	Dr. Santosh Kumar	Kathmandu, Nepal	Stress tolerant rice varieties in South Asia	24/07/2013 to 26/07/2013
9	Dr. Santosh Kumar	International Rice Research Institute (IRRI), Phillipines	Marker assisted breeding for drought tolerance	02/09/2012 to 09/09/2012
10	Dr. Santosh Kumar	International Rice Research Institute (IRRI), Phillipines	Abiotic stresses in rice	27/10/2011 to 11/11/2011

Conferences/Seminars/Workshops/Symposia Organized

Table 2.7 Number of trainings and seminar symposia organised and attended

S.N.	Events	Number
1.	Training and Workshops Organized	>75
2.	Training attended by DCR Scientists	>83
3.	Participation in Conferences/Seminars/Workshops/ Symposia	>286

Events Organized/Attended

Table 2.8 outlines the involvement of DCR scientists in organizing and participating in various national and international scientific events. The events included workshops, seminars, and webinars on diverse topics such as rice-fallow management, sustainability, greenhouse gas emission assessment, and integrated farming systems, with durations ranging from 1 to 7 days across different years.

Table 2.8 Important events organized by the division

S.N.	National Conference/Workshop	Org. Sec.	Year	Duration (days)
1.	Workshop on Rice Fallow	Rakesh Kumar	2025	02
2.	National Conclave on Sustainability-Production and Green Growth	Santosh Kumar	2024	01
3.	DST SERB *Karyashala* on "Advanced Instrumentation for Assessment of Greenhouse Gas Emission and Molecular Techniques in Microbial Diversity Analysis"	Rachana Dubey	2023	07
4.	National Seminar on Rice- fallow management in eastern India	Rakesh Kumar	2021	01
5.	Integrated Farming Systems: A Tool for Enhancing Income and Nutritional Security	Sanjeev Kumar	2021	03
6.	National Webinar on Crop Diversification: A way towards Nutritional Security	Shivani	2021	01
7.	International Training cum Workshop on "Quantitative farming systems typologies applications with the R statistical computing software	Sanjeev Kumar	2018	03
8.	Workshop on AICRP on IFS	Sanjeev Kumar	2014	01

Awards, Honours and Peer Recognitions

- Dr. Sanjeev Kumar received Rajiv Gandhi National Award from the President of India for book titled "Samekit Krishi Pranali ek Vrihad Drishtikon" on 14 September, 2015 at "Vigyan Bhawan, New Delhi.
- Dr. Rakesh Kumar awarded "ICAR-Fakhruddin Ali Ahmad Award 2015" for Outstanding Research in Tribal Farming System on 16 July 2016 in New Delhi.
- Dr. Sanjeev Kumar received 'Best Centre Award' for AICRP on IFS at ICAR-RCER, Patna during V Biennial Workshop on AICRPIFS at UAS, Bengaluru Sept. 20-23, Dec, 2018.
- Dr. Rachana Dubey: Awarded "Early Career Research Award- 2019" from DST- SERB with research grant of ₹ 43 lakh.
- Dr. Rakesh Kumar received "NAAS Associateship 2022" by the National Academy of Agricultural Sciences (NAAS), New Delhi, India.
- Dr. Saurabh Kumar: Awarded "Startup Research Grant- 2021" from DST- SERB with research grant of ₹ 30 lakh.



Dr. Sanjeev Kumar receiving Rajeev Gandhi Gyan-Vigyan Puraskar



Dr. Sanjeev Kumar receiving Best Centre Award (IFS)



Dr. Sanjeev Kumar receiving ISA Fellow Award



Dr. Rakesh Kumar receiving NAAS Associates 2022 award



Dr. Rakesh Kumar receiving NAAS Associates 2022 award

Publications

The division published more than 225 research and review articles in reputed international and national journals including some high impact factor journals like Journal of Cleaner Production, Agronomy for Sustainable Development, Journal of Experiment Botany, Field Crops Research, Environmental and Experimental Botany and Journal of Hazardous Materials. In addition to this DCR has also published 11 books, >102 Book Chapters, 10 Bulletins, 5 Training Manuals and > 200 Extension Folders.

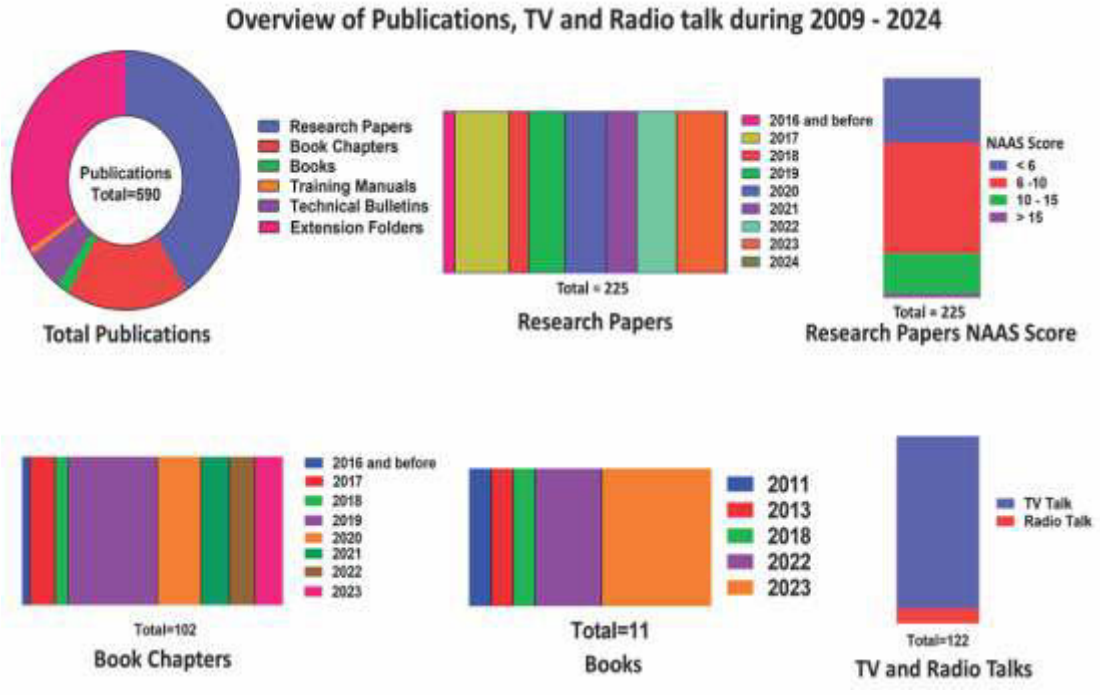

Fig. 2.47. Overview of publication of the DCR division

Future Research Thrust

- Biointensive insect-pest management in major crops of Eastern India, including the use of artificial intelligence for timely detection of plant diseases.
- Quantification of greenhouse gases in major cropping systems/farming systems of the Eastern Gangetic Plains.
- Development of climate-resilient crop varieties.
- Screening of germplasms of different crops for biotic stresses and development of disease management strategies.
- Development and scaling up of Integrated Farming System (IFS) models and Nutrigarden initiatives for small and marginal farmers, especially in malnutrition-affected areas of Bihar

Sustaining the Future: Advances in Land and Water Resource Management

Ashutosh Upadhyaya, Arti Kumari, Bikash Sarkar, A K Singh, Pawan Jeet, P K Sundaram, Kirti Saurabh, Ved Prakash, Akram Ahmed, Sonaka Ghosh, Ajay Kumar, Shivani, Manibhushan
Division of Land and Water Management

Background

Recognizing the need for integrated research, the ICAR Research Complex for Eastern Region (ICAR RCER), Patna, was restructured in 2001, giving birth to a specialized research wing dedicated to the sustainable management of land and water resources. On April 1, 2001, the Directorate of Water Management Research underwent a significant evolution, emerging as the Land, Water, and Environment Engineering Research Programme (LWEERP). This transformation was more than a change of name-it was a bold new direction, broadening its focus from traditional water management to a holistic approach that encompassed land conservation, environmental sustainability, and innovative agricultural engineering.

At the helm of this newly envisioned program was Dr. R D Singh, a visionary leader appointed as its first Head. His tenure, though brief (April 1, 2001 – April 11, 2002), was foundational in shaping the program's identity. Dr. Singh ensured that research expanded beyond irrigation technologies, embracing a more integrated approach where agricultural productivity coexisted with ecological stewardship. With the baton passing to Dr. R.K. Batta on April 12, 2002, the program gained a new momentum. Over the next seven years (2002 – 2009), Dr. Batta steered research toward critical areas such as water conservation, soil health, and sustainable farming practices. His leadership saw the program becoming a hub for solutions in climate-resilient agriculture and land restoration.

A defining moment arrived on January 5, 2009, when the program was renamed the Division of Land and Water Management. This new identity reflected a sharper focus on addressing agricultural sustainability, water conservation, and integrated resource management—an essential pivot in an era of climate uncertainty. The first to lead the Division under its new name was Dr. Janardan Jee, who took charge in July 2009. Though his time at the helm was brief (July 28 – October 22, 2009), his role in ensuring a seamless transition was invaluable. Then came a period of significant expansion under Dr. Ashutosh Upadhyaya, who led the Division from October 23, 2009, to June 24, 2015. His tenure was marked by groundbreaking research that blended modern technologies with traditional knowledge, enhancing both productivity and sustainability. The Division flourished, establishing itself as a center of excellence in land and water management.

A series of transitions followed, each leader contributing to the Division's growing legacy. Dr. J S Mishra (June 25, 2015 – February 28, 2016) ensured research continuity and farmer oriented solutions, while Dr. R K Singh (February 29, 2016 – August 12, 2016) emphasized water-use efficiency and land conservation. Dr. S K Singh (August 13, 2016 – December 31, 2019) led efforts to combat water scarcity and soil degradation, reinforcing the Division's role as a frontrunner in tackling environmental challenges. The journey came full circle when Dr. Ashutosh Upadhyaya returned as Acting Head in January 2020, eventually assuming formal

leadership on June 14, 2023. With a renewed vision, he continues to steer the division toward sustainable resource management, cutting-edge research, and farmer-centric innovations.

Since inception as a water management entity to its evolution into a pioneering Division tackling land, water, and environmental challenges, the division has continually expanded its mandate to address the pressing needs of modern agriculture. Through its expertise in watershed management, soil conservation, precision irrigation, and water resource planning, the Division has pioneered technology-driven solutions that have significantly enhanced water productivity and soil health. Its contributions to drought and flood mapping have provided crucial insights for climate resilience and disaster preparedness. Research on soil and nutrient dynamics has optimized fertilizer application strategies, improving both crop yield and soil fertility.

Table 3.1. Heads of the Division of Land and Water Management

Name	Designation	Tenure	
		From	To
Dr. Janardan Jee	Head (In-charge)	28/07/2009	22/10/2009
Dr. Ashutosh Upadhyaya	Head	23/10/2009	24/06/2015
Dr. J. S. Mishra	Head (In-charge)	25/06/2015	28/02/2016
Dr. R. K. Singh	Head	29/02/2016	12/08/2016
Dr. S. K. Singh	Head (In-charge)	13/08/2016	31/12/2019
Dr. Ashutosh Upadhyaya	Head (In-charge)	01/01/2020	13/06/2023
Dr. Ashutosh Upadhyaya	Head	14/06/2023	Present

Research Contributions

Analysis of climatic patterns in Patna

The institute has conducted an in-depth analysis of Patna's weather and climate, focusing on rainfall data from 2000 to 2024. The study found considerable seasonal and annual variability in rainfall, with the monsoon season being the primary source of precipitation. However, the intensity and distribution of rainfall during the monsoon vary significantly from year to year. Notably, extreme wet years such as 2007 (1464.2 mm) and 2020 (1045.1 mm) were contrasted by drier years like 2009 (504.4 mm) and 2015 (649.2 mm), highlighting the unpredictability of rainfall patterns (Fig. 3.1). These fluctuations are influenced by global climate phenomena such as El Niño and La Niña, along with regional atmospheric conditions, which have important implications for agriculture and water management.

The temperature analysis provided additional insights into the seasonal characteristics of Patna's subtropical climate. The minimum temperature (Tmin) is lowest in January (9.3°C) and gradually rises through February and March, reaching a peak of 26.9°C during the monsoon months. Maximum temperatures (Tmax) peak at 36.8°C in April, before the cooling effects of the monsoon set in, reducing Tmax to 33.2°C by July. The study also highlighted the significant diurnal temperature variation during the summer months, with large differences between daytime highs and nighttime lows, while the monsoon period saw less temperature variation

due to cloud cover and high humidity. These findings provide valuable data for understanding the region's seasonal shifts, which are crucial for agricultural planning, water resource management, and energy demand forecasting in Patna and the surrounding areas.

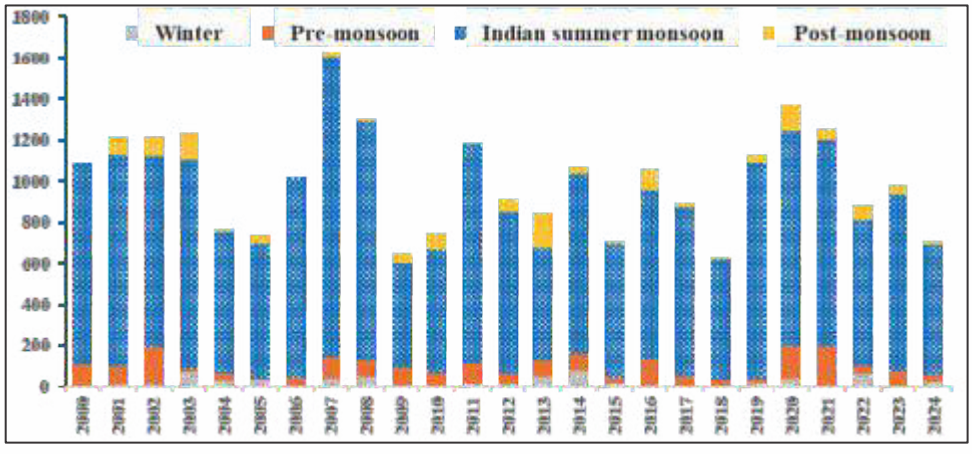

Fig. 3.1. Rainfall variability of Patna from 2000 to 2024

Impact of climate change on hydrological response

Notable progress in understanding the impacts of climate change on water resources has been made. A key achievement is research in the Brahmani-Baitarni basin in Odisha, covering 51,822 sq. km across Odisha (67%), Jharkhand (30%), and Chhattisgarh (3%). Under the ICAR Network Project on Climate Change, the study analysed long-term rainfall, temperature, and stream flow data. Rainfall analysis from 1884 to 2003 revealed a decline of 0.7 mm/year during the monsoon season. However, from 1974 to 2003, trends indicated an increase in summer rainfall by 2.9 mm/year, monsoon rainfall by 5.5 mm/year, and annual rainfall by 12.1 mm/year. Temperature trends showed warming, especially in July and August, with significant increases observed at Angul and Jashpurnagar. These findings suggest a shift in seasonal weather patterns, with implications for the region's water resources.

Modeling of hydrological impacts used the Modular Modeling System (MMS) and the Precipitation Runoff Modeling System (PRMS). The basin was divided into hydrologic response units (HRUs) based on terrain, soil, and vegetation characteristics. The results projected changes in stream flow patterns, which are critical for water resource planning. GIS-based delineation revealed that cultivated land makes up 70% of the basin area, while forests cover 28%. These insights are crucial for managing water resources under the influence of climate change. Furthermore, work extends to the Bhavani basin, where the IHACRES model projected an increase in annual stream flow by 2020, followed by a decline by 2050 under various emission scenarios, including A2a and B2a (Fig. 3.2). Seasonal patterns showed decreases in monsoon stream flow but increases during the pre-monsoon period, highlighting the need for adaptive strategies.

In addition to the Brahmani-Baitarni and Bhavani basins, DLWM also studied the impacts of climate change in Bihar for the years 2030 and 2050, using global climate models (GCMs) under scenarios like A2a, B2a, and RCPs. For Bihar, the projected increase inmaximum temperatures could reach 2.21°C by 2050. Rainfall variability, especially in February, showed reductions up to

51.90% under certain emission scenarios, which would significantly affect crop yields. For instance, rice yields in Patna could drop by 5.5% to 14.4% under the A2a scenario, with even higher reductions under B2a. These studies underline DLWM's pivotal role in providing valuable data and modelling tools to develop adaptive management strategies for climate change's impact on water resources and agriculture.

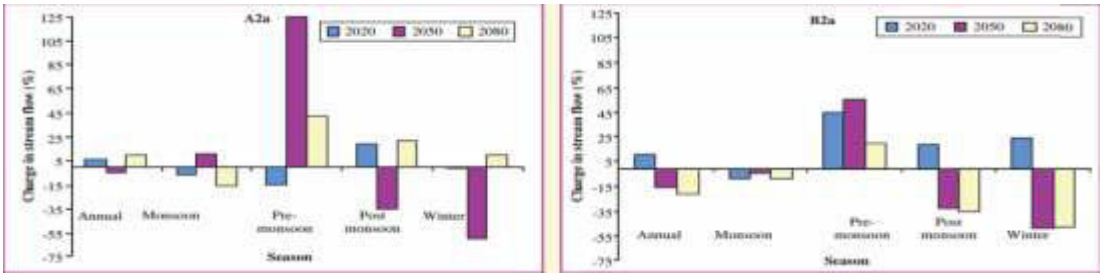

Fig. 3.2. Changes in seasonal and annual stream flow

Likewise, a study on climate change in Bihar was carried out to identify climate hazards and opportunities for 2030 and 2050 using baseline weather data and GCMs under RCP4.5 and RCP8.5 scenarios. Baseline annual rainfall ranged from 1092 mm (Sabour) to 1165 mm (Patna), with a mean of 1130 mm. Average annual Tmax ranged from 31.4°C (Sabour) to 31.9°C (Patna), with a mean of 31.7°C. Future projections indicate a 0.68–0.79°C rise in Tmax by 2030 and 1.59–2.21°C by 2050, depending on the emission scenario. Rice, wheat, and potato yields were simulated for three locations under RCP4.5 and RCP8.5 scenarios. Patna shows a minimum yield reduction of 5.5% to 14.4% from 2030 to 2050 under RCP4.5, with a higher reduction under RCP8.5. Wheat yields in Patna decrease slightly by 2030 under RCP4.5, while Sabour sees larger reductions of 11.2% to 28.2% from 2030 to 2050. The study projects a wheat yield decrease of 8.9% to 14.3% by 2030 and 7.6% to 28.2% by 2050 under both scenarios. Potato yields decrease similarly in Patna and Samastipur, while Sabour experiences minimal reductions.

Land use and land cover change assessment

A study was conducted for analyzing land use and land cover (LULC) changes in East and West Champaran districts of Bihar over 18 years using satellite imagery (LISS III and LANDSAT). The findings highlighted a notable increase in areas dedicated to rice, wheat, and maize cultivation from 2000 to 2018, indicating a growing demand for staple crops. This underscores the importance of spatial planning to optimize agricultural land use in the region. The classified LULC images of the districts (Fig. 3.3) visually demonstrate these changes.

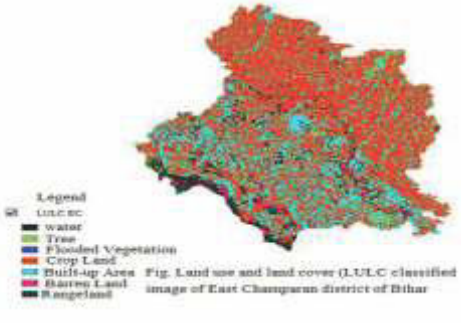

Fig. 3.3. Land use and land cover changes (2000 -2018) in East Champaran district of Bihar

Irrigation water pricing

Studies conducted at the Nalanda Corridor Project site and the Paliganj distributary aimed to determine the cost of irrigation water for various crops, including rice, wheat, and moong. The research used the Residual Value Method to estimate water prices, providing critical economic data for irrigation management. For the Nalanda Corridor, the estimated irrigation water prices were 12.96 ₹/m^3 for rice, 29.59 ₹/m^3 for wheat, and 9.02 ₹/m^3 for moong. In contrast, prices in the Paliganj distributary ranged from 4.73 ₹/m^3 to 6.24 ₹/m^3 for rice and wheat, depending on water applied. These findings are essential for developing water pricing policies and improving water-use efficiency in irrigation systems.

Integrated organic farming model

An integrated organic farming model was proposed for an acre plot to promote sustainable farming practices while enhancing farmer income and reducing environmental impacts. This model incorporated various components such as livestock, bio-gas production, vermi-compost, cereals, fodder crops, fruits, vegetables, floriculture, mushrooms, apiculture, and Azolla. By recycling by-products from one component to serve as inputs for others, the model-maintained soil health and reduced water pollution. Additionally, it demonstrated the potential for increased income through diversified farming practices, all while maintaining sustainability, improving soil and livestock health, and minimizing waste. The model highlights the benefits of organic farming as a holistic and economically viable approach.

Participatory land and water management (Learnings from DFID project)

The Division has achieved significant advancements in optimizing water use for agriculture through technical interventions. Conjunctive use of groundwater and canal water was promoted by optimizing rice transplanting time (25 June–15 July), leading to increased pumping hours and improved groundwater markets. Demonstrations showed that raising bund heights from 7.5–15 cm to 25–30 cm helped farmers store rainwater, reducing their dependence on canal irrigation by 1–2 applications while maintaining soil moisture for longer periods. Additionally, low-cost wooden gates installed at water outlets saved 25–30% of water and minimized waterlogging. Two SHGs and individual farmers at 7 locations diversified their use of water by growing fish in previously unused ponds and unutilized seasonally waterlogged areas. Following very limited demonstration and awareness building, these farmers experimented with rice–fish culture, and achieved a fish yield of 500–700 kg/ha (equivalent to 4–5 t/ha of paddy). This was harvested from the previously underutilized, water-congested areas and provided them with additional income. Approximately, 1.2 to–3.0 t/ha of fish was harvested from waterlogged areas or abandoned pits that were previously unused. The results of these interventions produced an overwhelming response and their benefits are beginning to spread through word-of-mouth. Villagers are enthusiastically taking up these interventions and about 20 farmers/groups are adopting them.

Assessed rainwater harvesting potential of Bihar

The study on rainwater harvesting (RWH) in Bihar assessed the potential for RWH systems to mitigate water scarcity, focusing on agricultural, domestic, and industrial uses. In Nalanda, a weighted sum approach was used to evaluate hydrological trends from 1985 to 2019. The study

found a decline in monsoon and post-monsoon rainfall, with an increase in pre-monsoon rainfall, underscoring the importance of capturing water during this period. Through an analysis of hydrological, morphometric, and other landscape features, the study identified areas where RWH interventions such as farm ponds, check dams, and conservation ditches should be prioritized. Results showed that 56.3% of the area was classified as very high priority for water management, 30.5% as high priority, and only 2–7% as low to very low priority (Fig. 3.4). This comprehensive assessment provided actionable insights, guiding the construction of RWH structures to enhance groundwater recharge and water security in the region.

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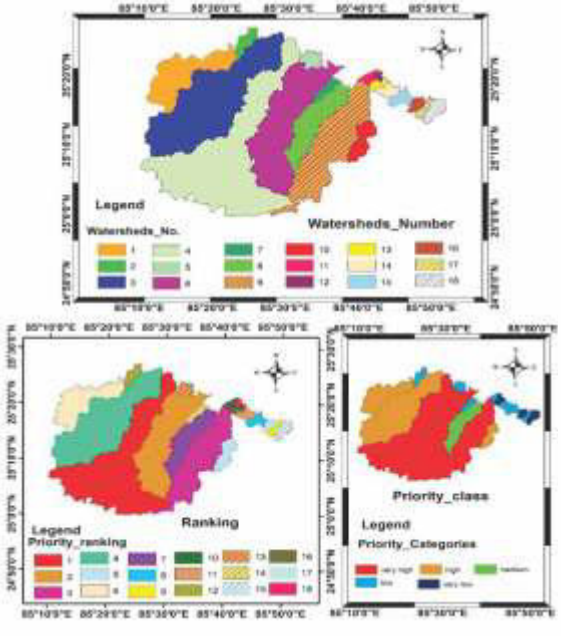

Fig. 3.4. Watersheds prioritization for water harvesting planning

Sustainable drought management in Sakri river basin

The study conducted in the Sakri River Basin provides a comprehensive drought management strategy that enhances agricultural productivity and water security in water-scarce regions. By analyzing climatic trends from 1991 to 2020, the study revealed an upward trend in rainfall but highlighted challenges posed by spatial and temporal rainfall variability and rising temperatures. This led to recommendations for drought-resistant crops, efficient irrigation systems, and soil conservation techniques. The study prioritized five sub-watersheds (SW3, SW5, SW6, SW8, and SW9) for targeted soil and water conservation measures (Fig. 3.5), covering nearly 47% of the basin area. Strategies proposed included constructing check dams, contour bunds, promoting agroforestry, and optimizing cropping patterns to enhance resilience and ensure sustainable water management. This data-driven approach to drought management in the Sakri River Basin has not only addressed the immediate impacts of drought but also promoted long-term sustainability. By implementing these strategies, the project aims to improve agricultural resilience, conserve water resources, and secure livelihoods for communities facing frequent drought conditions.

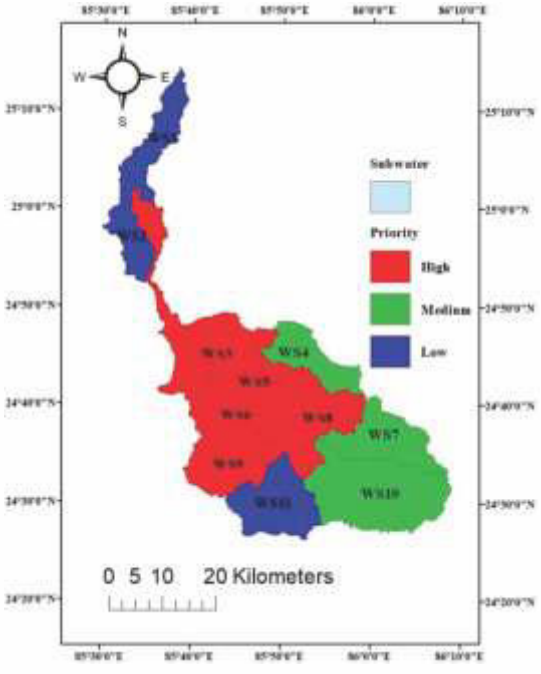

Fig. 3.5. Priority of sub-watershed based on morphometric analysis

Flood hazard assessment and strategic mitigation in Bihar

Flood hazard assessment and monitoring play a crucial role in managing water-related challenges in flood-prone regions like Bihar. Using advanced tools such as remote sensing and GIS technologies, flood-prone areas can be identified, and flood events can be predicted, enabling authorities to design effective mitigation strategies. The flood hazard mapping conducted in Assam serves as a valuable reference, where approximately 29.9% of the state's area was found to be prone to flooding (Fig. 3.6). This mapping, combined with agricultural resilience measures, helped integrate flood management strategies with crop planning, improving flood impact mitigation. In Bihar, similar efforts have been made by using crop simulation models to assess climate change effects on staple crops like rice and wheat. Flood hazard areas in Bihar were categorized based on flood frequency into five risk levels, with districts such as Lakhimpur, Nagaon, and Dibrugarh identified as highly vulnerable. This classification provides a strong foundation for developing targeted flood management strategies that enhance land and water productivity, ensuring better resilience for affected communities.

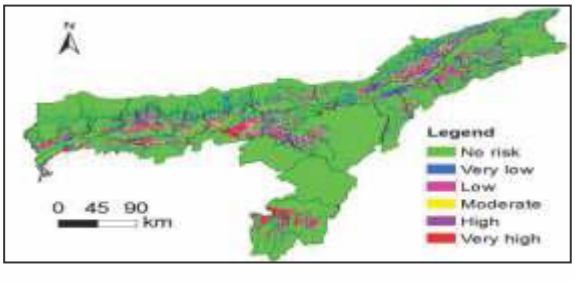

Fig. 3.6. Flood hazard zones in Assam

Bio-drainage

The division recommends incorporating biodrainage tree species such as Terminalia arjuna (Arjun) and Syzigium cumini (Jamun) into waterlogged areas, as they showed exceptional growth and 0% mortality when planted on properly mounted mounds (Fig. 3.7). The trees successfully bio-drained the area, improving soil conditions and enabling year-round crop cultivation. This approach not only helps mitigate waterlogging but also enhances land productivity. For sustained farmer income, it is advisable to use intercropping with crops like maize+moong, lentil, mustard, and pigeon pea in the interspaces of these trees, ensuring a diversified and profitable cropping system.



Fig. 3.7. Tress planted on mounds and in flat land of Chakramdas, Bihar

Solar based tube well irrigation

To address water shortages, particularly in the Bharatpura sub-distributary with 886 ha under canal command, the DLWM implemented tube well irrigation systems across 30.5 ha, with a provision for flexible pipe irrigation systems. This setup improved conveyance efficiency to 95%, significantly enhancing water use efficiency. Furthermore, the installation of a 2hp solar water pump with a dynamic head of 45m provided a cost effective, eco-friendly solution, reducing irrigation costs by 73% compared to diesel pumps and 21% compared to electric pumps (Fig. 3.8). The solar pump proved to be a viable clean energy solution, contributing to reduced carbon emissions.



Fig. 3.8. Solar water pumping system at Bharatpura

In terms of irrigation scheduling, the study assessed crop water requirements (CWR) and irrigation needs for paddy, wheat, and lentil crops from 2016 to 2019. The research found that paddy required the most water in October (175.9 mm) and June (117.6 mm), while wheat needed more water in March (92.9 mm) and February (41.9 mm), and lentil's highest requirements occurred in February (43.0 mm) and January (35.6 mm). This data enabled more accurate irrigation planning, improving water use efficiency across the region.

Solar photovoltaic systems evaluated

A significant milestone achieved with the installation of the first-ever solar-powered groundwater pumping system in Eastern India. This system, designed to harness the region's abundant solar energy, supports efficient groundwater extraction and pressurized irrigation, enhancing water use efficiency and crop productivity. The system includes a 3060 Wp crystalline silicon solar array powering a 3 HP submersible pump, capable of extracting up to 170 m^3 of water daily during peak solar conditions. The water is stored in a 117 m^3 tank and redistributed for irrigation through a 2 HP DC pump. Performance tests confirmed the system's hydraulic efficiency of 71%, providing a reliable water supply even during months with lower solar radiation. This innovation allows farmers to plan crop schedules based on water requirements and has set a precedent for solar applications in agricultural practices at ICAR RCER (Fig. 3.9).



Fig. 3.9. Solar Photovoltaic System model for Groundwater Pumping

Solar submersible pumps in Eastern India

Quantified the groundwater abstraction capacity of small solar submersible pumps in Eastern India, a significant step in promoting sustainable water management. Solar pumps with capacities ranging from 1hp to 3hp were tested, suitable for the small operational holdings of farmers (≤ 2.0 ha) in the region. With groundwater depth typically ≤ 10 meters year-round, these pumps proved efficient, with tracked array systems showing 19-23% higher water extraction compared to fixed setups. The study also highlighted the importance of optimizing crop choices, encouraging farmers to grow more profitable crops like vegetables and fruits, thereby maximizing the potential of solar-powered irrigation systems.

Farm mechanization

Ergonomic evaluation of tools/ equipment

Ergonomic evaluation of tools and equipment is crucial for enhancing user comfort, safety, and productivity, reducing injury risk. Considering anthropometric dimensions, such as height, weight, and arm length, ensures tools are designed to fit the user's body, promoting comfort and efficiency. A survey was conducted to gather 20 anthropometric measurements from farm workers in Bihar, Jharkhand, and Eastern Uttar Pradesh for ergonomic farm implement design. Anthropometric data such as age (yrs), weight (kg), stature (cm), eye height (cm), shoulder height (cm), elbow height (cm), knuckle height (cm), knee height (cm), middle finger to elbow (cm), upper arm length (cm), forward arm reach (cm), elbow breath (cm), elbow height from base (cm), elbow to elbow at forward hands (cm), circumference at elbow (cm), circumference at biceps (cm), palm breath at metacarpal (mm)/hand breadth, hand length (mm), grip diameter (mm) and foot length (cm) were recorded. Results of anthropometric parameters were presented in the form of mean with SD, 5th and 95th percentile and documented. Based on the anthropometric dimension following tools/equipment (Table 3.2) were modified and evaluated in field.

Table 3.2 Modified and evaluated farm tools

Cono and Mandava weeder	Sickles
Star and SWI weeder	Khurpi
Motorized Crop Cutter	Spade
Stirrup hoe	Axe
Octagonal manual Maize sheller	Animal drawn plough
Pedal operated paddy Thresher	Grubber
Twin wheel hoe	

Status of farm mechanization

Two surveys were conducted to assess agricultural tools and mechanization in the region. The first, in Ramgarh district, Jharkhand, documented traditional tools used by tribal farmers, finding that 75% of farmers owned bullocks and primarily used tools such as the desi plough, leveller, sickle, and dao. The second survey in Bihar, covering 366 farmers across 11 districts, revealed the adoption of mechanized equipment, with 21% owning tractors and 9.8% using power tillers. Traditional tools like sickles and khurpees were still widely used alongside modern machinery, indicating a blend of old and new practices in the region's farming system.

Energy analysis and GHGs emission studies in Agriculture

The study on energy input-output and GHG emissions in vegetable production on the Chhotanagpur Plateau highlighted key insights into energy use and environmental impact. Focusing on okra and tomato, it was found that okra required 8,828.71 MJ/ha of energy, with human labor, petrol, and farmyard manure being the primary inputs, while tomato required 4,798.66 MJ/ha, mainly from petrol, fertilizer, and diesel. The benefit-cost ratio was higher for tomato (7.87) than okra (1.71). Additionally, GHG emissions were found to be significantly lower for tomato (322.75 kg CO_2-eq/ha) compared to okra (875.41 kg CO_2-eq/ha), underscoring the potential for emission reductions through efficient input management. Furthermore, an eco-energetic analysis of cropping systems over four years across three agroecosystems in eastern India (the eastern Indo-Gangetic plain, coastal agro-ecosystem, and hill & plateau region) revealed that partly mechanized tillage and the coastal agro-ecosystem were the most energy-efficient systems. Partly mechanized tillage systems demonstrated an energy ratio of 8.88, while the coastal system showed a ratio of 9.81, making them the most energyand carbon-efficient in the region. This research establishes that partly mechanized tillage is a sustainable choice for improving energy efficiency and reducing carbon footprints in rice-based production systems across eastern India.

Technologies Developed

Multiple use of water bodies

The division successfully promoted the multiple use of water bodies by encouraging farmers and Self-Help Groups (SHGs) to diversify water usage through fish farming in previously unused or seasonally waterlogged ponds. This approach included rice-fish culture, yielding 500–700 kg/ha of fish, which was harvested from water-congested or abandoned areas. This innovation not only utilized underutilized land but also provided additional income for

farmers, with yields of 1.2–3 t/ha of fish from waterlogged areas. The overwhelming success of this initiative has led to its adoption by approximately 20 farmers and SHGs, with the benefits of the practice spreading rapidly through word-of-mouth and community support.

Integrated agriculture and fishery in secondary reservoir system

The Integrated Agriculture and Fishery system in the Secondary Reservoir System (Fig. 3.10) was developed to address the widespread issue of waterlogging in seasonal lowlands, particularly along canal banks and near river banks. In eastern India, waterlogged areas span approximately 4.5 m.ha., often left underutilized. By converting medium-deep waterlogged lands (0.5-1.0 m depth) into secondary reservoirs, about 20% of farm areas were repurposed for multiple uses. Bunds built around the reservoirs helped prevent water overflow, and high-value horticultural crops such as banana, lemon, guava, and strawberry were cultivated on these bunds using seepage water supplemented by minimal groundwater, making previously underutilized land highly productive.

The system also integrated fish farming alongside livestock components like duckery, poultry, and piggery, which enhanced both water and land productivity. The net income from the Integrated Agriculture and Fishery system with secondary reservoirs was about 1,32,590 ₹/h/yr. Fruit crops contributed 56% to the net income, followed by fish (27%) and vegetables (17%). This innovative approach demonstrates the potential for transforming seasonal waterlogged areas into profitable, multi-use agricultural systems, offering a sustainable solution to enhance land and water productivity across eastern India.



Fig. 3.10. Secondary reservoir system with fish, duckery and horticulture

Fish trenches-cum-raised bed system

In response to the persistent waterlogging issues in seasonal lowlands, particularly along canal banks and chaurs, an effective farming system model was developed to enhance land and water productivity. In areas of south Bihar, waterlogging begins in July and can last until January, with water standing up to 1 m deep. This system, similar to practices in Kerala's backwater regions, involves excavating trenches in waterlogged areas with more than 1 m of stagnant water. The excavated soil is used to create bunds, with the raised tops positioned above the highest flood level, making the land suitable for cultivating vegetables or horticultural crops.

Developed two models for trench-based farming: a meandering model, which simulates river flow conditions, and an island-type model, which mimics pond conditions (Fig. 3.11). The meandering model allows water to flow from one side into the trench, with provisions for fish culture, while the island-type model creates raised beds surrounded by trenches, ensuring security for high-value crops and continuous fish movement. By stocking fries at 15,000 per hectare, fish yields of up to 2 t/ha can be achieved. In addition, banana and vegetables are grown on the raised beds, alongside composite fish culture. The net income from this system is approximately 81,000 ₹/ha/yr, with fruit crops contributing 54% to the net income, followed by fish (24%) and vegetables (22%). To maintain water levels in the trenches and irrigate the beds during dry periods, the system requires an investment of about ₹10,000 per hectare for diesel-operated pumps. This model has shown great potential in transforming seasonal waterlogged areas into productive farming systems.

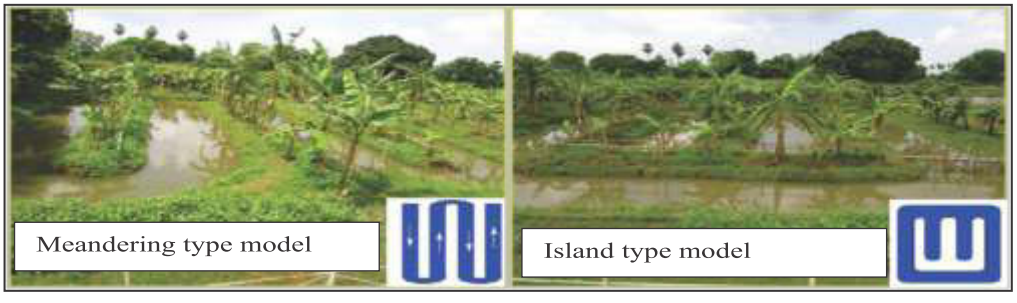

Fig. 3.11. Meandering type model and Island type model

Rice-fish culture in lowland rice-wheat system

An innovative Rice-Fish Culture system in lowland rice fields were developed to overcome poor land and water productivity (Fig. 3.12). In areas with 30-50 cm of stagnant water, about 10% of the rice field is converted into a central refuge area with a depth of 1 m. Fingerlings or yearlings are released into the field, two weeks after transplanting the rice. The central refuge area protects the fish during dry spells and plant protection operations, providing enough space for fish movement. This system not only enhances the productivity of waterlogged areas but also makes efficient use of both land and water resources. At the end of the rice crop, the grown fish are selectively harvested, and smaller fish are returned to the refuge, which continues to function during the wheat season. This system leads to better fish growth and increased body weight, resulting in improved yields. The net income from rice-fish culture is 10-18% higher than traditional rice-wheat systems, demonstrating a sustainable and profitable solution to enhance productivity in lowland rice fields.



Fig. 3.12. Rice-Fish Culture in Lowland area

Decision support tools for optimization of land and water productivity

Beneficial crop sequence selection model

A Decision Support Tool entitled 'Beneficial Crop Sequence Selection Model' was developed in English and Hindi employing Visual Basic platform in order to compute (i) Benefit Cost ratio, (ii) Land Productivity and (iii) Water Productivity from various possible crop sequences considered by farmers and ranking of these three values in decreasing order was also done. The model computes 'income from output' by adding the product of yield (q) and sale price (₹/q) of main product and bi-product during all the three seasons. 'Profit' is computed by subtracting 'cost of input' from 'income from output'. The developed decision support tool is capable of providing information to farmers about suitable crop sequences from benefit-cost ratio, land productivity and water productivity point of view. Since benefit-cost ratio indicates about profitable crop sequence only and does not consider the land and water resources availability with the farmers, this tool provides information about land productivity and water productivity along with benefit-cost ratio and can help farmer to take decision about selection of beneficial crop sequences in a wider perspective.

Maximization of water productivity through linear programming

In an effort to optimize water productivity in the region, a simplex linear programming model was applied to maximize the use of available water for cropping systems. The study focused on areas with specific constraints, such as limited canal water, labor availability, and crop affinity in the Paliganj distributary and Nalanda Corridor project sites. The application of linear programming resulted in significant improvements in water productivity, increasing from 29.61 kg/m^3 to 32.62 kg/m^3 in Paliganj and from 18.28 kg/m^3 to 22.77 kg/m^3 in the Nalanda Corridor. This modeling approach optimized the crop areas, demonstrating a clear pathway to enhance water use efficiency while considering on-ground constraints.

Optimization models for integrated farming systems

An IFS information system was developed using SQL, Java, and HTML to optimize land allocation, cost and profit calculations, and meet family food requirements (for a 2+2 size) (Fig. 2.14). The system incorporates output recycling between farming components, weather parameters, soil conditions, and more. Simplex linear programming is utilized for land allocation and profit maximization, aiming to optimize net returns.



Fig. 3.13. User login GUI of information system of IFS

Decision support tool to explore conjunctive use options

A Decision Support Tool (DST) was developed to explore and promote conjunctive use of rain, surface and ground water in the canal command as well as convincing farmers to adopt conjunctive use practice which will not only promote efficient and judicious use of water but will

also enhance agricultural production due to timely establishment of Kharif and Rabi crops. The concept and methodology of DST (Fig.3.14) is based on following flow chart

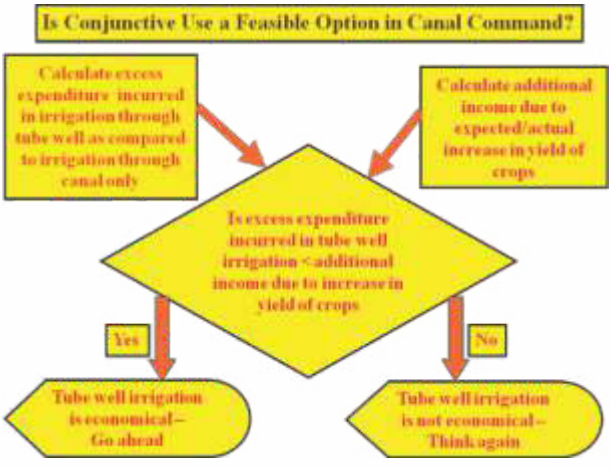

Fig. 3.14. Decision Support Tool to explore and promote conjunctive use of rain

This tool was found quite convincing and effective to farmers in exploring and promoting conjunctive use options. This tool is based on economic criteria, it informs if the required yield increases to compensate the additional cost of irrigation is less than real yield increased, than decision is that conjunctive use is economical option otherwise decision is 'NO'. The results reveal that conjunctive use of tube well and canal water has tremendous scope in canal command, and it can be propagated in the area provided water users are convinced about yield improvement resulting in economic benefits, which compensate the additional cost of irrigation. Analysis showed that compared to owning tube well, water purchasing is the most economical option followed by getting only pumping sets on rent basis to run tube wells for irrigation.

Crop water management

Irrigation schedules to improve system productivity

The project aimed to improve crop yields and irrigation water productivity through efficient water management practices. The study focused on optimizing irrigation schedules for crops like peas, vegetables, and maize. Results showed that the highest green pod yield for peas (7.95 t/ha) was achieved with an irrigation-water-to-cumulative-evapotranspiration ratio (IW:CPE) of 0.8, while maize production peaked at 18.41 t/ha with an IW:CPE of 1.2. This research demonstrated how strategic irrigation management can boost crop yields and maximize water productivity, contributing to better resource utilization in the agricultural sector.

Crop water management for optimizing water and nutrient efficiency

Drip irrigation at 80% evapotranspiration (ETc) has resulted in remarkable yield increases, including 85.7 tonnes per hectare for tomatoes, 61.7 t/ha for cabbages, and a 40% yield improvement for okra compared to traditional methods. The Low Energy Water Application (LEWA) system has further optimized resource use, reducing water consumption by 50% in rice and 15% in wheat, while decreasing energy use by 60%, making it highly suitable for small and

fragmented farms. Zero tillage in rice-wheat systems improved yields by 15-25% while achieving 11.3% water savings. Deep summer ploughing enhanced soil health and crop performance. The introduction of water-use-efficient cropping systems, such as ricemaize-mungbean, achieved a water productivity of 1.11 kg/m^3, significantly surpassing traditional systems. Solar-powered irrigation systems reduced irrigation costs by 73% compared to diesel pumps, further promoting sustainable farming practices.

Nutrient management practices combining farmyard manure (FYM) at 15 tonnes per hectare with 75% of the recommended NPK dose achieved a 25% reduction in fertilizer usage and improved water-use efficiency in wheat cultivation. Studies on irrigation and nutrient optimization showed that pulse-based cropping systems (rice-lentil-greengram) used water more efficiently (78.9 and 75.62 kg/ha-cm) than cereal-based systems (rice-wheat-greengram) at both optimum and sub-optimum irrigation levels. While cereal-dominated systems had higher NPK uptake, pulse-based systems exhibited superior water-use efficiency. Optimal irrigation and nutrient levels further enhanced nutrient uptake and productivity across both systems.

Crop diversification for enhancing resource use efficiency

Innovative tillage practices, such as deep summer ploughing (DSP) every three years, have resulted in higher yields (5.21 t/ha) and reduced economic costs compared to annual DSP. Zero tillage practices for wheat have increased yields by 4-5 q/ha over conventional tillage. Crop diversification systems, including Rice-tomato-bottle gourd and rice-cauliflowerspinach-green gram, have significantly increased yields and net profits, with the rice-tomatobottle gourd system yielding 1,59,904 ₹/ha (Fig. 3.15). Additionally, nitrogen management strategies using 75% mineral fertilizer and foliar sprays of Nano urea have provided efficient nutrient management, yielding similar results to 100% nitrogen. Finally, the adoption of mini-sprinkler irrigation systems has improved water productivity, offering a sustainable alternative to surface irrigation, contributing to better water and resource use efficiency. These advancements have enhanced agricultural sustainability and significantly improved farmers' yields and income.



Fig. 3.15. Rice-tomato-bottle gourd cropping system

Varieties developed for irrigated and rainfed ecosystems

The development of Swarna Suraksha and Swarna Gaurav faba bean varieties addresses water management challenges by offering options for both rainfed and irrigated conditions. These varieties have shown superior performance compared to national checks, achieving yields of 5.38 t/ha under irrigated conditions and 3.94 t/ha under rainfed conditions (Fig. 3.16). Details of variety released and their applicability were shown in Table 3.3.

Table 3.3 Variety released and their applicability

Variety	Applicability
Faba bean	
Swarna Suraksha	Nutritionally superior (Phytate <0.10 % & iron >200 ppm) faba bean variety, for rainfed condition and released by SVRC, Bihar
Swarna Gaurav	Nutritionally superior (Phytate <0.10 % & iron >200 ppm) faba bean variety, for irrigated condition and released by SVRC, Bihar.

Both varieties, enriched with high iron content and low phytate levels, contribute to sustainable farming by enhancing productivity without excessive water dependency. These advancements support efficient water management strategies, ensuring higher yields while conserving vital water resources in Bihar's diverse agricultural landscapes.



Fig. 3.16. Faba bean varieties developed

Weed management for optimizing water use and enhancing agricultural productivity The study examined weed emergence under both conventional tillage (CT) and conservation agriculture (CA) practices, revealing differential effects on soil moisture and temperature. A combination of pre-emergence and post-emergence herbicide applications was found to significantly reduce weed density and biomass in rice, achieving 89.4% weed control efficiency. In wheat, post-emergence herbicide application led to a 93.2% weed control index. For green gram, integrated herbicide applications resulted in 78.1% weed control efficiency. The study recommended that CA-based practices, such as zero till direct-seeded rice (ZTDSR) (Fig. 3.17), zero till wheat (ZTW), and zero till green gram (ZTG), along with the use of new generation efficient herbicide molecules, enhanced cropping system productivity by 5.9% compared to conventional practices. These methods also contributed to improved soil health, with a 35.9% increase in soil organic carbon concentration and a 33.5% reduction in global warming potential. The integration of crop residue retention and herbicide use offers a sustainable weed

management strategy that promotes efficient resource use and can support the intensification of rice-wheat-green gram systems under CA.



Fig. 3.17. Effect of pyrazosulfuron-ethyl as pre-emergence fb cyhalofop-butyl + penoxsulam at 20 DAS in zero till DSR with residue retention

Canal water management and conjunctive use

In order to efficiently utilize canal water, some practices like (i) formation of Outlet Management Group (OMG) at outlet level, Water users Associations (WUAs) at distributary level and Federation of Water Users at Canal level, (ii) frequent meetings and dialogues among water suppliers and users and strengthening of communication facilities in order to address issues related to adequacy, equity and timeliness, increasing reliability, maintaining regularity and flexibility in flow rate, frequency and duration, (iii) training through communication product, and awareness campaigns (iii) staggering of paddy transplantation period, (iv) crop diversification, (v) revision in crop planning from head to tail reach, and (vi) seem quite promising. Participatory Irrigation Management (PIM) has been identified as one of the potential interventions to efficiently utilize canal water.

Soil management for optimizing nutrient and water management practices

A significant achievement in rice cultivation was the identification of the optimal combination of water and nitrogen.

- Water and nitrogen management in rice: Maintain 8 cm water depth and apply 80 kg N/ha to maximize tiller production and achieve 5.0 t/ha grain yield, preventing excessive nitrogen losses.
- NPK and FYM integration in wheat: Apply NPK at 100:60:40 kg/ha for better yield and water-use efficiency. Use 15 t/ha FYM to reduce the NPK requirement by 25%. For progressive farmers, irrigate at key growth stages with 75% NPK + FYM, while under water scarcity, apply 3 irrigations with 75% NPK or 50% NPK + FYM.
- Nutrient and water use efficiency in wheat: Reduce fertilizer by 25% and apply 15 t/ha FYM to maintain yields comparable to 100% NPK while improving soil moisture retention and infiltration. Use 125% NPK to achieve the highest yield of 3.66 t/ha.
- Zinc and sulfur application in rice-lentil systems: Apply 5-6 kg Zn/ha and 30-40 kg S/ha with the recommended NPK dose to increase rice grain yield and improve resistance to false smut and lodging.

- Maize transplanting for higher yields and efficiency: Use broad bed and furrow (BBF) planting with nitrogen application at critical growth stages for higher yields, water-use efficiency, and early maturity in rabi maize.
- Nano DAP for rice and wheat: Replace up to 50% of conventional DAP with nano DAP without compromising yield. In rice, apply 50% RDF + two foliar sprays of nano DAP (2 ml/L and 4 ml/L) to achieve grain yields of 5.86-6.04 t/ha, with the highest water-use efficiency (370.3 kg/ha cm) and benefit-cost ratios (2.37-2.36). In wheat, use 75% RDF + one foliar spray (T6, 4.8 t/ha) or 50% RDF + two sprays (T10, 4.7 t/ha) for higher productivity and water-use efficiency (Fig. 3.18).
- Carbon sequestration in rice-wheat systems: Adopt reduced tillage with 30% residue retention (RT30) to improve soil organic carbon (SOC) levels, with the highest SOC stock (11.4 t/ha) recorded in the rice-maize-RT30 system.

Development of low energy water application system and testing

A water application device developed is Low Energy Water Application (LEWA) (Fig. 3.18), which operates at 0.4-0.6 kg/cm² pressure and can be used for irrigating rice, wheat and other close growing crops. The cost of LEWA system is less and it saves water, time and energy. This is very efficient, effective and beneficial irrigation system for small and marginal farmers having fragmented land holdings. During lab testing of LEWA device gives throw diameter of 6-8 m, application rate 2.6-3.1 cm/h. The surface uniformity is observed greater than 70% when operated at an operating pressure of 0.5 kg/cm² or above and sub – surface uniformity is greater than 90%. It has a great role in improving yield and water productivity. It was found that there is 45% and 10% water saving as well as 50% and 55% energy saving over surface and sprinkler irrigation system. Yield values vary as 3.775, 3.581 and 3.525 t/ha and water productivity values as 1.91, 1.62 and 0.95 kg/m³ in LEWA, sprinkler and surface irrigation system, respectively.



Fig. 3.18. LEWA system in field

Solar energy application in agriculture

Solar Photovoltaic System for Groundwater Pumping

A solar-powered groundwater pumping system was installed consisting of a 3060 Wp crystalline silicon solar array that powers a 3 HP, three-phase AC submersible pump. The system supplied 170 m³ of water per day in April and 104 m³ per day in December on sunny days. The extracted water was stored in a 117 m³ tank (9.75 m × 4.8 m × 2.5 m) and redistributed using a 2 Hp DC pump, powered by a 1400 Wp solar array, to support pressurized or traditional flood irrigation methods. The system's high delivery pressure allowed water to Fig. 3.18. LEWA system in fieldbe transported up to 250–300 meters. This type of system allows farmers to plan their crop calendars based on water requirements and cropping patterns. The centrifugal pump operates with a static delivery head of 0.9–1.5 m under solar radiation ranging from 550–850

W/m² between 9:30 AM and 2:30 PM, except during November and December. This configuration reliably supports pressurized irrigation systems requiring operating pressures of 1.0–1.5 bar, ensuring continuous agricultural support throughout the year.

Solar photovoltaic aerator for fish pond

Developed and tested a spray-type solar aerator, a pioneering solution to improve dissolved oxygen levels in fish ponds. The aerator, powered by a 900 Wp solar panel and a 1-Hp DC surface pump, was tested in a 20 × 30 × 1.5-m fish pond in Patna (Fig. 3.19). The system sprays oxygen-deficient pond water into the air, promoting vertical mixing and disrupting thermal stratification, which usually prevents the oxygen-rich surface water from mixing with the lower layers. Operating 6–7 hours daily, the aerator increased dissolved oxygen levels by 20–22% at 0.5 m depth and by 40–50% at 1.0 m depth, compared to control conditions. This innovation offers a sustainable solution to enhance pond oxygenation, improve water quality, and support aquatic life.



Fig. 3.19 A spray type solar aerator installed in fish pond.

Solar photovoltaic system for animal shed cleaning

A solar photovoltaic watering system was designed and installed at the institute's animal shed to provide water for medium and large herds, taking advantage of the Eastern region's strong solar radiation potential, which ranges from 6.4 to 4.3 kWh/m²/day with 250 to 300 sunny days annually. The system features a 1 Hp DC motor pump powered by a 900 Wp solar panel. It draws water from a pond and delivers it to nearby animal sheds within a 50-m radius. Operating from 8:00 AM to 2:30 PM, the system supplies water at a discharge rate of 5000-6000 l/h, maintaining relatively high pressure throughout the day.

Design and development of farm tools

A novel method for manual weeding in row crops

For small and marginal farmers, affordable weeding solutions often involve hand weeding or simple manual mechanical weeders. A new prototype manual mechanical weeder, designed with the anthropometric parameters of Eastern India's farm workers, improved weeding efficiency by 85% in maize fields with a field capacity of 0.0120 ha/hr (Fig. 3.20). Priced affordably at ₹1200–1400, it offers a competitive alternative for local manufacturing.

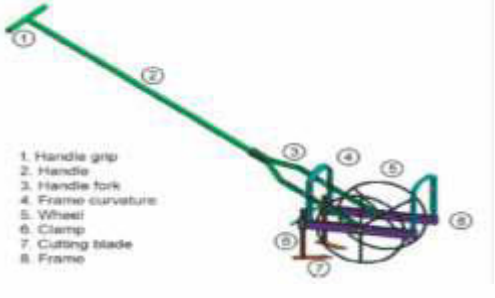

Fig. 3.20 Schematic diagram of developed weeder

Design and development of Makhana grader

A prototype hand-operated makhana grader was designed and developed, featuring a circular drum and cylindrical bars. The grader was specifically created to sort makhana seeds into five size categories: 14 mm, 12 mm, 9 mm, 7 mm, and below 7 mm in diameter. The prototype grader, illustrated in Fig. 3.21 has an output capacity of 550–600 kg/h.



Fig. 3.21. Hand operated makhana grader

Design and fabrication of stirrup hoe

The stirrup hoe is primarily used for intercultural operations, particularly weeding. A stirrup hoe was designed and fabricated for this purpose, consisting of three main components: the blade, housing frame, and handle (Fig. 3.22). The blade was crafted from spring steel with a cutting edge thickness of 0.8 mm. The frame structure was constructed using mild steel flats, while the handle was made from MS hollow pipe. A clamp was welded to the top of the frame, allowing the handle to be securely attached using fasteners. The cost of the stirrup hoe is ◎ 800, and its field capacity is 0.0182 ha/h. Operated in a standing-pulling posture, the stirrup hoe uses a push-and-pull action, enabling the worker to move faster compared to using a khurpi.

Design and development of peripatetic fish vending cart

The purpose of a Peripatetic Fish Vending Cart is to provide a mobile and efficient solution for fish vendors to transport, preserve, and sell fresh fish directly to customers. Considering these issues a prototype of a fish vending cart was designed and fabricated (Fig. 3.22). The cart features a water tank for live fish storage, an aerator powered by a solar module, a box for frozen fish storage, cutting tools, a toolbox, and a dustbin. The rear wheel was replaced by a pair of tires, and the rim was constructed from 20 mm MS hollow pipe to handle additional load. Before fabrication, a layout design was prepared to accommodate essential working facilities, such as space for live and frozen fish boxes, a cutting and processing area, water storage, utility space, and waste disposal. On the base frame, a 100-L polyethylene insulated (PUF) box for frozen fish and a 250-L live fish container were placed. Three 5-liter plastic tubs were positioned at the rear for waste disposal, which can be easily removed when full. The cutting and processing area, measuring 650×500 mm, was made with a 4 mm thick ACP



Fig. 3.22. Peripatetic fish vending cart.

sheet over an MS structure to prevent fish contamination. Continuous aeration was provided using two 40 Wp solar PV panels connected to a storage battery, which charges during the day and is used during off-sunshine hours. The cart uses a simple chaindrive mechanism. A traditional cutting knife (Boti) was fixed with a nut and bolt at the side of the processing area, designed for stability during use and easy removal when not in use.

Modification of manual octagonal maize sheller (OMS)

The Manual Octagonal Maize Sheller is a practical tool designed for smallscale maize farmers to manually remove kernels from the cob. Its octagonal shape and design enhance shelling speed and convenience compared to traditional methods. However, the original version involved considerable effort and had limited efficiency. To improve this, the Octagonal Maize Sheller (OMS) was modified by adding a rotating handle and a clamp, allowing it to be securely attached to a table or rack (Fig. 3.23). This change frees one hand for continuous rotation while the other feeds maize cobs into the sheller. An ergonomic evaluation of the original and modified OMS was conducted with farm women at ICAR RCER, Patna, from 7–15 July 2022. Using maize cobs harvested from the institute's farm, which had a moisture content of 12.65%, the modified OMS showed a slight increase in average heart rate (from 86.60 to 87.60 bpm), energy expenditure, and oxygen consumption. However, it significantly boosted output capacity by 32%, demonstrating improved productivity with manageable physical effort, making it a more efficient tool for small-scale maize shelling.

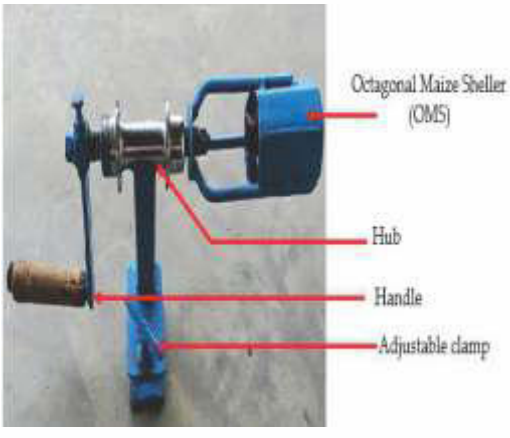

Fig. 3.23. Modified octagonal maize sheller

Teaching, Extension and Capacity Building

Teaching and research guidance

Dr Ashutosh Upadhyaya was Co-guide to 1 Ph.D. student from Gautam Buddh Technical University, Lucknow and 6 M. Tech. students of Water Resources Engineering Division at NIT Patna. Several courses for students' programs like B.Sc. Agriculture (5 courses), M. Tech. (11 courses) and PhD (6 courses) are also being taught by the scientist of the division.

Technology dissemination

Technologies demonstrated at farmers' fields

The Division of Land and Water Management (DLWM) has developed and demonstrated a number of innovative technologies (Table 3.4) to enhance agricultural productivity and water efficiency, including water-saving systems and climate change adaptation strategies. These solutions, tailored to local challenges, promote sustainable farming practices and improve water productivity across various regions.

Table 3.4 Applicability of the technology developed and demonstrated

Sl. No	Name of Technology	Applicability
1.	Optimization of rice transplanting date for efficient rainwater utilization	Irrigated rice ecosystems of Bihar.
2.	Surface seeding of wheat in excess moisture condition	Excess soil moisture fields of rice-wheat system, where rice is harvested by late December.
3.	Adaptation of bed planted wheat under timely sown condition	Declining groundwater table or head reach of canal having water logging fields during winter in Bihar, Jharkhand, Chhattisgarh and West Bengal.
4.	Water productivity of crop sequences under multiple water use system	Applicable in irrigated midland and lowland situation in clay loam soils of middle Gangetic plains.
5.	Multiple use of water with trench-cum-raised bed system in waterlogged areas	Seasonal waterlogged areas in canal banks *chaurs* etc.
6.	Vegetable crop production system under drip irrigation	Irrigated midlands and uplands in Bihar.
7.	Development of Low Energy Water Application (LEWA) System	Small and fragmented land holders and water scarce areas.
8.	Design and Development of Low Energy Sprinkling Nozzle	Suitable for field crop irrigation with significant savings of water and energy.
9.	Solar Energy Application for Ground Water Pumping	Bihar, west Bengal and Assam where groundwater utilization ranges from 22 to 40% due mainly to lack of energy supply in agriculture sector.
10.	Decision Support Tool to Explore and Promote Conjunctive Use of Water	Decision support tool can be applied where good quality shallow groundwater aquifers are available for crop production system.
11.	Decision Support Tool for canal Operation	Irrigation canal command areas of eastern states.
12.	Modeling the impact of climate change on Rice and wheat and probable adaptation measures for Bihar	Applicable to different agro-climatic zones of Bihar.

13. Potential impact of climate change on maize crop and probable adaptation measures for Bihar	Forecast of impact and adaptation to climate change is applicable to different agro-climatic zones of Bihar.
14. Improving water productivity through micro-irrigation in SRI and SWI	Irrigated area having less water resource and combating environmental impacts
15. Multiple water use system with integrated agriculture and fishery for	Kharif season water logged area
16. Development of waterlogging tolerant lines of pigeonpea for Eastern India	Water logged ecologies of Bihar
17. Scaling up of different water saving techniques, water harvesting methods, productivity in agriculture for livelihoods through teaching –cum – demonstration	Demonstrated in Ara and Hajipur, improving water productivity, yields, and crop quality.
18. Characterization and classification of ground water quality in respect to dissolved arsenic	Spatial maps of arsenic and iron in irrigation water developed using GIS analysis.
19. Development of modified non-weighing paddy lysimeter	The methodology is useful for edaphoclimatic and data-scarce regions where lysimeters are unavailable.

Technology dissemination

By involving self-help groups (SHGs) and outlet management groups (OMGs), the division fostered community-based involvement, empowering local stakeholders to adopt and manage water and land management technologies. This bottom-up approach not only led to increased agricultural productivity and diversification but also ensured the sustainability of the initiatives by giving stakeholders a personal stake in the outcomes. Among the successful innovations was the promotion of multiple water-use systems, where farmers and SHGs were encouraged to adopt fish farming in previously unused or waterlogged ponds. The integration of rice-fish culture optimized water use and provided additional income sources for farmers, with successful adoption by 20 farmers and SHGs.

Demonstration of water management technologies

In the realm of capacity building, FPARP Project entitled 'Scaling up of Water Productivity in Agriculture for Livelihoods through Teaching cum Demonstration, training of trainers and farmers' under the XI Plan Scheme of ICAR, which significantly enhanced the dissemination of water management technologies. The project included 69 one-week training programs and two two-week training sessions designed to equip farmers and trainers with knowledge on rainwater harvesting, groundwater management, and pressurized

irrigation systems. Hands-on field exposure visits and demonstrations further emphasized the practical applications of participatory canal and groundwater management, directly contributing to improved water productivity.

Establishment of farm machinery resource centre

The Farm Machinery Resource Center (FMRC) was established at ICAR Patna and inaugurated on June 28, 2016, by the Hon'ble Union Minister of Agriculture, Shri Radha Mohan Singh (Fig. 3.24). The FMRC aims to enhance agricultural productivity and sustainability by promoting farm machinery development. Its primary focus is providing support, training, research, and resources to improve farming efficiency and operations.



Fig. 3.24 Inauguration of FMRC by Shri Radha Mohan Singh, Hon'ble Union Minister of Agriculture and Farmers Welfare

Establishment of custom hiring centres

A Custom Hiring Centres (CHCs) (Fig. 3.25a) was established to improve farm mechanization and accessibility to essential agricultural tools. The first CHC was set up at KVK, Buxar, in 2017, equipped with a variety of power sources and implements like a 45 hp tractor, disc plough, rotavator, and multi-crop thresher, among others. These machines are provided to farmers at affordable rates, promoting efficient farming practices. The second CHC was inaugurated at Krishi Vigyan Kendra, Ramgarh, Jharkhand (Fig. 3.25b), on January 8, 2020. This center further expanded the range of equipment available, including power tillers, motorized crop cutters, and weeding tools, enhancing productivity in the region and making mechanization more accessible to farmers.



Fig. 3.25a. Custom Hiring Centre at KVK, Buxar



Fig. 3.25b. Custom Hiring Centre at KVK, Ramgarh

Capacity building

Between 2001 and 2024, the DLWM played a pivotal role in enhancing agricultural practices by delivering 137 lectures and conducting 106 training programs. Inauguration of FMRC by Shri Radha Mohan

Singh, Hon'ble Union Minister of Agriculture and Farmers Welfare aimed at disseminating knowledge and fostering skill development among farmers, extension workers, and agricultural professionals, ensuring the widespread adoption of efficient and sustainable farming techniques. The number of training programs conducted, lectures delivered during various training programs, and seminars and symposiums attended between 2001 and 2024 at five-year intervals are presented in Fig. 2.26, and Fig. 2.27, respectively.

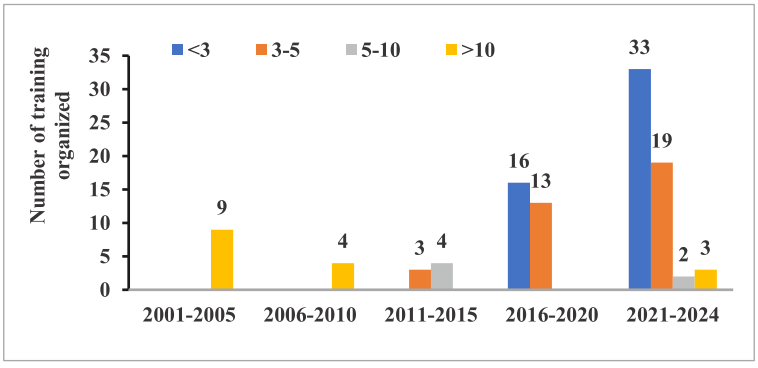

Fig. 3.26. Number of training programs organised

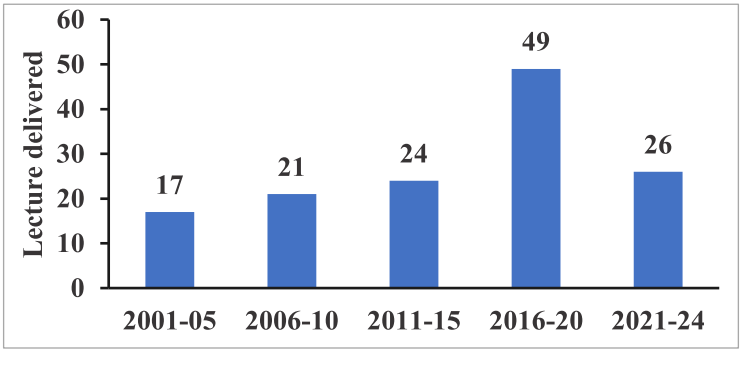

Fig. 3.27. No. of lectures delivered during various training programs

Foreign deputation and training

Several scientists from DLWM have visited foreign countries to enhance their expertise and stay at the forefront of advancements in their respective fields. Table 3.4 highlights these international visits from 2001 to 2024, showcasing their contributions to global knowledge exchange and skill development. This table encapsulates the significant international experiences of DLWM scientists, enhancing their research and expertise.

Table 3.4 International visits made by DLWM scientists between 2001 and 2024

Sl. No.	Name of Scientists	Duration	Place and Event
1	Dr. A R Khan	May 18, 2001	Salinity in agriculture at Faculty of Agriculture, University of Udine, Italy;
		May 22-23, 2001	Management and reclamation of saline alkaline problems at Faculty of Agriculture, University of Padova, Italy

		Mar 25-Jun 22 2002	International Centre for Theoretical Physics (ICTP), Trieste, Italy
		Feb 2-5, 2005	IFAD funded project at Bangladesh Agricultural Research Institute, Gazipur, Bangladesh.
3	Dr. S S Singh & Dr. B Saha	Aug 20-31, 2001	Soil and crop management decisions at IACR, Rothamsted, UK
4	Dr. R D Singh	Aug 22-31, 2001	System approach to characterize productivity limiting constraints at University of Reading and University of East Anglia, UK;
5	Dr. U S Gautam	Sept 7-8, 2002	Workshop at School of Applied Statistics, University of Reading, White Knights Park, Reading, UK
6	Dr. P.R. Bhatnagar	Mar 4-15, 2002	International Water Management Institute (IWMI), Colombo, Sri Lanka
7	Dr. N Subhash	May 19-23, 2003	Data and information management workshop at IMWI, Colombo, Sri Lanka
		Oct 15-17, 2003	Database Networking Software (DBNS) at Friedrich-Schiller-University and Firmengruppe Dr Buch Jena, Germany
8	Dr. Atul Kumar Singh	Oct 19-Nov 2, 2003	Visit to Texas A&M, USA on Pressurized Irrigation System funded by NATP
9	Dr. Abdul A Harris	Oct 19-Nov 2, 2003	Training visit to Texas A&M, USA under Team of Excellence on Pressurized Irrigation System funded by NATP
10	Dr. Adlul Islam	Dec 13-15, 2005	GECAFS meeting on basin scale analysis of food system vulnerabilities at Kathmandu, Nepal
11	Dr. Janardan Jee	Aug 25-27, 2007	Exploration of Makhana plant at Nikada, Japan
12	Dr. R K Batta	Feb 27-28, 2008	Annual stakeholders workshop of CPWF at Dhaka, Bangladesh
		May 9-11, 2008	Challenge Program Working Group meeting at Addis Ababa, Ethiopia
		Jul 21-22, 2008	ICAR-IWMI steering committee meeting at Colombo, Sri Lanka
13	Dr. Ashutosh Upadhyaya	Mar 4-15, 2002	International Water Management Institute (IWMI), Colombo, Sri Lanka
		Apr 2-4, 2003	Global Environmental Change and Food Systems (GECAFS) Indo-Gangetic Plain

			Research Planning Workshop, Kathmandu, Nepal
		Oct 19-Nov, 2003	Texas A&M, USA under Team of Excellence on Pressurized Irrigation System funded by NATP
		Dec 5-18, 2004	University of Edinburgh, U.K. to learn the use of OPTALL and LATGA packages for optimal irrigation allocation
		Nov 10-17, 2006	International Forum on Water and Food in Vientiane, Lao PDR
		May 3-8, 2009	Innovation Asia Pacific Symposium at Kathmandu, Nepal
		Jun 18-20, 2013	Integrated Model Development Workshop of Koshi Basin Program Phase –I in Kathmandu, Nepal
		Jun 12-13, 2014	Koshi Basin Program Partners Forum Meeting at ICIMOD, Kathmandu, Nepal
		Sept 17-19, 2014	Workshop on improving water use for dry season agriculture in Eastern Gangetic Plains at Kathmandu, Nepal
		Apr 24-26, 2024	Global Science-Policy Forum on Socially Inclusive Solar Irrigation Systems at Kathmandu, Nepal
14	Dr. Anil Kumar Singh	Oct 28-Nov 8, 2013	Rice Post Production to Market at International Rice Research Institute (IRRI), Las Banos Manila, Philippines
15	Dr. Kirti Saurabh	Mar 31-Apr 5, 2024	Soil & Root Health Training Course at CIMMYT, Ankara and Eskisehir, Turkey

Conferences/Seminars/Workshops/Symposia Organized and attended

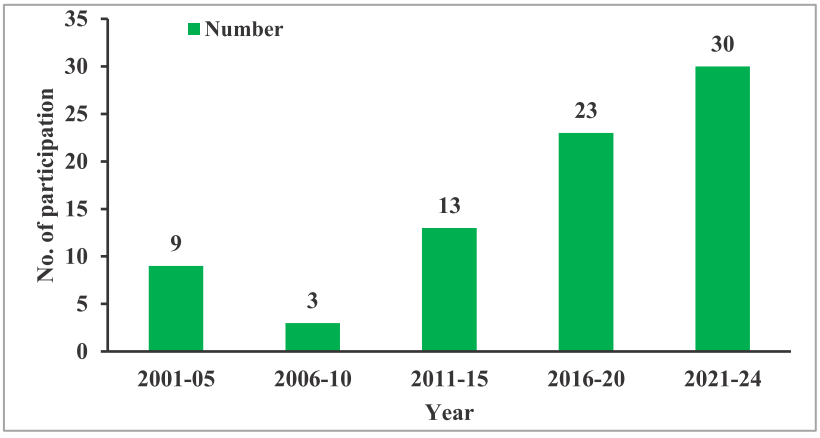

Fig. 3.28. Seminars and symposia attended by DLWM scientists

Awards, Honors and Recognitions

A distinguished list of awards and recognitions received by various scientists for their outstanding contributions in their respective fields is shown in Table 3.5.

Table 3.5 Details of Awards Received by Scientists, Including Year, Awarding Institution, and Area of Recognition

Sl. No.	Name of Scientist	Award Name	Year	Awarding Institution	Remarks
1	Dr. Ashutosh Upadhyaya	Lal Bahadur Shastri Young Scientist Award	1999-2000	ICAR	Outstanding research in water management
		Jawaharlal Nehru Award	2000	ICAR	Outstanding Post-Graduate Agricultural Research
		International WATSAVE Young Professional Award	2002	ICID	Contribution to water conservation & sustainable use
4	Dr. Bikash Sarkar (Team Member)	Ch. Devi Lal Outstanding AICRP Award	2012	ICAR	Awarded for contributions in AICRP
6	Dr. Shivani	Rajeev Gandhi Rashtriya Gyan-Vigyan Puraskar	2015	Govt. of India	Awarded for original book writing in Hindi
7	Dr. A. K. Singh	Associate Fellow, National Academy of Agricultural Sciences	2014	NAAS, New Delhi	Recognition for contributions to agricultural sciences
		Raj Bhasha Gaurav Award	2017	Ministry of Home Affairs	Recognition for contributions to Hindi language

Publications

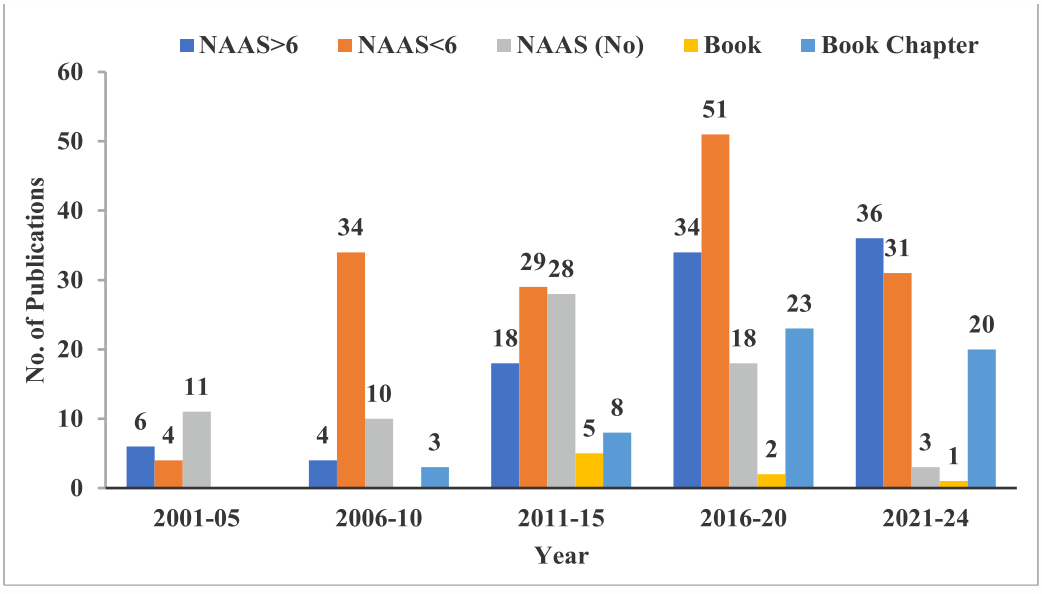

Fig. 3.29. Total research papers, book chapters and books published during 2001-2024

Future Research Thrust

The Division of Land and Water Management is actively exploring advanced technological solutions to address evolving agricultural challenges. These initiatives focus on improving ater management, boosting productivity, and fostering climate resilience, particularly in water-scarce and vulnerable regions.

- Harnessing drone technology and multispectral remote sensing to provide real-time insights into crop water stress, helping optimize irrigation and enhance crop resilience, especially in water-scarce regions.
- Integrating solar power with farming practices to ensure sustainable energy production, improve food security, and enhance climate resilience in rural communities.
- Utilizing indigenous sensor-based lysimeters to optimize irrigation scheduling, conserving water and promoting healthy crops.
- Developing advanced Decision Support Systems (DSS) powered by AI, ML, and IoT to offer data-driven insights for better land and water resource management decisions.
- Designing cutting-edge agricultural implements tailored for small-scale farmers, improving productivity and supporting the livelihoods of fragmented landholders.
- Addressing soil and water contamination risks, particularly from substances like iron, arsenic, and fluoride in groundwater, through innovative management strategies to protect agricultural production.

Enhancing Productivity and Sustainability: Transformations in Livestock and Fisheries Research

Kamal Sarma, P C Chandran, M K Tripathi, Surendra Kumar Airhwal, Amitava Dey, Shanker Dayal, Reena Kamal, Rajni Kumari, Pradeep Kumar Ray, Jyoti Kumar, Tarkeshwar Kumar, Vivekanand Bharti, Pankaj Kumar
Division of Livestock & Fisheries Management

Background

This division started its journey in August 2003 as Livestock and Fishery Improvement and Management Programme (LIFM) with the joining of Dr. Amitava Dey. Soon, this program expanded, and four scientists and one technical staff joined. The activity in the LFIMP focused on Infrastructure development, including the Institute's main building, Livestock Farm, Land outline and development for fodder production, roads, etc. Due to the need to take up solution based challenges in the livestock and fisheries sector in the region, the LFIM program evolved to the formation of the Division of Livestock and Fisheries Management in 2009. The first selected head, Dr. D K Kaushal, joined this division in 2009 leading a team of five other scientists and technical and supportive staff. The creation of this division aimed to address the problem of low productivity in the livestock and fisheries sector in the region. This region had many challenges with demography, with 83% of rural households, 69 economically most backward districts, and about 40% of the population under BPL. These areas also had high livestock population density (224 number/km^2) compared to the national average (115 number/km^2). These regions also bestowed with large fishery resources in rivers, ponds and tanks, reservoirs, oxbow lakes, wetlands etc. However, both these sectors exhibited low productivity, with per capita milk production ranging 0.8-1.9 kg/d and fish productivity averaging 3.0 t/ha which was comparatively low compared to other parts of India.

The Division of Livestock and Fisheries Management has been actively engaged in diverse research areas aimed at enhancing agricultural and livestock productivity. With a total of 79 projects, the division focuses on improving livestock and poultry production, aquaculture management, and feed resources. It also conducts studies on disease surveillance, environmental stress management in fisheries and livestock, and livelihood improvement through integrated farming systems. Additionally, the division appraises and inventories natural resources to support sustainable practices in livestock and fisheries management.

Table 4.1 Heads of the Division of Livestock and Fisheries Management

S.No.	Head of Division	Designation	Tenure	
			From	To
1	Dr. D.K. Kaushal	Programme In-Charge	2003	2005
2	Dr B.P.S. Yadav	Programme In-Charge	2005	2009
3	Dr. D.K. Kaushal	Head	29/04/2009	31/01/2013
4	Dr. J.J. Gupta	Head	01/02/2013	30/06/2013
5	Dr. Amitava Dey	Head	01/07/2013	02/01/2018
6	Dr. Kamal Sarma	Head (In-charge)	03/07/2018	12/01/2023
7	Dr. Amitava Dey	Head (In-charge)	13/01/2023	14/06/2023
8	Dr. Kamal Sarma	Head	15/06/2023	Till date

Research Contributions

New breeds of livestock germplasms 'Purnea Cattle' registered

After detailed studies on Indigenous populations' characteristics and production performances reared in the eastern region, Purnea cattle and Maithili ducks were registered as 'New Breeds' in the Gazette Records of India. Selected milch animals from the Purnea cattle population had milk yield 5 to 6 liters per day, maintained only on dry fodder and available green grasses. The lactation yield and length were 658.77±5.87 kg and 183.81± 8.77 days, respectively. Purnea cattle are small to medium-sized cattle. The breeding tract has two different varieties of this breed based on their coat color (Fig. 4.1). The light gray coat colour variety constituted 63.8% of the entire population and the remaining 36.2% had a red coat colour. The skin, muzzle, eyelashes, and hoof were black irrespective of coat colours. The occasional presence of animals with pink-colored muzzles was observed in 6.7% of the population. More than 53.5% of animals possessed horns with lateral and forward orientation. The tail was black in colour and hanging beyond the hock joint. The animals' body trunk is diminutive in length and the legs compactly fit with the body. Bulls of Purnea cattle possessed medium to heavy humps, whereas Purnea cows had small to medium-sized humps. The nasal bridge is flat, and the face length is medium to long. The udder of the cows is compact and small in 85.8% of animals. Teats are cylindrical in 65% of cows and 93.4% of animals do not have prominent milk vein.



Fig. 4.1 Purnea cattle of different sexes and age group

Table 4.2 Mean and range of pooled body measurements (cm) for adult Purnea cattle

District	Body Length	Height	Girth
Araria (N=445)	111.56±0.38 (86.5 to 122.0)	112.23±0.28 (84.0 to 125)	128.13±0.31 (100.0 to 152.5)
Purnea (N=585)	114.21±0.35 (82.0 to 130.5)	114.56±0.26 (87.0 to 132.5)	134.07±0.32 (107.5 to 160.5)
Katihar (N=502)	110.33±0.37 (81.5 to 120.5)	109.87±0.27 (78.5 to 125.0)	127.12±0.32 (102.0 to 148.0)

New breeds of livestock germplasms submitted for registration

Diara buffalo

The breeding tract of Diara buffaloes is almost linear along both sides of the banks of the Ganges and its tributaries from Buxar to Bhagalpur district in Bihar and some extent in the territories of Jharkhand beyond Bihar.

Diara buffaloes were medium-sized, docile animals with black coat colour and loosely curved horns (Fig. 4.2). The study also revealed that 17.7% of animals possessed varying degrees of white markings on the forehead, and in carpal and pastern regions of forelimbs or tarsal and pastern regions of hind limbs or both limbs. The forehead of the Diara buffalo was distinct and marginally convex. The horns were typical, varying from 25 cm to 56 cm in adult buffaloes. The horns were oriented laterally downwards, then grew backward and curved forward with semi-coiled curvature at the tip. The tail twitch was generally black in colour. The height, length, and girth of female Diara buffaloes were 94.96±0.58 cm, 92.96±0.49 cm and 115.93±0.81 cm up to 1 year of age and 133.60±0.69 cm, 138.36±0.74 cm and 200.79±0.95 cm above 7 years of age, respectively. The estimated adult body weights of Diara buffaloes were 494.99±27.15 kg in males and 483.21±3.58 kg in females. Diara buffaloes are good milker with average per day milk was 7.8 L, and the mean peak yield reached 10.5 L/day. The estimated lactation length of these buffaloes was 354.48±4.56 days.



Fig.4.2. Diara buffaloes of different sexes and age groups

Seemanchali sheep

Detailed study on Seemanchali sheep (Fig. 4.3) indicated that the estimated population size of Seemanchali sheep was around 80000 as estimated by Livestock Census 2017. Chest girth was the highest body measurement at all ages, followed by height at withers and body length while all the body measurements were increasing at decreasing rate. Though the growth almost stopped till 6-teeth stage, there was some insignificant increase in all morphometric traits up to

full mouth stage.

The field study showed that the age at 1st mating and age at 1st lambing in Seemanchali sheep were 8.4 and 13.8 months, respectively. The lambing percentage in the flock was 72.5 whereas the lambing interval was found to be 11.2 months. Generally, an ewe was observed to give birth to a single lamb at one lambing with an occasional twinning. The lambing rate was estimated to 0.9.



Fig.4.3. Seemanchali sheep of different sexes and age groups

Characterized livestock germplasms of the eastern region

Bachaur cattle

The Bachaur breed of cattle was characterized by visiting 53 villages within 5 blocks of the Sitamarhi district of Bihar, which is their breeding tract. A total of 752 animals of both sexes belonging to different age groups were studied. The study revealed that the Bachaur cattle was a small-sized breed with height at withers, body length and chest girth were found to be 119.23±0.47 cm, 116.99±0.48 cm and 150.88±0.55 cm in adult males and 112.53±0.25 cm, 109.71±0.25 cm and 140.46±0.32 cm in adult females, respectively (Fig.4.4). The estimated body weights of Bachaur cattle were 246.76 ± 2.42 kg in adult males and 200.55 ± 1.32 kg in adult females. Among the draught breeds of India, the Bachaur cows were reasonably good milkers (Table 4.3). The breed is reported to be regular in the reproduction cycle with age at first calving and calving interval of 31.55±0.35 months and 14.44±0.22 months, respectively, in its breeding tract.



Fig. 4.4. Bachaur cattle

Table 4.3 Performance of Bachaur cattle in the breeding tract.

Traits	Mean	Range
Lactation yield (kg)	752.10±5.82	540 – 850
Peak yield (kg)	4.70±0.07	3 - 6
Lactation length (days)	258.79±2.26	220 – 280
Age at sexual maturity (months)	21.44±0.36	17 - 26
Age at first calving (months)	31.55±0.35	26 – 37
Calving interval (months)	14.44±0.22	12 – 17
Services per conception	1.23±0.06	1 - 3

Gangatiri cattle

The Gangatiri breed of cattle habituated in the Ghazipur and Balia districts of Uttar Pradesh and Buxar, Kaimur and Bhojpur districts of Bihar. The study was conducted in Itarhi block of Buxar district. The Gangatiri cattle are medium-sized cattle. The herd size of Gangatiri



Fig.4.5. Gangatiri cattle - Different sexes and age groups

cattle with the farmers ranged from 4 to 16. The coat colour of the cattle was light grey; however, the study witnessed 15.5% of cattle with dark grey coats (Fig. 4.5). The face was long and slender whereas the shoulder was compact. Horns were generally crescent in shape. Eyelashes, hoof, and tail switch were black in colour. The udder and milk vein were moderate in size.

The production and reproduction traits of Gangatiri cattle were analyzed. Considering its significant performance in the breeding tract, it is essential to undertake field level breeding and development program concerning Gangatiri cattle.

Ghungroo pig

The Ghungroo pigs are distributed in northern West Bengal and adjacent areas of Assam state. A field study was undertaken in 14 villages under the Alipurduar I and Alipurduar II blocks of Alipurduar district of West Bengal to evaluate the performance of Ghungroo pigs and to analyze the socio-economic characteristics of farmers rearing them (Fig. 4.6). The average body weights of Ghungroo pigs at 1, 3, 6, 9 and 12 months of ages were 7.12±0.12 kg, 18.20±0.23 kg, 45.67±0.28 kg, 81.04±0.33 kg and 92.58±0.68 kg, respectively. The average litter size was 11.18 at birth and 10.56 during weaning. Age at sexual maturity was 11.36 months whereas the interval between two parturitions was 5.12 months. The average herd size of the pigs available with the farmers in the study area was 1.7. The farmers mostly rear the pigs in a small herd size for the fattening purpose and sell them around 9 to 12 months of age. With a significant part of feeding being managed from household resources, Ghungroo pigs played a vital part in the tribal economy as they contribute 22% in the Gross Household Income.



Fig. 4.6 Ghungroo pig

Genetic variability of ducks of the eastern region

To explore phylogenetic relationship based on mitochondrial DNA sequence was done for ducks of White Pekin (WP), Khaki Campbell(KC), Maithili (M) breeds and Chhattisgarh duck. Mitochondrial genome NC_009684.1 was used from the reference assembly. The GC content in mitochondrial genomes of three breeds- WP, KC and M breeds was 48.64%, 47.6 % and 46.59 %, respectively.

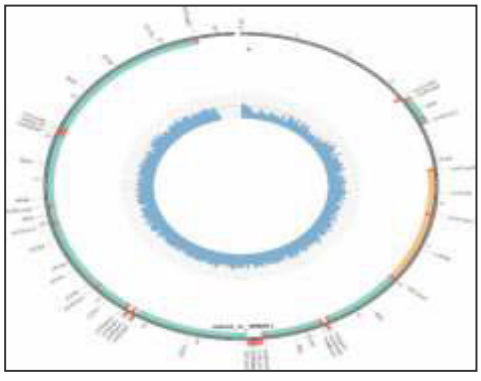

Fig. 4.7 Annotated mitochondrial genome of Maithili duck

Generation of mitochondrial genome map of duck germplasms of eastern India-complete mitochondrial genome sequences was characterized (Fig.4.7) and following GenBank accession numbers were obtained- Indian Runner duck (NCBI Accession No OQ561754), Khaki Campbell Duck (NCBI Accession No OQ561755), Chhattisgarh Duck (NCBI Accession No OQ561756), White Pekin Duck (NCBI Accession No OQ561757), Bihar duck (NCBI Accession No OQ561758), Bengal duck (NCBI Accession No OQ561759), Maithili Duck (NCBI Accession No OQ561759).

Faster growth in Sahiwal calves recorded

Sahiwal cattle were introduced to the institute farm to study the production potential and heat tolerance ability of Sahiwal in the Eastern IndoGangetic Plains (Fig. 4.8). The average daily milk yield of Sahiwal cattle was 9.3 kg. The average daily body weight gain of male calves upto 4 months of age was higher (227 g/day) compared to the body weight gain (203 g/day) in HF x Indigenous crossbred calves.



Fig. 4.8 Sahiwal breed Management

Optimal productivity achieved from Murrah buffaloes in eastern region

In order to improve the productivity of buffaloes, the institute is maintaining a herd of Murrah buffaloes with a herd strength of 90 animals. The project's objective is to assist in selecting elite Murrah bulls to improve milk productivity. Subsequently, the Network Project on Buffalo Improvement (NPBI) was initiated in the Insititute with funding from the network main centre, ICAR-Central Institute for Research on Buffaloes (CIRB), Hisar. The total herd strength of Murrah buffaloes during



Fig. 4.9 Herd of Murrah buffaloes at institute farm

2023-24 was 90, including 32 adults, 32 heifers and 26 calves (Fig. 4.9). The average lactation yield, lactation length, service period and inter-calving period of the herd during the Year 2023-24 were 2467.32±140.55 kg, 347.45±21.43 days, 129.07±22.54 days and 434.35±28.16 days, respectively. The project has also witnessed significant improvement in vital traits over the years.

Heat stress mitigation in buffaloes

Buffaloes have poor heat tolerance capacity compared to other domestic ruminants due to scarcely distributed sweat glands, dark body color and sparse hair on the body surface. A 503 bp fragment spanning 5'UTR and partial coding sequence and 2561 bp fragment spanning complete coding sequence of HSP 70 gene were amplified. Single strand confirmation polymorphism (SSCP) was used to study single nucleotide polymorphism in 503 bp fragment of heat shock protein 70 (HSP70) gene in Murrah and Diara buffalo breeds. Both Murrah and Diara were polymorphic for this fragment. Analysis of whole sequences of HSP 70 sequence revealed four alleles named A, B, C and D. We found that wallowing increases feed intake by 15%, milk yield by 12% in summer. Similarly, supplementation of sodium bicarbonate @ 30 mg in two equal doses per day in buffalo feed increases milk yield by 8% in the summer. Mustard oil supplementation (150 ml/d) also has a significant effect ($P \leq 0.05$) on milk yield in summer in buffalo.

Genetic basis of mastitis resistance in livestock explored

Transcriptome analysis was carried out to identify genes showing differential expression in animals suffering from subclinical mastitis. RNA was isolated from somatic cells in milk of three Murrah buffalo diagnosed with subclinical mastitis and three healthy buffalo as control. The average number of raw, processed, and mapped reads for six libraries were 51154816, 42049137 and 38995206, respectively. The mean mapping percentage against Bubalus bubalis reference assembly was 92.7%. The annotation of the transcriptome count table was created using the feature counts option of Rsubread package using the gene transfer format as a reference. Differential gene expression analysis revealed that 3482 genes showed differential gene expression in animals suffering from subclinical mastitis. Out of these, 2147 genes showed significant upregulation, whereas 1334 genes showed significant downregulation in subclinical mastitis, compared to healthy animals. IL12 B, SLA, CSF3R, CD177, THBD, ICOSLG, NCF1, SELPLG, IL3RA and CXCR2 are some of the important genes that showed significant upregulation in animals suffering from subclinical mastitis. KRT24, PIK3C2G, LALBA, CSN2, CSN3, CSN1S1, CD36 and CD59 are some of the common genes that showed highest downregulation in animals suffering from subclinical mastitis.

Early pregnancy diagnosis method in buffaloes developed

Investigation was carried out to employ whole blood sample as an alternate to peripheral blood mononuclear cells for studying expression profiling of select ISGs – ISG 15 (Interferon stimulated gene 15), MX 1 (Myxovirus resistance 1) and MX 2 (Myxovirus resistance 2) during peri- implantation period in artificially inseminated dairy buffaloes using SYBR green chemistry based quantitative real time reverse transcription PCR. Our results showed, transcriptional abundance of ISG-15 and MX2 genes were up regulated during periimplantation

period in buffaloes, but MX1 gene was found to be downregulated post day 18 of artificial insemination. We suggest that whole blood can be successfully used as PBMC surrogate for expression profiling of genes involved in maternal recognition of pregnancy.

Expression profiling of chemokine genes CCL 8 (C-C motif chemokine 8) and CXCL10 (C-X-C motif chemokine 10) as indicators of pregnancy observed in dairy buffaloes. Therefore, it can be concluded that expression profiling of CCL8 and CXCL10 can be used as a signature for pregnancy establishment, irrespective of the parity status of the animal.

Growth hormone and prolificacy gene explored for improvement in Black Bengal Goat

Two fragments 245 and 472 bp, of growth hormone gene were amplified and allelic variants were identified (Fig. 4.13). The least-square analysis revealed that 245 bp genotypes had a significant effect ($P \leq 0.05$) on birth weight, whereas 472 bp fragment genotypes had a significant effect ($P \leq 0.05$) on body weight. Animals with AC genotype had 47% more birth weight than those with CC genotype. Similarly, animals with AC genotypes had 65% more body weight than those with CC genotypes at 6 and 9 months. The BMPR1B locus in Black Bengal Goats revealed two genotypes- GG and GA and consequently two allelic variants A (wild) and G (mutant). Animals having homozygous mutant genotype for Fec B i.e. GG was found to have 2.1 kids per kidding whereas carrier animals i.e. heterozygous, GA, had 1.6 kids. Twinning % in homozygous mutant (67.66%) was much higher than the heterozygous carrier (54.75%) animals.

High prolificacy in Black Bengal goats

Bengal goats are known for their fecundity rate as most goats are twins and triplets, whereas quadruplets are reported sporadically (Fig. 4.10). In order to collect the baseline information, an initial survey was undertaken to study the production and reproduction performances of Black Bengal goats in Katihar and Purnia districts of Bihar. The result showed that the body weights of Black Bengal goats at the ages of 3, 6, 9, and 12 months ranged from 3.2 to 4.1 kg, 5.3 to 6.26 kg, 9.85 to 10.2 kg and 12.9 to 13.5 kg, respectively. Concerning reproduction traits, the age at 1st kidding and kidding interval varied from 395 to 440 days and 200 to 290 days, respectively. Total distribution of types of birth of high prolific Bengal-type goats was 75% singlet and 25% twins in primiparous goats, and 5% twins, 45% triplets, 40% quadruplets, and 10% quintuplets in multiparous Black Bengal goats. Women members of farmers' families played a proactive role (90%) in the rearing of goats.



Fig. 4.10 Quintuplets in institute goat farm

Improvement of Black Bengal goats under AICRP on Goat Improvement

The institute initiated the Centre for ICAR-All India Coordinated Research Project on Goat Improvement in 2018-19, in five clusters in Bihar, selected based on the Bengal goat population density. Under this project, 50 high-quality buck are distributed yearly in selected clusters for genetic improvement of the Black Bengal goat found in the field. During the year, the population growth in the selected villages expanded to 267.84 % with new additions of

breedable does and new births. The mortality rate was controlled within 3.15 % due to comprehensive vaccination efforts, deworming, timely therapeutic interventions, and awareness programs. A total of 4030 breedable female goats are available for breeding. The tupping percentage was 92.72 while breeding efficiency was 98.96% based on does tupped. A total of 7 multiplier flocks were developed. The average income of goat farmers from each goat increased from ₹ 3,482 in 2018 to ₹ 7,627 in 2023-2024.

Characterization of indigenous ducks in the eastern region

India is home to diverse indigenous duck germplasm. The present study characterized the phenotypic and morphometric traits of desi ducks from Odisha, Jharkhand, and Bihar, focusing on their unique attributes and management practices (Fig. 4.11). Ducks in Odisha, with small flock sizes (9–30), were reared under semi-intensive systems, relying on scavenging. Drakes and ducks exhibited significant morphometric differences, with average body weights of 1.80 ± 0.02 kg and 1.41 ± 0.02 kg, respectively. Jharkhand ducks, identified by their distinct black and white plumage, were well-adapted to local agro-climatic conditions, showing an average annual egg production of 66.92 ± 2.00 eggs. Maithili ducks in Bihar displayed a mosaic plumage pattern with annual egg production ranging between 50–60 eggs. Their average body weights were 1.40 ± 0.07 kg for drakes and 1.37 ± 0.08 kg for ducks. The study underscores these indigenous ducks' phenotypic diversity and adaptability, emphasizing their potential for genetic improvement and conservation.



Fig. 4.11. Indigenous ducks a) Odisha b) Bihar c) Jharkhand d) West Bengal

Characterisation of the backyard production system of duck in the eastern region

A study was conducted in the Eastern plateau region of India (Jharkhand, Odisha and Chhattisgarh) to evaluate the smallholder duck production systems in the region. A total of 251 duck farmers were selected for this study. The average flock size is higher in Chhattisgarh (11.76±0.60) compared to Jharkhand (9.51 ±0.67) and Odisha (9.47± 0.52).

The ducks were raised both for meat and egg purpose. The average annual egg production per duck in Jharkhand, Odisha and Chhattisgarh was ranged to be 50-70, 60-80 and 52-111 eggs per annum, respectively. The flock size is usually small, 7.27±0.49 to 9.51±0.67. In both Drake and Duck, the body carriage was slightly upright and the Bill shape was horizontal. The average adult body weight (kg) of Odisha, Bihar, Jharkhand and West Bengal of drake and duck were 1.80±0.02 & 1.40±0.07, 1.06 ±0.084 & 1.71±0.01, 1.41±0.02 & 1.37±0.08 and 0.950±0.079 & 1.58±0.02, respectively.

The Table 4.4 details a comparative evaluation of desi duck germplasm of Odisha, Jharkhand, Bihar, and West Bengal. Hen day egg production (%) up to 30th week of age recorded was higher in Khaki Campbell (45 %) followed by desi duck germplasm of Odisha (35%), Jharkhand (28%) and Bihar (27%). The hatchability percentage was higher for Khaki Campbell (70 %) followed by White Pekin (65%), Odisha desi (60 %), Jharkhand desi (60 %) and Bihar desi (55%).

Table 4.4 Comparative performance of indigenous (Desi) duck germplasm

Traits	Odisha	Bihar	Jharkhand	W. Bengal
Hatchability %	60	55	60	45
Day-old body weight (g)	37±0.37	35.8±0.29	35.9±0.34	35.8±0.28
Average daily gain up to 12 weeks (g/day)	8.49	5.64	5.75	6.08
Mortality % up to 12 weeks of age	8.5%	5.5 %	5.2%	6.05 %
Age at first lay (days)	165	163	175	165
Body weight at first lay (g)	1140±0.20	1120±0.2	1420±0.2	1390±0.11
Average annual egg production (nos.)	75-80	35-42	45-55	80-95
Egg weight (g)	52.90±2.4	46.60±0.37	46.93±0.32	47.28±0.4

Feeding system for backyard Kadaknath chicken production

The study evaluated the effects of earthworm and groundnut fodder on the growth performance of Kadaknath chickens reared in a backyard system. A total of 300 one-monthold Kadaknath chickens were divided into two treatment groups: T1 (commercial ration with a deep litter system) and T2 (natural feeding with earthworms, maggots, groundnut fodder, and broken rice under a backyard system), with five pens per treatment and ten chickens per pen. Over 28 weeks, chickens in the T1 group exhibited higher feed intake, while weight gain was nearly identical across both groups. The final body weight of the T1 group was significantly higher (1559.17g) compared to T2 (1368.50g), with T1 showing slightly better weight gain. Natural feeding systems with earthworms and groundnut fodder can be a viable, sustainable, and cost-effective alternative for backyard poultry systems.

Evaluation of chickens under the backyard system

This study compared the performance of Kadaknath, Vanaraja, and Grampriya chickens in a backyard system (Fig. 4.16). Kadaknath exhibited higher age at first laying (22 weeks) compared to Vanaraja (18 weeks) and Grampriya (20 weeks). Hatchability was recorded at 82% in Kadaknath, with a hatch weight of 30–35 g, whereas Vanaraja and Grampriya recorded higher hatchability (85.45% and 84.74%) and greater hatch weights (39.0–40.5 g and 35.0–38.2 g). Hen-day egg production up to 28 weeks was lowest in Kadaknath (35%) compared to Vanaraja (55%) and Grampriya (62%). Kadaknath had the lowest daily weight gain (6.55 g/d) and body weight across ages, while Vanaraja consistently outperformed both Grampriya and Kadaknath. Around 63,000 (nos.) of the germplasm of Vanaraja, Gramapriya and Kadaknath were

distributed to farmers as fertile eggs, chicks and growers to see the performance at farmers' field. There was 80 % hatchability in Vanaraja bird under natural incubation method by local desi birds. The study revealed that farmer preferred the Vanaraja poultry birds for their improved dual purpose, less mortality, coloured plumage with better growth rate, good eggs production and larger egg size.



(a) Vanaraja **(b) Gramapriya** **(c) Kadaknath**

Fig. 4.12 Prominent backyard chicken breeds

Glucosamine supplementation in poultry

The effect of glucosamine on egg-laying performance was evaluated in layer birds. Results showed that the age at first egg laying was 5 days less and gave the highest egg count in the first six months in the birds supplemented with glucosamine hydrochloride @ 10 mg/kg body weight compared to the control group. There was a significant increase in the plasma estrogen and leptin levels between 15 weeks and 22 weeks of age in birds, showing their role in attaining puberty.

Swarna Min- an area-specific mineral mixture for health and production

Soil-plant-animal continuum studies in 12 districts of Jharkhand across three agro-climatic zones indicated the deficiency (25 to 63%) of P, Zn and Mn in animal, soil and feed samples. Swarna Min Jharkhand, an area specific mineral mixture (ASMM), was prepared considering the deficient state. The formulated mineral mixture was evaluated in the Institute farm and farmers' fields (Fig. 4.13). This formulation has resulted in a 10% higher milk yield in cattle when compared with the milk productivity of cattle fed with commercially available mineral mixture. Milk production in cattle increased 15-20% when fed Swarna Min compared to milk production of cattle fed no mineral mixture.



Fig 4.13 ASMM for livestock

Phytase enhances the performance of crossbred pigs and Divyan Red poultry

The role of phytase on growth performance was studied using a feeding experiment for 80 days conducted on CB (Hampshire x Ghunghroo) male finisher pigs (16; 40.63±1.30kg body weigh (BW)) having 50% exotic inheritance at NRC on Pig, Rani, Guwahati. The study revealed that the levels of inclusion of rice polish with different doses of phytase enzyme supplementation did not exhibit any significant effects on the performance of finisher pigs. However, the highest average daily gain with better feed conversion ratio (FCR) and lower feeding cost per kg gain was recorded in pigs fed on rice polish at 50% level with one lac unit of

phytase enzyme. Rice polish can be fed up to 50% with 20g phytase (one lac unit/100kg feed) to finisher pig for maximum growth performance.

Similar experimentation on 40 days old Divyan red poultry (421±4.58g BW) revealed that supplementation of phytase in diets improved the daily growth rate of 18.38% with an improvement of 15.12% in FCR value in chicks than in the control group. It is recommended that the Divyan red bird be reared under a backyard farming system with zero inputs from the resource-poor (Fig. 4.14). In another study on broiler chicken, supplementation of phytase enzyme @ 20g/100 kg feed improved average daily gain by 2.25% and feed conversion ratio by 5.62% over a control group



Fig. 4.14 Divyan Red chicken

Round-the-year fodder production technology standardized.

Annual cereal and legume fodder were grown in 3.5 ha land for round the year production (Fig. 4.15). Multi-cut sudan as cereal and cowpea (Bundel-2), rice bean (RBS-16) and soybeans (NRC-37) as legumes were grown during the rainy season. Cereal fodder was grown in under 85% of areas, whereas legumes were grown in under 15% of areas only. The cereal fodder oat in 40% of the area and legume fodder berseem in 60% were grown on the same land during winter. The yield of perennial groundnut legume fodder, transplanted two years back, was recorded at 57.00±3.00 t/ha in three cuttings with inter-cutting gap of 55 days having DM and CP contents of 32.24 and 14.36 percent, respectively. The that total biomass production estimate of 67.90 t during rainy season and 51.99 t during winter season from one ha land area is sufficient to meet the fodder requirements of 14 crossbred cows year round. Thus, this type of fodder production system is beneficial for balance-feeding of ruminants.

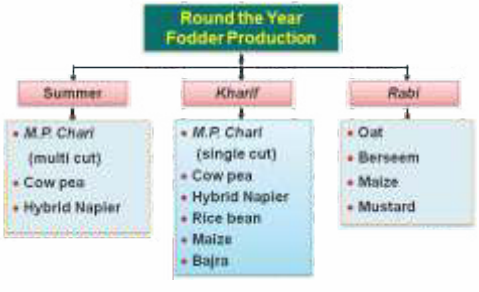

Fig. 4.15 Round the year fodder production

Productivity and quality of fodder under different land-use system

The relative performance of annual fodder crops viz. multi-cut sorghum, local sorghum, pearl millet, maize and cowpea were evaluated during Kharif 2016. Annual fodder crops were sown in the main field from May to June 2016, while Napier grass root slips were transplanted on bunds in June 2015. Fodder yield of different crops was recorded and its nutrients were analyzed (Table 4.5). Cumulative annual fodder yield from Napier var. CO3 from bunds was recorded as 300 t/ha. Hence, from a bund area (400 m2) of one acre of land, 12 t green fodder was harvested to meet the requirement of two adult cattle round the year (25 kg/d/animal). The performance of multi-cut sorghum was better due to more numbers of cuttings. Fodder productivity of legume fodder (cowpea) was recorded as 28.67 t/ha with almost

50% higher protein content than annual cereal fodder. Multicut sorghum and cowpea grown in combination (3:1 ratio of area) during the kharif season can provide good quality fodder of 49 t/ha, sufficient to meet the requirement of 16 adult cattle for balanced feeding @ 20 kg green fodder per day per animal for 150 days.

Table 4.5 Fodder productivity with nutrient content

Crop	Harvesting days	Fodder yield (t/ha)	DM (%)	Nutrients (g/100g DM)			
				CP	EE	CF	TA
Hybrid Napier *var.* CO3	50,90,140, 200,320	300.33±8.37	16.45	10.18	1.28	32.01	14.67
Multicut Sorghum *var.* Hybrid Gagan	70,110	55.60±1.06	22.96	8.64	1.38	36.93	7.52
Maize *var.* African tall	70	35.63±1.17	14.18	9.30	1.19	33.66	9.18
Pearl millet *var.* Bajra local	70	32.63±1.43	22.07	8.10	1.12	38.73	9.21
Sorghum *var.* Jowar local	70,110	36.10±0.13	22.08	7.85	1.19	34.18	9.44
Cowpea *var.* Bundel-2	70	28.67±0.37	14.53	13.12	2.24	24.53	9.91

Performance evaluation of various forage crops completed

Digestibility trials were conducted in crossbred heifers to study the nutritive value of berseem, oat, wheat, annual rye, maize and sudan forage crops. The individual forage was provided as sole feed to heifers for 21 days as an adaptation period and a digestibility trial was conducted for the period of four days. A set of another digestion trial was also conducted in buffalo calves using berseem and oat fodder to study the comparative nutritive values in cow and buffalo calves. Significantly, maximum dry matter intake (DMI) and crude protein digestibility (CPD) were recorded in heifers fed annual rye which was at par with wheat and berseem fodder. However, berseem fodder obtained the highest digestible crude protein (DCP) value. The nutritive values of maize and Sudan forage were lowest.

The nutritive value of berseem and oat in cow and buffalo calves indicated that berseem forage had significantly ($P<0.01$) higher DMI, CPD and DCP values than oat forage. Similarly, the DMI, DMD, CPD and DCP intake values were significantly ($P < 0.01$) higher in cow calves than buffalo calves. The nutritive value of berseem forage is better than the oat. The oat forage requires supplementation of legume forage to balance nutrient contents. The forage intake and nutrient digestibility are better in cattle than in buffalo calves.

Integrated fish farming techniques standardized

A study on integrated fish farming was carried out on cattle-fish, buffalo-fish, goat –fish, poultry–fish, pig- fish, duck-fish integration, and control in the institute fish farm (Fig. 4.16). The study was carried out in 7 identical ponds with a surface area of around 800 m2 . Advance fingerlings of six species ie. rohu (*Labeo rohita*), catla (*Catla catla*), mrigal (*Cirrhinus mrigala*), grass carp (*Ctenopharyngodon idella*), batta (*Labeo batta*) and puthi (*Puntius gonionotus*) were stocked in the fish pond at a stocking density of 10,000 number/ha. Manures were applied to their respective treatments based on intial nitrogen level.



Fig. 4.16a Integrated cattel-fish farming.



Fig. 4.16b Integrated goat-fish farming.

The four-year study found that the highest productivity of 4.57 t/ha/yr was from cattle-fish, followed by pig-fish integration (3.60 t/ha/yr). The data also revealed that the fish rearing with concentrate feed increased the fish yield (5.46 t/ha/yr). Net water productivity was also best in cattle, followed by pig-fish and buffalo-fish. When fish culture was done alone, net water productivity was the best, followed by cattle-fish and pig-fish integration. The plankton densities estimations under different integrations revealed that the annual average plankton density was highest in fish-pig integration (1194.44 number/L), followed by fish-cattle (1105.56 number/L) and fish-duck (1050.00 number/L) integrations and least in fish-buffalo integration (888.89 number/L).

Based on the estimation of ammonia, nitrite, and phosphate concentration in water, it can be concluded that livestock-based integration has not significantly deteriorated water quality parameters. Primary productivity and water quality management play vital roles in integrated aquaculture system. Gross primary productivity (GPP) was recorded as highest in fish-goat integration (0.18g C/m^3/h) followed by cattle-fish integration (0.16g C/m^3/h). Net primary productivity (NPP) was highest in fish-pig integration (0.10 g C/m^3/h) followed by cattle-fish integration (0.07 g C/m^3/h), while the respiratory quotient was higher in fish-goat integration (0.13 g C/m^3/h). Overall, the condition was more congenial in cattle–fish integration than in other integrations.

Impact of combined application of organic manure on fish production evaluated

Study was conducted using a combination of cattle and goat manure with fish as treatment 1 (T1) and cattle and duck manure with fish as treatment 2 (T2) and compared with treatment 3 (T3) provided commercial feed @ 3% body weight. Three species (catla, rohu, and mrigal) were stocked @ 7000/ha. The overall survival rate in T3 was maximum (81.1%) followed by T2, and the lowest survival (69.7%) was recorded in T1. A similar trend was also recorded in the case of overall production. From the study, it can be suggested that feed-based treatment showed the maximum fish production followed by cattle & duck manure combination.

Concentrated feed as major constrain in fish production can be reduced by use of manures by resource-poor farmers.

Water productivity for milk production in Gangetic plains evaluated

Addressing water productivity in farming systems has become a critical challenge in the context of a growing competition for water and land resources in the region. For the study, 3 districts across the Gangetic plains were selected having diverse cropping systems and crop livestock interactions. Hisar district from Trans-Gangetic Plains, Etawah district from Upper Gangetic and Bankura district from Lower Gangetic plains were selected. Water productivity for milk production varied from 0.46-0.77 L/m3 for buffalo, 0.61-0.73 L/ m3 for crossbred cattle and 0.03-0.42 L/ m^3 for local cattle.

The evaluation of livestock water productivity (LWP) at the district and household level indicated that there was a high potential to enhance water use efficiency in the crop-livestock systems of the Ganga Basin. Results showed that higher LWP gains might occur when interventions target the poorest households with low access to land and water and agricultural systems with lower livestock water productivity.

Water productivity of forage crops assessed

Study conducted at the institute farm revealed the water productivity (kg/m^3) of winter fodder maize, oat and berseem to be 13.35 ± 0.42, 12.54 ± 0.67 and 15.25 ± 0.23, respectively. However, the water productivities (kg/m^3 water) of summer fodder M P Chari, Sorghum Hybrid, maize and cowpea were recorded as 6.51±0.10, 8.50±0.09, 5.72±0.15 and 6.29±0.12, respectively. Significantly highest water productivity was recorded in berseem crop during winter season than maize and oat. Similarly, the significantly highest water productivity of multicut sorghum var. hybrid forage (8.50), DM (1.35) and protein (0.11) kg/m^3 was recorded during summer season. The protein water productivity was recorded similar for cow pea and multicut sorghum var. hybrid crop during summer.

Breeding techniques for Mangur standarised

The *Clarias magur*, popularly known as magur, is the most promising species among the catfishes for freshwater aquaculture in asian countries due to its high growth rate, efficient food conversion, high nutritional value, and high market price. Magur is naturally a hardy species and an obligatory air breather that can thrive in adverse ecological conditions. However, breeding and seed rearing of this species is major bottlenecks.



Fig. 4.17 Standardisation of bredding techniques of magur

The induced breeding of magur was carried out at an indigenously designed and standardised flow-through hatchery system. The induced breeding using Wova-FH® (analog of gonadotropin-releasing hormone) started with selecting potential brooders. In this technique, male fishes were sacrificed for the removal of the testis for collection of sperm suspension.

Generally, females become ready after 18 hours of hormone injection. Male brooders injected with @1.0 ml/kg of hormone showed the best performance as eggs freely oozed out without giving any pressure (Fig.4.17). Fertilization (70.23%) and hatching percent (85%) were also highest. A study was initiated to standardize the breeding performance of this species using the WOVA-FH® hormone. Results indicated that the total weight of stripped eggs and spawning fecundity were the highest ($p<0.05$) when females were injected with 1.0ml of WOVA-FH® hormone per kg of body weight. Hence, it is recommended that for breeding mature Magur, the highest spawning fecundity was observed with a dose of 1.0 ml of WOVA-FH® hormone.

Brood stock of *Labeo gonius* developed

Labeo gonius is an important minor carp available across the eastern region. Seeds are the major problem for this species' culture. Hence, an attempt was made to develop brood stock and standardize breeding technology. A healthy fingerling was stocked in cemented tank at different stocking densities. The best performance was recorded with stocking density 1/m³. Hence, it is recommended that the space requirement of broodstock fish of *L. gonius* should be at one number/m³. The average weight should be around 300 g and above for breeding purposes. Hormone WOVA-FH® can be used for breeding, and 0.6-0.8 ml/ kg and 0.3-0.4 ml/kg body weight for females and males are the best dose (Fig. 4.18). Spawning can be observed at 10-12 h after injection. Fecundity can be around 80-90 no/g of body weight. The better fertilization (75-80%) and hatching (65-75%) of fertilized eggs can be obtained for this species.

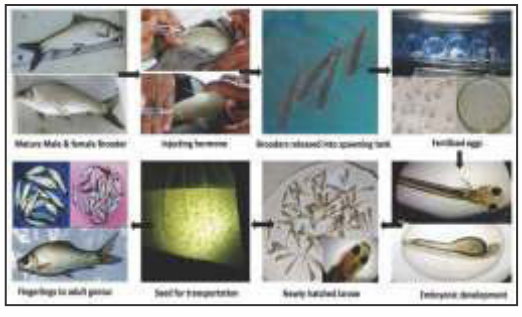

Fig. 4.18 Induced bredding and life stage wise development of *Labeo gonius*

Induced breeding and mass seed production of climbing perch standarised

Climbing perch, *Anabas testudineus* commonly known as Kawai is an important air breathing fish. Kawai is not popular for aquaculture due to the non-availability of quality seed and grow-out technology. Mature brooders were maintained in earthen pond and during breeding collected and maintained separately in the cement cisterns for easy manoeuvring the process during the monsoon season. Brooders were fed daily with a supplementary diet of 35% protein @ 5% of the total biomass. Males are slander, and milt oozes out upon gently pressing, while females exhibit outgrowth at the vent in the form of the genital papilla and have bulging abdomen. The selected brooders were injected with Wova-FH® synthetic inducing hormone @ 0.1-0.2 ml/kg (male), and 0.3-0.4 ml/kg (female). It was observed that spawning starts after 10-12 hr and hatching 24-26 hr of hormone injection (Fig.4.19). The total fecundity was around 380-400



Fig. 4.19 Induced breeding and seed production of Kawai

no./g of body weight, and 66% fertilization and 70% hatching of fertilized eggs were obtained. This technique can be easily adopted by the farmers and can produce copious quantities of hatchling, which can be reared for production of stocking materials.

Techniques for induced breeding of *Labeo bata* standarised

The objective of the study is to standardize the breeding protocol and rearing practices of Labeo bata and to evaluate the performances in different fish farming system. *Labeo bata*, locally called as Bata belongs to the Family Cyprinidae (Fig.4.20). Breeding trials of Bata was taken induced using Ovaprim® @0.3ml for female and 0.1 ml for male per kg body weight. The hatching of larvae took place between 5-6 hours after ovulation at 27-28°C in all the breeding trials. The highest percentage of hatching was recorded at 84.00% and the lowest at 39.67%. Approximately 20 lakhs fish spawn seed have been produced for further rearing them to stunted fingerling. Regular water quality and sampling were done to monitor and assess the growth and maturation of *L. bata*. Average fish production was 3.625 t/ha.



Fig. 4.20 Minor carp *Labeo bata*

Formulation of enriched diet to achieve higher growth and survival

Feed formulation for *Labeo rohita*

High cost and scarce availability of fish feed for the production of carps limits production. A feed formulation was made to improve the quality of locally available feed ingredients with fortified with supplements like vitamin C and minerals. The best survival rate (76%) was recorded when feed was supplemented with vitamin C and mineral (Zn, Cu and Mn) supplement. The fortified diet reduced the cost of production (38.4%) and resulted in higher revenue generation (152.6%) compared to commercial feed.

Magur rearing with varying protein level standarised

Seed raising of magur is cruicial for its rearing, so the technique was standardised. After the yolk-sac absorption (3rd day), hatchlings were fed with the milk powder, boiled egg and powdered supplementary feed twice a day and water exchange was done to remove the uneaten feed and other waste materials. We reared them from the 8th day of hatching to 120 days at 500 L FRP tanks. Magur fry was fed ad libitum with combination of live plankton, fined meshed egg custard, fishmeal-based starter feed (38-40% protein) as well as fishmeal based commercial sinking pellet feed (30–35% protein; 6–10% lipid) at different stages and different rates. The average weight at the end of 30, 60, 90 and 120 days was 0.085 g, 4.47 g, 11.77 g and 23.77 g, respectively with an overall survival rate was 26%. Further rearing of fingerling to production of juvenile fish study was conducted for 90 days with different formulated feed from 20%, 25%, 30%, 35% and 40% protein levels, prepared using locally available feed ingredients. The study found that percentage growth increment, specific growth rate and daily weight gain were better at 35% protein level.

Feed formulation for *Labeo gonius* standarised

Minor carp species can be considered an alternative to the cultivable major carp species for diversification in freshwater aquaculture. The growth performance of fries was determined based on supplementary feed (SF) and traditional feed (TF). Four types of feeding were used: SF @ 5% and 10% body weight and TF @5% and 10 % body weight. The fry of *L. gonius* (0.067±0.005g and 19.11±0.37 mm) @ 300 numbers was stocked in each tank. It was found that pelleted feed with 38% protein level @ 10% body weight showed better growth performance. Similarly, Fingerling rearing of minor carp, in each tank was attempted. In fingerlings @ of 240 numbers fry (9.9±0.07 g and 89.23±0.21 mm), SF with a 32% protein level @ 10% body weight showed a better growth rate and survival percentage (Fig. 4.21).



Fig 4.21. *Labeo gonius* after 100 days rearing

Composite fish culture for livelihood improvement

Grow-out technology of freshwater prawn culture under polyculture system standarised

Grow-out technology of giant freshwater prawn (*Macrobrachium rosenbergii*) aims at a sustainable production of 1.5t/ha/crop. This technology involves an initial nursery phase for a period of two months followed by a grow-out phase of six months. The grow-out pond is often stocked with post-larvae, which usually lead to poor survival and hence low yield. Therefore, a nursery phase of 45-60 days is advocated prior to the grow-out phase for successful farming. Mixture of groundnut oil cake and fish meal in the proportion 1:1 is used as supplementary feed. Freshwater prawn was stocked @30,000 PL/ha and prawn after 240 days of rearing in polyculture attained an average weight of 94 g and size of 184 mm (Fig. 4.22).



Fig. 4.22. Prawn harvest from earthen pond

In another similar study, an earthen pond of 1000m² was used. The pond was sundried followed by water filling and liming @ 15 kg/0.1 ha. The pond was initially manured using 100 kg of cow dung followed by mixture of rice bran (5kg), agrimine (100gm) and DAP (0.5kg) etc. The plankton develop after 4-5 days of manuring. Stocking was done in the month of April @ 5000 nos./ha of fish Catla and Rohu (135g) and 20,000 nos./ha (0.005g) of prawn seeds respectively. Feeding was done with Starter 1 feed @ 100% body weight of prawn till they attain the body weight 1 g and floating feed @ 4% of the body weight was used for feeding of Catla & Rohu. Monthly length-weight data were collected for growth analysis and health management of prawn and fish. During the 150 days of culture period, Catla attained a size of 1053 gm while Rohu attained 760.75gm and prawn attained 49.66 gm. At the end of culture catla, rohu and prawn gave production of 1580 kg/ha, 1160 kg/ha and 638 kg/ha, respectively.

Composite fish culture to evaluate growth and survivability

An experiment was conducted to evaluate the growth, survival, and recovery percentage of different fishes in the mixed culture system. Stunted fingerlings of *Catla catla, Labeo rohita, Cirrhinus mrigala, Ctenopharyngodon idella,* and *Puntius gonionotus* at the combination of 35:30:20:7:8 were stocked at the rate of 10,000 numbers /ha. Commercially available sinking pelleted supplementary diet was provided @ 2% of the body weight having 22% crude protein. The highest average body weight obtained for grass carp (2.5 kg) but maximum recovery percentage of 93.25% recorded for *Labeo rohita*. Total fish production in polycuture was 5.01 t/ha/yr.

Plant-based feed: Evaluated forage crops in grass carp

Grass carp (*Ctenopharyngodon idella*) though feed mostly on aquatic vegetation, many times sufficient qualities of aquatic vegetation are not available (Fig. 4.23). To compare the performance of forage crops vs. aquatic macrophytes, a study was performed in earthen ponds. Fishes in one Pond 1 were fed with forage crops, chopped Napier grass (*Pennisetum purpureum*) from June to November and chopped berseem (*Trifolium alexandrinum*) from January to May. Similarly, fishes in Pond 2 were fed with Azolla (Azolla pinnata) and Lemna (*Lemna minor*) during the period June to November and January to May, respectively. The application of forage and aquatic macrophytes had no significant effect on the fluctuations in the water quality. Moreover, results also revealed that fish survival is not much affected by these sets of plants as a feed material for grass carp and estimated fish production of 6.0 t/ha can be achieved by feeding Napier grass and berseem. The finding suggests that aquaculture of grass carp with Napier and Berseem grass at 10% of the feeding rate delivers better production than similar use of Azolla and Lemna.



Fig. 4.23 Grass carp harvested

Biofloc technology: Exploring production and economic viability

Biofloc unit of a capacity of 5,000 L/tank was established (Fig. 4.24). Freshwater prawn, Macrobranchium rosenbergii and minor carp Labeo gonius were stocked and cultured under different stocking combinations such as; fish and prawn together; monoculture of prawn and fish. The C: N ratio for better floc activation was maintained between 10:1 to 15:1 by adding carbon source jaggery. The feeding in the biofloc tanks was managed by providing floating feed @ 2% of the total culture biomass. It was observed that the fish and prawn combination performed better in growth, SGR, and FCR. Each tank recorded a monthly biofloc concentration of 2.10-11.59 ml/L.



Fig. 4.24 Biofloc exprimental unit

Standardised rearing of striped snakehead fry in cement tanks

Channa striata (striped snakehead) brood stock was collected from nature and maintained in the institute earthen pond (Fig. 4.25). Natural breeding was stimulated by manipulating fertilization and optimum feeding.



Fig. 4.25. Advance fingerling of *C. striata*

During the rainy season (July) fishes were breed naturally. A total of 300 advanced fry (53.6±1.57 mm & 1.17±0.20 g) were collected from the pond in the month of August 2023 and stocked in the cemented tanks (5 × 5 m²). Before stocking the fish, the cement cistern were layered with about 10 cm soil bed to provide a natural environment for the fish. Water depth was maintained at about 0.5 m throughout the rearing period and slowly increased as the fishes grew. The experimental fish fries were fed daily in the morning at 5% body weight with formulated feed (20% crude protein) along with chopped chicken waste and trashed fish ad lib. The monthly weight gain and mortality percentage of fish during the cultured period were recorded. Fish attained a weight of 124.36±1.94 mm after 132 days of rearing with 78% survival.

Optimisation of salinity tolerance level in freshwater fish

The study was undertaken to investigate the effects of short-term and long-term exposure of the species to various salinity levels on growth, survival of Rohu and Catla fingerlings under laboratory conditions. At the end of 90 days of exposure, it was found that the average weight gain was maximum at 0% followed by 2.5%, then 3.5% and the least at 4.5% in both Rohu and Catla. It can be concluded that with increase in salinity, the survival rate, growth and tissue ascorbic acid level in Rohu decreases and Catla can be reared in low saline (up to 3%) areas for some time, which will not only help in the utilization of salt-affected areas.

Identification of freshwater ectoparasite, *Argulus foliaceus* in Rohu

Classical morphology and DNA barcoding were used to identify the freshwater ectoparasite in rohu under NSPAAD project. Morphological attributes of the parasites were studied by light microscope (LM) and Scanning Electron Microscope (SEM) which showed dorsoventrally flattened body comprising of head, thorax, abdomen, a pair of large compound eyes, suctorial organs with sclerotised support structures and two openings of spermatheca at posterior end (Fig.4.26). Posterior incision of abdomen do not reach the mid-line and the cephalo-thoracic carapace have not extended beyond the beginning of abdomen. Further validation was done using molecular tools for accurate parasite identification. The mitochondrial cytochrome c oxidase subunit 1 (COI) sequences of *A. foliaceus* formed one cluster with the present studied samples, integrating morphological and rapid DNA barcoding tools, the species was delineated as *A. foliaceus*.



Fig. 4.26 Fish ectoparasite Argus under (a) LM and (b) SEM

Biological parameters of freshwater *Lamellidens marginalis* and *Pila globosa*

Lamellidens marginalis, the most commonly available freshwater mussel, is widely distributed in Bihar's ponds and derelict water bodies (Fig. 4.27). A growth study was also conducted for 160 days to record the performance of this species when reared at the subsurface and bottom of a fish pond. Crude protein, fat, ash, and moisture content in the flesh were 7.19, 1.64, 3.70 and 83.92%, respectively. Among essential amino acids, lysine was most abundant; low levels of isoleucine were recorded, while glutamate was dominant among non-essential amino acids. Moreover, 32 fatty acids were recorded in the mussel, including omega-3 fatty acids like eicosapentaenoic acid and docosahexaenoic acid. Length-frequency distribution revealed that more than 50% of male and female specimens were within 35 to 45 mm in length. Females have significantly longer shells and are heavier than males. The length-weight relationship indicated that the species had negative allometric growth.



Fig. 4.27. Harvested *L. marginalis*

Biometric traits of five indigenous fish species from the river Ganga

Study generated baseline Biometric traits data of five indigenous fish species, the *Barilius barila, Cirrhinus reba, Chanda nama, Mystus bleekeri*, and *Clupisoma garua*, belonging to the families, Danionidae, Cyprinidae, Ambassidae, Bagridae, and Schilbeidae, respectively. A total of 557 fish individuals were collected seasonally from the stretch of river Ganga using a monofilament drift gill net and a conical trap net Khairel jal. In morphometric analysis, the highest degree of correlation was observed between the total and standard lengths for all species (except *C. garua*). The fish and otolith morphometrics showed a positive correlation, and the highest coefficient of determination was observed between total fish length and otolith weight followed by fish length and otolith length. All of these relationships are significant to fisheries management and useful for future time series studies on food-feeding habits, stock structure, environmental change and resource conservation.

Prevalence of animal diseases documented in Eastern region

Viral diseases of Goat



Fig. 4.28 a. Congested eye (PPR)



Fig. 4.28b. Necrotic ulcer in oral cavity

A total of 12 districts were surveyed in all the four agro-climatic zones of Bihar for serosurveillance of goat viral diseases, and 855 samples were collected. The overall prevalence of PPR in Bihar was 34.39%. Sero-surveillance of PPR antibody indicated very low prevalence in kids of age group <5 months. The highest circulating PPR antibody recorded in non-pregnant goats, with a non-significant difference between genders. The seroepidemiology of the Bluetongue virus (BTV) antibody indicates a prevalence of 14.68% in Bihar. Gender had a nonsignificant difference for BTV seropositivity. Few goats were positive for both BTV and PPR. CAE antibody was generally absent in Biha goats except for two seropositive. These two positive Sirohi goats had a recent history of purchasing goats from Rajasthan. PPR is the most devastating contagious disease of goats. The four outbreaks were reported in 2010, each in Patna, Motihari, Supaul, and Jehanabad districts. The various signs recorded in animals in natural disease were high fever (105°-106° F), erythema of oral mucosa, conjunctivitis, nasal discharge – which was initially serous and later turned to mucopurulent, respiratory distress characterized by labored breathing, dyspnoea and coughing followed by diarrhoea (Fig.4.28). Less commonly observed signs were necrotic lesions in the buccal mucosa, lips, and dental pads. These outbreaks had morbidity ranging from 65-100%, and the mortality ranged from 55% to 71% in different flocks. The concurrent prevalence of PPR and BT viruses was 15.60%. These findings suggest that PPR and Blue Tongue are epizootic to Bihar state. Serum antibodies indicate that PPR and blue tongue viruses are concurrently present as natural infections in field animals.

Subclinical mastitis in lactation cattle



Fig. 4.29. Screeing using CMT reagent

The subclinical mastitis in crossbred cattle of peri urban areas of Bihar, Jharkhand and Eastern UP. Screening was done based on a modified California Test (CMT), followed by bacterial isolation and culture sensitivity testing. The prevalence of subclinical mastitis was 38.57% and 39.42% in the peri-urban cattle of Bihar and Jharkhand, respectively. The prevalence of subclinical mastitis was 27.27% animal-wise and 8.18% udder-wise in the peri-urban cattle of Eastern Uttar Pradesh. The incidence pattern of SCM teat wise was maximum in left hind followed by left

fore and then right hind and right fore. Validation of Modified CMT reagent with conventional CMT regent for SCM detection (Fig. 4.29). The reagent was modified by replacing Teepol (Sigma) with the commercially available detergent Ezee® (Godrej) to make the reagent cheaper. It validated the results with anionic detergent Teepol® (Sigma-Aldrich) based CMT reagent. The Cohen's Kappa coefficient for measuring the reliability of modified CMT with conventional CMT was 0.7, indicating a substantial measure of agreement.

The result of the clinical trial of feeding 100 gm dry powdered curry leaves and 30 gm dried powder of Methi (Fenugreek) seed for 10 days orally as supportive therapy in CB cattle with SCM provides evidence of ameliorative potential for its use as an adjunct therapy. The observed outcome may be attributed to its anti-oxidant, as evidenced by its levels in milk and blood and possible anti-inflammatory potential.

Respiratory viral diseases of calves

Calf mortality is a perennial problem for cattle farmers worldwide. Diseases that cause mortality in calves result from a complex interaction between infectious agents, environment, management practices and calf immunity. The study's objective was to study the disease pattern in bovine calves from birth to 1 year old and the epidemiology and pathology of important viral respiratory diseases in calves. The diseases affecting cattle and buffalo calves were recorded up to one year of age. Out of 134 calves examined, 34 (25.37%) calves were affected with diarrhea, 22 (16.41%) calves showed respiratory disease symptoms, 17 (12.68%) with naval ill or joint ill, 2 with scabies (1.49%) and 26 with pyrexia of unknown origin (19.40%), 4 calves (2.98%) with coccidiosis 3 (2.23%) calves with urinary tract obstruction, 7(5.22%) calves with FMD lesions, helminthic parasites in 16 animals (11.94%) and three calves (2.23%) were affected with injury. PCR technique was standardized for the detection of bovine Coronavirus using Pan-Corona primers CorFW and CorR. All samples were found negative by PCR for bovine paramyxoviruses and coronaviruses.

Brucellosis and *E. coli* infection in goat and cattle

The objective of the study was to determine the current status of Brucellosis and shiga toxin producing *E. coli* in Bihar under outreach programme on zoonotic diseases. Sero prevalence of Brucella in cattle and goat was determined in selected districts of Bihar based on indirect ELISA and Rose Bengal Plate test respectively. Sero-prevalence of Brucella in cattle samples from 11 districts of Bihar was 6.28% of samples from a total of 1242 bovine samples. Highest seroprevalence was in agro-climatic zone III B. The sero-prevalence of Brucella in goats was determined to be 4.14% (30/723) of the samples. Standardization of PCR Assay for detection of Shiga- Like Toxin Producing E. coli (STEC) using primer pair for verototoxin gene which identifies common verotoxins. A 518 bp product was obtained after amplification in the samples positive for STEC organisms.

Milk and faecal samples were collected from cattle and buffaloes for isolation of *E. coli* and were serotyped based on Somatic antigen (O). A total of 19 serotypes were identified based on somatic antigen. The *E. coli* isolates were typed based on the shiga toxin production and type of shiga toxin produced. Out of 101 isolates, 50 isolates were found to be positive for Shiga toxin production (49.5%). Of these, 31 isolates were positive for production of Stx 1 (30.69%), 33

isolates were positive for production of Stx 2 (32.67%) and 14 isolates were both producing Stx1 and Stx 2 (13.86%).

Animal health interventions and economic losses from animal diseases

The project was initiated based on the need to undertake field level study to record epidemiological data of animal diseases by undertaking animal health camps (24 camps) at a regular interval (at least two/year) in selected villages (8 in Bihar and 4 in Jharkhand) and estimating economic losses related to PPR in goat and mastitis in cattle. Health care and prophylaxis for livestock in deprived areas of Bihar and Jharkhand were undertaken, which reduced the outbreak of important animal diseases like FMD, HS, BQ, PPR, and Brucellosis. A total 2028 animals were screened and provided interventions. An average loss of ₹1283.00 per PPR affected goats was estimated. The major loss (37.35%) was due to the mortality of goats in PPR. The total cost of losses from mastitis in milch cattle was estimated to be around ₹ 480.0 million, contributing to losses from depreciation (38%), production (32%) and treatment (30%) losses.

Therapeutic management of tropical Theileriosis in Bihar

More than 1000 samples were screened for bovine theileriosis using Giemsa-stained blood and lymph node aspirate smears. The presence was confirmed by finding piroplasm in RBCs and Macroschizonts in lymphocytes, commonly known as Koch's Blue Body. Random blood sampling had a prevalence of 34.25% infection of Tick borne disease (TBDs). Higher numbers and incidences of TBDs infection in the rainy season, followed by summer and least in the winter season, were observed depending on tick cycle (Fig.4.30). Combined with Furosemide, Buparvaquone is better for Theileria-infected cattle with respiratory distress and supports antioxidants.



Fig. 4.30 Ticks larva of *Hyalomma* sp.

Further, they were confirmed based on Genomic DNA isolation and specific PCR amplification of the organism and characterization based on sequencing. Bovine theileriosis in the region is due to two species of Theileria, i.e. *Theileria annulata* and *T. orientalis*. PCR amplification with subtype-specific primers, the circulating T. orientalis subtype in the cattle population of Bihar was found to be chitosi, which is considered a pathogenic type. Early confirmation of these co-infections, a novel multiplex PCR was developed to detect *T annulata, B bigemina* and *A. marginale* simultaneously in single PCR amplification. This multiplex PCR was sensitive with the ability to detect the presence of 150ng of genomic DNA.

The limitation of molecular diagnosis for large-scale field studies related to time and cost was felt. An indirect enzyme-linked immunosorbent assay (ELISA) kit was developed using partial r-Spm^2 antigen that exhibited high sensitivity (100 %) and specificity (90.9 %). Thus, it can be used as a diagnostic antigen for sero-epidemiological studies of *T. annulata* infection.

Antimicrobial drug resistance in bacteria of animal origin assessed

A total of 110 *E. coli* were isolated from fecal samples collected from cattle and buffaloes. Tentatively identified *E. coli* isolates from fecal samples were confirmed by PCR amplification of 187 bp uidA gene. Similarly, isolation, identification and characterization of *Staphylococcus aureus* was done from 41 milk samples. All the 22 culturally identified Staphylococcus aureus were confirmed by 279 bp amplicon of nuc gene. The *S. aureus* was coagulase positive as visualized by amplicon of ≈700 coa gene on PCR. In AST of S. aureus isolates, all isolates were found to be resistant to ampicillin, enrofloxacin, polymixin-B and penicillin-G. 59 % showed resistance to amoxyclav and quinolones (ofloxacin, norfloxacin and ciprofloxacin), and 50 % were resistant to Amoxicillin. Laboratory based antimicrobial sensitivity profile of *E. coli* isolates revealed that more than 40 % were multidrug resistant strains and mostly resistant to commonly used antibiotic drugs. Out of 134 tested, 49 (36.5%) *E. coli* were phenotypically confirmed Extended Spectrum β-lactamases (ESBL) producer strains as tested by Double disc synergy test. In genotypic study, amr genes relevant for ESBL production like TEM, SHV and CTX, integrons and sulI were assessed in *E. coli* isolates. In the present study on ESBL phenotypes of E. coli, 113 (84.3%), 61 (45.5%) and 55 (41.1%) were positive for TEM, integron I and sulI, respectively.

Environmental arsenic exposure in animals of Bihar

Arsenic contamination in Indo-Gangetic Plain's groundwater is considered a constant threat to life sustained on it. Animals in these areas are exposed to arsenic-contaminated feed and water, slowly affecting their health and production. We are assessing arsenic toxicity's sources, extent, and impact on animal health and production. Samples were collected from hot spots of arsenic in groundwater of Bihar for evaluating arsenic concentrations in drinking water and fodder and biological samples from affected animals (Fig.4.31). The mean level of arsenic (µg/L) in the water samples from the Bhojpur and Saran districts were 27.73±5.63 and 46.48±9.34, respectively, and were higher than the maximum permissible limit of 10µg/L recommended by WHO. The mean level of arsenic (µg/L) in milk, blood, and urine samples of cattle of Bhojpur was found to be 66.96±9.72, 159.91±22.03 and 105.33±46.79, respectively.



Fig. 4.31. Urine sampling

Status of fluorosis in livestock of Bihar

Extended exposure to fluoride in animals can result in toxicity, leading to adverse health outcomes and the onset of fluorosis. WHO prescribes arsenic in drinking above the permissible limit of 1.5 ppm as toxic. Bihar listed as a category III fluoride endemic state (>50% of the districts affected) in India. A total 11 districts of Bihar report high fluoride concentrations in groundwater (Fig. 4.32). Water samples, cattle blood, and urine from reported sites in the Nawada, Jahanabad, Gaya, and Munger districts of Bihar were collected for the study. We

observed that animals suffered from dental and osteal fluorosis due to fluoride-contaminated water. The fluoride levels in groundwater ranged from 0.6-9.74 ppm. Affected cattle had visible symptoms of chronic fluorosis with serum levels ranging from 0.01-0.39 and in urine 1.86-39.75 ppm. 36.8% of animals in the studied region had serum levels higher than 0.2 ppm and 54.7% had urine fluoride levels greater than 5.0 ppm. Ameliorative properties of *Spirulina platensis* in calves afflicted with geogenic fluorosis was studied and found beneficial.

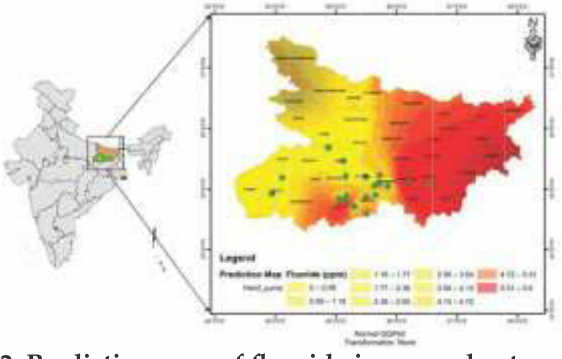

Fig.4.32. Prediction map of fluoride in groundwater of Bihar

Microplastics in the Ganga river system

Water, sediment, and fish samples were collected and analyzed to assess the severity and prevalence of microplastics in different regions of the Ganga, Sone, and Punpun rivers (Fig. 4.33). The sediment samples collected from the Ganga River exhibited high concentrations of microplastics, with an average of 553 particles/kg. The Punpun and Sone rivers recorded 376 and 301 particles/kg, respectively. The Ganga River had an average concentration of 364 microplastics/L, while the Sone and Punpun Rivers had concentrations of 223 and 180 microplastics/L, respectively. Most microplastics were classified as films, pellets, beads, and fibres.

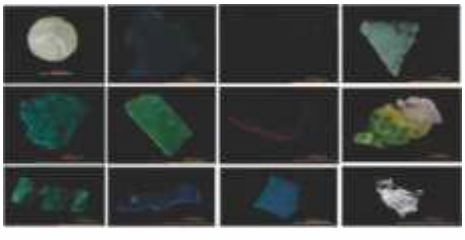

Fig. 4.33 microplastic sampled

Evaluation of diara land farming for sustainable food production

A study was undertaken to evaluate the sustainable food production system in diara land of Bihar. "Diyara" or "diara" denotes the flat, riverbank areas created by the accumulation of silt alongside riverbanks. These zones experienced occasional flooding which contributes to the enrichment of the soil with nutrients. In the present study, 3 sites of Ganga river (Buxar, Saran and Begusarai) and 2 sites of Gandak river (East Champaran and Vaishali) were selected (Fig. 4.34). Mean elevation of river bed diara and upland diara are about 49 m and 51 m, respectively in Gandak river at Hajipur. The total



Fig. 4.34 River bed Diara and Diara upland

diara land, including both riverbed and upland diara, in Bihar's Gandak River basin is determined to be 56,304 ha. The distribution of diara land along the Gandak River in Bihar is illustrated in Fig. 4.34.

Unlike other cultivated land, Microscopics detected in different rivers agricultural activities in upland diara commence in early November, taking advantage of the river's early water recession. Whereas farming in the riverbed diara begins after second fortnight of November. In the upland diara, wheat is the predominant crop cultivated by farmers, supplemented by other crops such as mustard, potato, and winter vegetables. Conversely, watermelon takes precedence in riverbed diara, accompanied by crops like sponge gourd and cucumber. The diara cropping season concludes in May or early June. To protect the crops from chilling winter in riverbed diara, farmers used to give thatch the crop in east-west direction. The material used for thatching is the dry khus grass (*Chrysopogon zizanioides*), naturally grown in river bank. It has been observed that in riverbed diara, where the sand content is relatively higher, farmers prefer cultivating watermelons exclusively. In the upland diara, the initial irrigation for crops is done using the water left in the abandoned river channels. Farmers who have irrigation facilities at their home provide a second irrigation, while other farmers rely on residual soil moisture. In upland diara, farmers supplement the plant's nutrition requirement by adding Farm Yard Manure (FYM) and inorganic fertilizers. Due to the high sand content, crops are sensitive to water. Initially, when the plants are small, river water meets water needs, and manual irrigation is provided. Farmers dig a 10-15 cm depth channel alongside each plant row, adding fertilizers (poultry manure and other inorganic fertilizers) to it and mixing it with the soil. The purpose is to encourage crop roots to extract nutrients and water from the channel. Since groundwater in riverbed diara is shallow, especially during the summer months when the groundwater depth decreases, farmers deepen the channels and continuously add fertilizers, mixing them with the soil.



Fig. 4.35. Distribution of Diara land along Gandak river

Improving the livelihood security in Salt-affected watersheds

Salt-affected soils are an important ecological entity occupying 6% of the global land are 2.6% of the geographical area in India. Bihar also has a large area under salt-affected soil (0. 37 m ha), around 12 % of the total Indo Gangetic Plain area. Utilization of the salt-affected areas for productive purposes is the region's major challenge. To assess the present condition soil and water samples were taken during dry season for analysis under NAIP component 3 projects. Rohu is that region's most widely cultured species. At the initial phase, adopted farmers had little knowledge and interest in fish farming. After continuous interaction and through awareness campaigns, many farmers repaired and renovated their existing pond and started fish culture activities (Fig. 4.36).



Fig. 4.36. Before and after intervention

Technologies Developed

1. Process: Method for serological diagnosis (Indirect ELISA) of *Theileria annulata* using recombinant spm2 antigen - ICAR-AS-RCER-Process-2023-105
2. Identification of CCL8 and CXCL10 as early pregnancy biomarker in buffaloes -ICAR-AS-RCER-Technology-2023-106
3. Area Specific Mineral Mixture "Swarna Min" for Dairy Animals Technological intervention in increasing herd health and production in livestock
4. 'Purnea Cattle' is registered as a separate cattle breed in the Gazette Records of India, adding to our country's breed repository.
5. 'Maithili Duck' is registered as a separate duck breed in the Gazette Records of India, adding to our country's breed repository.
6. A novel, rapid, and specific multiplex polymerase chain reaction was developed to diagnose haemo-parasitic infection in bovine blood co-infected with three of the most common haemo-parasites standardised and published.
7. The spectrum and nature of tick-borne infections in buffaloes explored and analysed the associated risk factors, including the role of acute phase protein, oxidative stress, etc.
8. HSP70 as a molecular marker for identifying animals prone to heat stress in Gangatiri cattle and Murrah buffalo
9. Mitochondrial genome characterization of duck germplasm inhabiting the eastern region of India
10. Transvaginal color doppler ultrasonography for comprehensive study of follicular dynamics and ovulation rate in goats standarised.
11. Round-the-year fodder production in Bihar computed
12. Standarised and published breeding, rearing, and juvenile seed production of Magur

13. Optimization of integrated fish farming systems for livelihood improvement of small and marginal farmers of the Eastern region
14. Formulated vitamin mineral-enriched diet for quality seed production of Rohu.
15. Technology for Grass carp culture with seasonal forage crops
16. Standardized and optimized the procedures and protocols for laboratory estimation of extent and pattern of antimicrobial resistance (AMR) in bacteria of animal origin
17. Biofloc model developed as sustainable techniques for seed rearing for air-breathing fishes
18. Rice fish culture in lowland areas of the eastern region standardised.

Teaching, Extension and Capacity Building

Teaching and research guidance

The DLFM teaching activities include guiding students across various academic levels, including Ph.D., M.V.Sc., M.Sc., and B.Sc., in collaboration with institutions like BASU Patna, AN College Patna, and other universities. Scientists mentor students in research and internships, contributing to capacity building in livestock and allied sciences. The scientist of the division are involved in guiding B.Sc. (14), M.Sc. (25) and Ph.D. (04) students of different universities viz. WBAFSU Kolkata, BASU Patna, AN College, Patna, LPU Ludhiana and IVRI-Izzatnagar etc.

Technology dissemination

1. Under AICRP on Goat Improvement, 50 genetic superior bucks have been supplied yearly to these clusters to improve the goat found in the field genetically. Goats registered in the project increased from 1243 to 11087. Approximately 31678 goats belonging to 2044 farmers have been registered under this project since 2018. A total 7377 non-descript goats have been upgraded with superior quality Black Bengal buck for improvement in their performances at farmer's field. Approximately 9560 goats have been vaccinated for PPR, enterotoximea and FMD and 11558 animals have been dewormed and treated for ectoparasite. Training has been provided to 686 farmers in scientific goat farming.
2. Methods to detect infectious agents such as *Anaplasma marginale, Babesia bigemina, Theileria annulata, Trypanosoma evansi*, PPR virus, *Mycobacterium avium* subsp. Paratuberculosis, *Brucella abortus* have been standardized at our in-house laboratory and more than 600 biological samples from farmers' animals have been processed for disease diagnosis. Outreach activities have been organized in villages in 5 villages to create awareness about various zoonotic diseases surveyed by the institute. Mode of spread, their symptoms and prevention methods have been discussed with about 700 farmers. About 80 health camps activities for various animals have been conducted and treatment has been provided by the Institute free of cost. About 7000 animals have been treated and vaccinated against common infectious diseases prevalent in the region. About 4000 farmers received mineral mixture and vitamin supplements for their animals. Modern technology on goat farming, dairy farming, and profitable backyard poultry farming has been disseminated by organizing more than 25 training programs for farmers, extension workers, and veterinarians in the eastern region.

3. Development of low-cost feed for the farmers of Bihar and feed was distributed to 8 districts, and around 120 farmers from 8 districts were benefited. During the study of soil, water, and plant materials from Bihar and Jharkhand were deficiencies in many minerals after studying. Hence, the Institute has formulated a mineral mixture for Jharkhand and Bihar. More than 4000 farmers benefited from this mineral mixture.
4. About 15 farmers adopted fish based IFS in different compositions. Duck-fish culture was adopted to 3 villages of Kanti block and two at Sarairanjan. Duck-fish and Pig- fish also carried out in three farmers of Rewa Maheswari village of Kamrup district. Poultry- cum fish culture was adopted in Nalanda district and getting reasonable remuneration. Tripurari choudhary, Jandaha in Vaisali (10 acres) practiced cattle integration in fish farm. Yatendra Kashyap, Sangrampur, Motihari (35 acres) is another adopted farmer who has a hatchery and is breeding fish on a large scale under ICAR RCER guidance. He also practices integrated fish farming by adopting goat-fish integration. Shri Kabindra Morya, Noorsarai, Nalanda (8 acre) and Pawan Kumar, Nalanda (7 acre) are adopted in integrated and composite fish culture under the guidance of our institute. Shri Sunil Thakur is practicing composite fish culture and prawn farming. During the last few years under the NSPAAD project 57 fish hatcheries and 214 fish farms were visited. Details water quality parameters and issues related to hatchery management and fish culture were discussed and suitable suggestions, etc., were given to the respective people. Simultaneously, about 22 awareness programs were conducted and different aspects of fish culture, water quality management, food and feeding and disease management aspects were discussed and suggested. Around 1100 people benefited from these awareness programmes.
5. Apart from that, the division also conducted several training programs and dissipated knowledge in livestock, fish culture, and integrated fish farming techniques among the farmers. In the livestock production system and on the vaccination methods a total of 11 training programmes were conducted and 310 farmers benefitted. In fisheries, 36 fisheries training programs were conducted primarily for Bihar farmers, and 931 farmers benefited. Whatsapp group created for fish farmers to discuss and get suitable solutions. More than 150 farmers registered in this group.

Capacity building

Table 4.6 Capacity building activities of the division

Sr. No.	Activity	Number	Number of participants/ beneficiaries
1	Farmers' training on livestock and poultry	11	310
2	Farmers' training on fisheries	35	931
3	Winter school /Model school	4	73
4	Animal health camp	88	6523
5	Awareness programme	27	2504

Foreign Deputation and Training

Dr Shanker Dayal: Visiting faculty at Animal Genomics laboratory, Department of Animal Science, Washington State University, Pullman, USA from 30 September- 28 December, 2013 and undergone training in the area of Marker assisted selection (MAS) sponsored by NAIP, ICAR.

Publications

The annual publication number has increased from 1 in 2004 to 28 in 2023 with a total of 246 research publication till date.

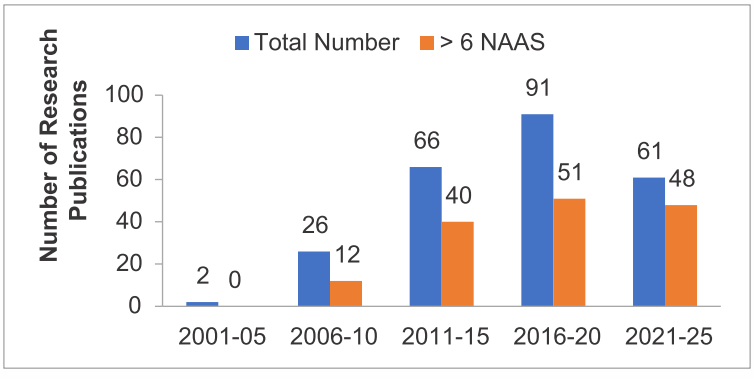

Fig. 4.37. Research paper published by DLFM

Revenue Generation

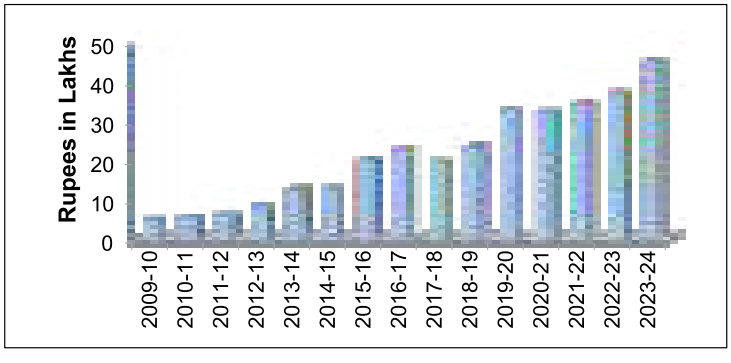

Fig. 4.38 Revenue generated from sale of farm produce

Future Research Thrust

1. Synergetic role of livestock in the farming system models, minimizing zoonotic risk and environment safety,
2. Genomic selection for improved productivity of livestock
3. High-value fish and seed production system
4. Integrated management of wetland ecosystem.
5. Recirculating aquaculture system (RAS) for improving water productivity.

Empowering Rural Communities : Social Science Innovations in Agriculture

Ujjwal Kumar, Abhay Kumar, D K Singh, T K Koley, Anirban Mukherjee,
R K Raman, Banda Sainath, Deokaran, Ramkewal, Harigovind, Sudhanshu Shekhar,
Indra Jeet, and Dharamjit Kherwar
Division of Socio-Economics and Extension

Background

The Division of Socio-Economics and Extension (DSEE) was established on April 1, 2009, evolving from the Socio-Economic and Extension Research Program (SEERP) to strengthen research and outreach efforts. With an initial sanctioned scientific strength of 11, including the Head of the Division, DSEE traces its roots to SEERP - one of the five core research programs of the ICAR Research Complex for Eastern Region, Patna. The program was first led by Dr. U S Gautam (April 1, 2001), with a team of five scientists specializing in Agricultural Extension, Economics, and Statistics. Dr. K M Singh later became the first official Head of DSEE (Table 5.1).

Since its inception, DSEE has played a pivotal role in technology assessment, refinement, and transfer, driving the adoption of improved agricultural innovations. Committed to empowering farmers and stakeholders, the division continues to bridge the gap between research and real-world application, fostering sustainable agricultural growth. From 2000 to 2010, the division focused on integrated agricultural technology evaluation, participatory impact assessment, and livelihood improvement through sustainable farming models. Between 2011 and 2015, research shifted towards water management challenges, value chain analysis, risk assessment in major crops, and rural poverty tracking, providing insights for policy interventions. The 2016–2020 period emphasized resilient farming systems, makhana value chains, climate adaptation strategies, and digital transformation in agricultural marketing. Since 2021, the division has advanced climate resilience, digital agriculture, carbon credit potential, zero-hunger villages, and FPO-led technology dissemination, ensuring sustainable, technology-driven agricultural development. DSEE remains committed to enhancing agricultural sustainability, improving farmer livelihoods, and driving economic transformation in the Eastern region of India.

Table 5.1. Head of the Division of Socio-Economics and Extension

Sl no.	Name	Tenure	
		From	To
1	Dr. US Gautam*	01/04/2001	04/10/2004
2	Dr. PK Thakur*	05/10/2004	21/04/2009
3	Dr. KM Singh	22/04/2009	21/04/2014
4	Dr. Abhay Kumar	22/04/2014	8/03/2017
5	Dr. Ujjwal Kumar	09/03/2017	Present

*Head, Socio economic and Extension Research Programme (SEERP)

Table 5.2 Journey of Socio economic Research during 2000-2024

2000 -2010	2011 -2015	2016 -2020	2021-2024
Production potential of integrated agricultural technology	Constraint and issues of water management in crop production in Bihar	Food and nutritional security of rural households	FPO based Technology Delivery model
Participatory impact assessment of technology	Value chain studies in milk and vegetables	Production and Value Chain Analysis of Makhana	Utilization of Digital tools in Agricultural
Technology assessment and refinement through institute village linkage	Technology out-scaling for sustainable food production and livelihood Improvement	Impact of e-NAM on Improving Marketing of Agricultural Produce in Eastern India	Participatory Research Application for Year-round income and Agricultural Sustainability (PRAYAS)
Training need assessment	Risk assessment of major crops	Socio-economic Characterization of Farmers in Bihar and Jharkhand	Resource Inventorization of Floodplains Wetlands
Understanding Makhana production system	Tracking changes in rural poverty	Climate Resilient Agriculture (CRA) Programme	Building Climate Resilient Model for Smallholder Dairy Production System
Sustainable livelihood improvement through need-based IFS	Growth and Instability in Production of Principal Crops		Unlocking Green Grain: Assessment of carbon credit potential in Bihar
			Development of Zero hunger and zero technology gap village

Research Contributions

A system approach to agricultural productivity to increase production in low production regions

The study was initiated with the collaboration of the Centre for Environmental & Agricultural Development (CEAD), New Delhi, and the financial help of the Technology Information Forecasting and Assessment Council (TIFAC) to identify technologies, individually or in combination for enhancing productivity with the sustainability of R.P channel-5 and Majhouli distributaries. After the inception of the project, during Kharif 2002, the full package of improved rice production technology was adopted by the farmers of the aforesaid distributaries in an estimated area of 658 ha. The partial adoption of the improved rice production technology package has spread over 11,054 ha in 140 villages. The farmers were harvesting on average 6 to 7 t/ha rice and 4 to 5 t/ha wheat instead of 1.30 t/ha rice and 1.99 t/ha wheat, respectively.

Technology assessment and refinement through Institute Village Linkage Programme (IVLP)

Farmers in the irrigated agro-eco region of South Bihar faced challenges in low crop productivity, inefficient input use, and limited diversification options. The need for scientific interventions to enhance farm incomes and livelihood security was critical (Fig.5.1).

Under the National Agricultural Technology Project (NATP) of ICAR (1999-2000), the Institute Village Linkage Program (IVLP) was implemented to assess and refine technologies. Scientific interventions included improved rice and wheat cultivation practices, introduction of banana farming with drip irrigation and fertigation, and intensive fish culture integrated with pumped irrigation water. Farmers' Information and Service Centers were established to facilitate input supply and knowledge dissemination.

Over four years, rice and wheat yields increased by 15.8% (0.46 t/ha) and 16.7% (0.30 t/ha), respectively. Banana cultivation enhanced profitability through better fruit quality and early harvest (2-3 months). Fish production increased by 42%, while irrigated fodder yield improved by 20-30%. Farm incomes saw a significant rise, leading to increased household expenditures on health (54%), education (39%), food (19%), and farming inputs (38%). Participatory management of water bodies enhanced fish production, social cohesion, and reduced conflicts. The program successfully demonstrated livelihood improvements through scientific interventions and diversification.



Fig.5.1. Interface meeting under IVLP project at Biranchak village, Patna

Understanding makhana production system

A mega project on "Understanding Makhana production system" was initiated in the year 2005 and stakeholders involved in makhana production and marketing were identified. The net income of makhana cultivation was found to be higher (₹ 36,809/ha) in the field condition in Katihar district compared to the pond condition (₹ 31,498/ha) in the Madhubani district. A study on the price and marketing of makhana in Katihar and Madhubani districts of Bihar revealed that 80 percent of popped makhana is purchased by the local traders from phodias and only 20 percent of the same is purchased from farmers. The fluctuation of price was also studied and it was found that in June-July price of makhana is lowest and it is highest in December. Seventy percent of makhana pop is sold outside Bihar.

Sustainable livelihood improvement through need based integrated farming system models

Marginal and landless farmers in disadvantaged districts of Bihar faced low farm productivity, income instability, and lack of diversified livelihood options. Addressing these challenges required the development of location-specific, need-based Integrated Farming System (IFS) models. Under NAIP Component-3 (2008), a multi-institutional project was implemented in Darbhanga, Samastipur, Munger, and Vaishali districts in collaboration with RAU, Pusa, ICAR-CIFRI, BIAF, IWMI India, and IFPRI. The project emphasized participatory development, targeting smallholders, sharecroppers, farm women, SHGs, and unemployed youth. Six different IFS models were designed and tested, integrating crop, livestock, horticulture, fishery, and agroforestry components.

A half-acre IFS model in Vaishali generated an annual net return of ₹ 55,578, while a one-acre model with agri-horti-livestock integration further enhanced profitability. A 2.5-acre model integrating field crops, vegetables, fruits, poultry, buffalo, and mushrooms provided sustainable income. The integration of fish and water chestnut with makhana increased net returns by 37.5%-77.0% over traditional makhana farming. Five best cropping systems were identified and adopted by 60% of farmers in Jandaha and Vaishali. Farmers' interest groups were formed for seed production, fisheries, and vermicomposting, with ₹ 5 lakh established as a sustainability fund for post-project activities. The project successfully demonstrated diversified livelihood opportunities, improving farm income and resilience.

Technology acceleration programme

Scientists of the division accelerated twelve technologies viz. multiple uses of water, multitier horti-based cropping systems, fish production in low land area program, polyhouse for raising early vegetable nursery in winter season and early summer crop, mushroom production by landless families, zero tillage in wheat, rice-fish system, backyard poultry for livelihood improvement of resource-poor farmers, small scale duck farming for livelihood improvement of landless families and unemployed rural youth, animal health care support to farmers, bund height and LEWA (Low Energy Water Application) device in farmer's fields. With the scientist's efforts, technology of raising early vegetable seedlings for winter and summer vegetables was adopted by many farmers and farm women. This increased their income by 2-3 times. More than 100 women started mushroom production in south Bihar. Women were earning a minimum of ₹ 50/kg from mushrooms by spending only eight rupees. The Zero Tillage

technology was popularized in 22 districts of Bihar, covering more than 6000 ha of area. Optimization of Rice Transplanting (ORT) technology was adopted by 80% farmers and it resulted in timely sowing of wheat crops apart from better utilization of rainwater in Kharif. It has also resulted in a saving of nursery seeds by more than 50 percent.

Constraints and issues of water management in crop production in Bihar

A study in the canal command area of Patna and the tubewell command area of Vaishali revealed that small and marginal farmers constituted 77% and 75% of the sample, respectively. In the tubewell area, 65% owned tubewells, while 85% had sufficient irrigation water, compared to only 39.16% in the canal area. Cattle or buffalo ownership was 84% in the tubewell area and universal in the canal command.

Portable pipe irrigation was common in tubewell areas, whereas 90% of farmers in canal areas relied on field-to-field irrigation. Diesel-operated pumps were used by 90% of farmers. Wheat received 2-3 irrigations, while rice received 3-4 in tubewell areas and 6-8 in canal areas. Tubewell water was sold by 18% and purchased by 55% at ⊚60-90/hour. Key constraints included costly irrigation and lack of implements in tubewell areas, while uneven bunds and neighbour-related issues were major concerns in canal commands.

Village dynamics study in South Asia

ICAR and ICRISAT collaborative project entitled "Tracking Changes in Rural Poverty in Household and Village Dynamics in South Asia" was undertaken to analyze the farm household income, income sources, economic inequality, and determinants of income of farm households in Bihar and Jharkhand (Fig.5.2). The main aim of this project was to address the dynamics of economic, social, and institutional development. Results revealed that the prevalence of poverty and lack of working capital for crop production is a major reason for low crop productivity on small land holdings. The findings of the study showed that the income level of farm households in the selected villages exhibited an impressive annual growth rate of 6% during 2010–11 to 2014–15. The income level showed a positive relation with the size of landholding. There was a clearcut visible transition of labour from the farm to the non-farm sector. It was found that income through farming constituted only 8 to 12 percent of total income in labour households indicating more involvement in the non-farm sector. Further, the sources of household income are quite diverse, and cultivation contributes only one-fourth to the total income of farm households. Inter- and intra-class inequality in farm household income is also



Fig. 5.2 A view of Kisan Diwas under the VDSA project at Susari, Darbhanga

prominent but diminishing with time. Thus, a strategy to increase non- farm employment may be one of the potential pathways for alleviating poverty in Bihar. In Jharkhand, it was observed that education, size of household, share of non-farm income, and adoption of high-yielding varieties exerted significant influence on income of households. Among different Government schemes, labour households with BPL cards had more access to social security schemes. Education, household size, share of non-farm income, and adoption of HYVs significantly influenced the household income. These findings have significant implications and call for holistic rural development strategies for enhancing farmers' income.

Technology out-scaling for sustainable food production and livelihood improvement



Fig. 5.3. Crop diversification in Sarairanjan, Samstipur



Fig. 5.4 Interaction with farmers of Sonmar Chaur, Samastipur

Farmers in Patna, Vaishali, and Samastipur districts faced challenges related to low crop yields, inefficient resource use, and limited livelihood opportunities. There was a need for integrated and sustainable farming approaches to enhance productivity and income (Fig.5.3, Fig.5.4).

A study was conducted to demonstrate and refine various agricultural technologies. Multi-tier cropping, improved crop cultivars, and integrated farming systems (IFS) incorporating poultry, fish, and agri-horti crops were implemented. Specific interventions included trench-cum-raised bed systems for fisheries and horticulture, vermicomposting for waste recycling, and livelihood support through goat and poultry farming. Cryo-preservation techniques were applied to enhance fish seed production.

Mango-based multi-tier cropping with turmeric and seasonal vegetables in Beerpur village generated an additional profit of ₹80,110/ha while conserving water. High-yielding rice varieties (Rajendra Sweta, Rajendra Suhashini, Pusa-1176) resulted in an average yield of 5.05 t/ha. Fish farming without supplemental feeding produced 1.04 t/ha across 10 farmers' fields. Integrated fish farming and quality broodstock development improved productivity in chaurs, with 45,000 fish fries produced using cryo-preservation at Jandaha. These interventions significantly enhanced farmers' income, resource efficiency, and livelihood security.

Risk proneness of major crops of Eastern India

A study was conducted in West Bengal to assess the risk proneness of major crops based on yield variability. Statistical analysis revealed that most crop yields followed a normal distribution, except for sugarcane, which exhibited deviations from normality. Districts were categorized into low, medium, and high-risk zones based on the extent of yield shortfall. The findings highlighted that district-level risk assessment is more precise and effective than state level risk evaluation for determining agricultural vulnerabilities.

To support risk mitigation strategies, crop insurance premium rates were estimated for medium- and high-risk crops in respective districts. This localized approach to risk assessment and insurance pricing enhances the effectiveness of agricultural risk management, ensuring better financial protection for farmers against yield fluctuations. The study underscores the necessity of district-specific interventions to optimize crop insurance policies and improve agricultural resilience in West Bengal.

Value chain study of selected commodities-case of milk and vegetables in Bihar

The study, initiated in 2012 in Nalanda and Patna districts of Bihar, examined milk and vegetable marketing channels and constraints. In Nalanda, three milk marketing channels were observed: Producer-Consumer (0% price spread), Producer-Retailer-Consumer (38%), and Producer-Retailer-Milk Processor-Creamery-Hotel Owner/Consumer (57%). Major constraints for milk producers included costly feed, lack of animal sheds, and capital. Retailers faced challenges with capital, transport, storage, and market organization. Milk adulteration and injection milking were issues for consumers.

For vegetables (tomato, potato, cauliflower), producers dealt with low prices, price fluctuations, costly feed, and lack of cold chains. Middle men and retailers struggled with capital, market infrastructure, and price instability. Price spreads for cauliflower, tomatoes, and potatoes were higher in Patna than Nalanda, indicating a less efficient vegetable market in Patna. The study highlights the need for improved market infrastructure and cold chain solutions to reduce inefficiencies and benefit both producers and consumers.

Growth and Instability in production of principal crops in Bihar

The study analyzed thirty years of secondary data (1982-2012) to assess the growth and instability in the production of principal food grain crops in Bihar. The findings showed a decreasing area under rice and pulses, though increased yield counterbalanced the decline in area, leading to a steady rise in total food grain production. Rice was the dominant crop, with a growth rate of 0.3% in production and 0.8% in yield despite a 0.5% decline in area. Wheat showed positive growth in area (0.6%), production (1.97%), and yield (1.36%). Maize also expanded in northern Bihar due to its higher yield potential. However, pulses and oilseeds faced setbacks due to reduced area and stagnant productivity. The study recommends focusing on innovative rice production technologies for north Bihar and efforts to improve pulses and oilseeds varieties to boost their production.

Sustainable and Resilient Farming System Intensification in the Eastern Gangetic Plains (SRFSI)



Fig. 5.5. Performance of potato + maize intercrop at Sukhet, Madhubani

This study was carried out in collaboration with CIMMYT in Madhubani district, of Bihar with the aim to reduce poverty in the Eastern Gangetic Plain (EGP) by improving the productivity, profitability and sustainability of smallholder's agriculture (Fig.5.5). Gender segregated key benefits, advantages, disadvantages, issues and the key decision processes and criteria for conservation agriculture technologies adoption were analyzed. Higher yield through adoption of ZTDSR was revealed by equal percentage (75%) of male and female farmers. All farmers expressed labour saving as one of the most important criteria for adoption of the ZT. Gender segregated data showed almost similar perception related to criteria adoption of ZT technology in rice-wheat system. Farmers participatory trials revealed that there was saving of water and manpower in zero tillage in comparison to conventional sown wheat. Water and labour productivity under different establishment methods in wheat revealed that there is an increase of 42% and 36 % water and labour productivity, respectively under zero tillage in comparison to traditional sown wheat. As many as 1264 farm families have been benefited in terms of field trials, training, exposure visits, field days etc through the project activities in Madhubani.

Agricultural vulnerability was also assessed for adopted farmers in Madhubani. Focus Group Discussion (FGD) technique has been adopted for getting information related to impact of biotic and abiotic factors and a total of 30 FGDs consisting of male, female and mix group were conducted in 5 villages. Agricultural vulnerability index was analyzed low (0.31) in Khairi village whereas it was medium in remaining four villages (0.36 to 0.48).

Production and value chain analysis of makhana

The project was started in 2017 to study the makhana value chain in the country. The data were collected from farmers, traders, processors and other stakeholders from Darbhanga, Madhubani, Purnea and Katihar districts of Bihar as well as Delhi and Kanpur using well structured interview schedule. It was observed that the yield of makhana seed varied from 1.8 to 2.3 t/ha. Harvesting of makhana seed alone contributed around 40% of the operational cost of cultivation.

Farmers - Processors - Local wholesalers - Distant wholesalers - Distant Retailers - consumers were identified as most important marketing channel. Nearly 70% of the total makhana is marketed through distant wholesalers located in major cities across the country.

In the Makhana value chain, local wholesalers purchase popped Makhana from processors, with farmers receiving only 10.8% of the consumer price due to selling Makhana seed instead of popped lava. The price spread from producer to consumer is 72.4%. It's suggested to form producer groups to sell packed Makhana lava after primary processing and explore secondary processing and branding. Market margins for distant retailers (19.56%), wholesalers (13.9%), and processors (8.63%) are notable, with processing costs accounting for almost half of the marketing expenses. Local wholesalers add value through grading, packaging, transport, and storage.

Growth and instability in production of principal crops in Eastern India

The study aimed to analyze the trends in area, production, and productivity of major food grain crops, particularly rice, in Eastern India. The decline in rice area in some states like Odisha, Bihar, and West Bengal, along with weather aberrations in Chhattisgarh, posed challenges for sustained growth. Despite the adoption of modern technology, the profitability in rice production remained stagnant, raising concerns about the sustainability of rice cultivation in the region.

The study utilized secondary data for the period 2000-2019, focusing on trends in area, production, and productivity of rice in Eastern India. Data from states like West Bengal, Bihar, Odisha, Jharkhand, and Chhattisgarh were analyzed for spatial and temporal variations. The study examined factors like operational costs, productivity rates, and net income, along with changes in yield due to technological adoption. Comparative analysis across different states and regions was conducted to assess productivity and cost-efficiency.

The results indicated that although rice area declined, production increased due to higher productivity, particularly in West Bengal, which led the region in rice output. However, operational costs were highest in West Bengal due to increased expenses on labour and fertilizers. The profitability of rice farming improved significantly in 2017-18 in some states, but the overall net income from rice cultivation showed little improvement over the last 15 years. The study concluded that focusing on cost rationalization, along with productivity enhancement, is crucial for improving profitability in rice cultivation in Eastern India.

Impact of e-NAM on improving marketing of agricultural produce in Eastern India

To study the Government of India Scheme i.e. e-NAM, started in 2016, an institute project on "Impact of e-NAM on Improving Marketing of Agricultural Produce in Eastern India" was initiated in December 2021. The current status of e-NAM was studied across all Eastern States. It was found that currently, as of March 31, 2023; a total of 1.75 crore Farmers and 2.43 Lakh traders are registered on the eNAM platform (Fig.5.6). Moreover, 2,575 FPOs have also been on boarded on e-NAM for electronic trade. A total of 1361 mandis of 23 States and 4 UTs have been integrated with the e-NAM platform. Uttar Pradesh leads Eastern India with the highest number of farmers registered on the e-NAM platform, accounting for 33 lakh farmers (17.4% of total farmers in the state). Other Eastern states, including Odisha, Jharkhand, Chhattisgarh, and West Bengal, have significantly fewer registrations, with only 6.65%, 6.45%, 3.4%, and 0.92% of farmers respectively enrolled. Eastern states contribute 21.7% of total e-NAM mandis in India, with Uttar Pradesh having the highest share (20.1%), followed by Jharkhand (10%) and Odisha (9.4%). In Jharkhand, Pakur district ranks first with 34,000 farmers (13.2% of the state's total). Major commodities traded include paddy, wheat, maize, and ragi, with paddy leading in trade volume (65,555 quintals worth Rs 1,035.8 lakhs). Vegetables like potato, tomato, brinjal, and onion, along with fruits such as banana and watermelon, are also popular on the platform.



Fig. 5.6 Interaction with e-NAM officials in Ranchi, Jharkhand

Transfer and adoption of improved agricultural technologies

A study was conducted from 2018 to 2022 in 9 districts of Bihar and 3 districts of Jharkhand to analyze technology dissemination and adoption among farmers and extension functionaries. The study aimed to identify effective methods and constraints in agricultural technology transfer.

Data was collected from 350 farmers and 123 extension functionaries through structured questionnaires and personal interviews. The study focused on technology dissemination methods, monitoring of government schemes, and adoption of improved agricultural practices.

Personal contact was the preferred method for technology transfer, used by 70.9% of extension functionaries. Monitoring of schemes was mostly done through field visits (50.90%). Major constraints included the unavailability of inputs on time. Adoption of improved crop varieties was high in rice (81%) but lower in wheat (less than 50%). Technologies like Zero Tillage wheat (42%) and seed treatment (16%) had low adoption rates. Zero Tillage wheat showed a yield increase of 1.5 t/ha and cost savings of ₹ 2,500/ha.

Status of utilization of digital tools in agricultural sector in Eastern India

A study on the application of digital tools among extension functionaries and farmers was conducted in Uttar Pradesh, Jharkhand, Bihar, and West Bengal from 2019-2024, involving 773 individuals (368 extension functionaries and 405 farmers). Data were analyzed based on age groups and educational categories to assess the usage of digital tools (mobile phones, smartphones, computers, laptops, tablets) and the internet. Results showed that farmers under 40 years were more likely to use digital tools, while illiterate individuals primarily used mobile phones. Over 80% of farmers had a positive view of digital tools, though they faced challenges such as high costs (88%), technical complexity (55%), and poor internet connectivity (67%). Among extension functionaries, 73% used smartphones, and 85% had a positive view of digital tools. The study highlights the need for improved digital literacy, reduced technical barriers, and better internet connectivity for effective adoption in agriculture.

Status of food and nutritional security of rural households in Eastern India

The study was initiated in 2018 to know the nutritional uptake by rural households in Eastern India. In this project data from different age groups of children were taken based on WHO Child Growth Standards. Data were collected from Lodhipur, Bodhibigha of Nalanda district; Karai, Rahgunathpur, and Bhelura from Patna in Bihar and Dewagain, Kerkata and Namkum of Ranchi district of Jharkhand. Nutritional data were collected based on personal observation and measurements by following the 24 hours recall method. The results showed BMI of all the 53 children of different age groups was in between 5th to 84th percentile which indicates the children were healthy. In the case of 10-12 years old girls the value was on the lower side of healthiness. It indicates the prevalence of less nutrition in this group. It is also reflected by their protein intake data (29.4 ±0.77 g/d), lesser than the other groups. Protein intake for almost all the age groups was found lesser than the recommended dietary allowance. It was also revealed from the study that the households having income more than ₹ 8,000 were spending ₹ 6,718 towards food in addition to the farm produce worth ₹ 3,547. The middle income group spent ₹ 3,064 and ₹ 4,535 from their own and farm produce, respectively. The lower income groups spent much less on food i.e., ₹ 1,797 while the majority of their food were consumed from the farm (worth ₹5,986) produce. The lower income groups were mainly the wage earners who earned wages and share of farm produce as remuneration.

Climate Resilient Agriculture Programme (CRAP)

ICAR-RCER, Patna has been implementing Climate Resilient Agriculture Programme funded by the Government of Bihar under the umbrella programme 'Jal Jeevan Hariyali' in Gaya and Buxar districts through respective KVKs since Rabi 2019. Major objectives are to develop climate-resilient and futuristic cropping system (crop-cycle) modules for different districts and increase awareness among the farming community about climate-smart technologies through on-farm demonstrations. Five villages have been adopted in each district i.e Rasalpur Manpur, Rasalpur Nagar, Rupaspur, Takeya and Rahimbigha in Gaya and Harikisanpur, Dalsagar, Churamanpur, Ramobariya and Balapur in Buxar. Along with demonstrations at selected farmers' field, long-term experiments are being conducted at KVK farms in these districts. A total of 10,924 acres area in both Gaya and Buxar districts has been covered under various demonstrations at the farmers' fields since 2019, with an annual coverage of 2,936 acres. Zero

tillage of rabi crops is identified as the most accepted CRA intervention with a nearly 100% acceptance rate (nearly 100% of farmers adopted ZT after the first introduction). Cropping intensity in the selected area was increased from 200 % to 300%. Area covered under Laser Land Leveler was 631 acres. The total number of capacity-building events organized was 482, with 24,679 beneficiaries. Each year 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, the introduction of mungbean in rice-wheat cropping system, intercropping of maize and potato, climate resilient irrigation scheduling and nutrient management, laser land leveling etc were conducted at the farmers field.

FPO based technology delivery model

This study was funded by NASF with the objective to develop and validate technology delivery models using Farmers' Producer Organization (FPO) in India's eastern region. Four separate models of technology transfer through FPO have been developed at ICAR-RCER, Patna, ICAR-IIVR, Varanasi, FSRCHPR, Ranchi, and UBKV, Cooch Behar for seed production, vegetable production, organic farming, and natural resource management, respectively (Fig.5.7). A generalized process model was also developed for wider use across eastern states. This model significantly enhanced crop productivity (rice: 18-22%; wheat: 15-25%; green gram: 30-45%) and farmers' income (12-17%). Through this model 16 different technologies were transferred to 789 farmers The model was successfully replicated to 26 more FPOs in 4 states of Eastern India.

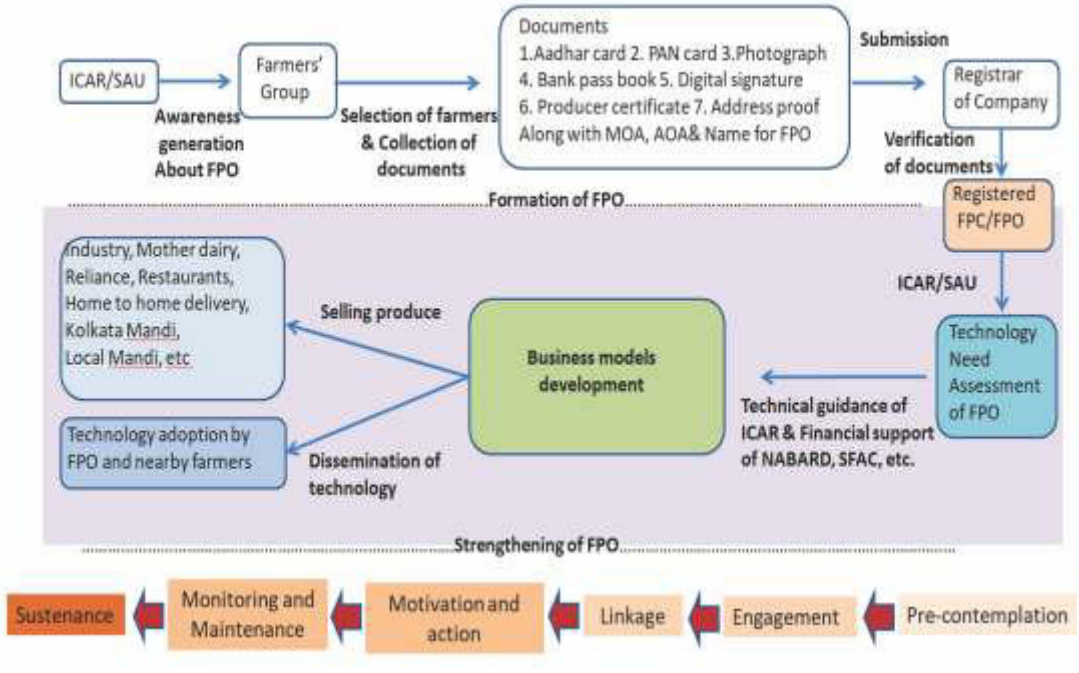

Fig. 5.7. Generalized Process Model of FPO based technology delivery



Fig. 5.8. Activities of FPO based technology delivery

As many as 5 FPCs were registered through this project one each in Bihar, Jharkhand, and Uttar Pradesh and two in West Bengal (Fig.5.8). The results of the Social Network Analysis indicated that the FPO farmers are better able to communicate with each other and have a greater impact on each other's decisions and opinions.

Model based inference on agricultural crops for food security in Eastern India

The study was initiated in the year 2021 with the objectives to study the trend, impact of climatic parameters and forecast the production of principal crops in eastern India. Secondary time series data on rice production of eastern India for the period from 2001 to 2017 were collected. Structural time series data (STSM) model has been used and data for the period from 2001 to 2014 were used for model development and data for the period from 2015 to 2017 for validation of the model. The trend analysis of rice production in eastern India revealed that the rice production might increase in the upcoming years till 2024 in eastern India. The model evaluation Akaike Information Criteria (AIC) values for the structural time series model was 245.33. The model was validated with the actual three years rice production data from 2015 to 2017 and observed that the model predicted the rice production within 10 % error.

Resource inventorization of floodplains wetlands in Eastern India

Resource Inventorization in Flood Plain Wetlands in Kamla Balan and Bagmati floodplain wetlands in North Bihar and Brahmaputra floodplain wetlands in Lakhimpur, Assam. Maximum income was gained through aquaculture followed by vegetable, fruit and food grain. The average annual income (₹/ha) from crops, horticulture and the fishery was found to be 81,437/-, 1,59,865/- and 2,55,190/- respectively. Based on flood plain resource data, a policy framework has been developed using a structural time series model (STSM), Kruskal–Wallis statistics, principal component analysis (PCA) and GIS mapping for the identification of productive areas for fruit crops and its management strategies in Bihar. The model framework identified North West alluvial plain of Bihar as a highly productive zone for banana, litchi, and mango, while the south Bihar alluvial plain zone was for Guava.

Participatory Research Application for Year-round income and Agricultural Sustainability (PRAYAS)

The project is implemented across seven states in Eastern India comprising West Bengal, Bihar, Assam, Jharkhand, Chhattisgarh, Odisha, and Eastern Uttar Pradesh (Fig. 5.9 and Fig. 5.10).

The primary objective was to demonstrate improved agricultural practices to enhance productivity and sustainability in the region. Additionally, PRAYAS aims to create awareness and provide skill development opportunities for resource-poor farmers in Eastern India, fostering their capacity to adopt profitable farming practices. Based on the need assessment survey and problem prioritization conducted using the Analytic Hierarchy Process (AHP) method, the identified needs and gaps were evaluated based on their significance and impact. Each identified issue was assigned a score to reflect its priority in addressing agricultural sustainability and income generation in the targeted regions.



Fig. 5.9. Activities under PRAYAS



Fig. 5.10. Process model

Zero hunger and zero technology gap village through innovative interventions

The study was initiated in collaboration with ICAR ATARI, Patna for developing a Model Zero hunger and zero technology gap village in Buxar district (Chhotka Dhakaich, Simri) (Fig 5.11). The main objective of the project is to minimize hunger and technological gaps based on the available resources and livelihood options as well as improvement of existing livelihood and creation of alternate income generating sources of income through allied activities viz. mushroom farming, poultry production, nursery raising, IFS models etc. The Chhotaka Dhakaich village of Simri block in Buxar district of Bihar has been identified for all types of technology interventions related to cereal crops, horticulture, livestock, poultry, water management, climate resilient varieties and technologies etc. In order to achieve zero hunger in the village, interventions like promotion of nutri-garden, use of biofortified foodgrains, pulses, oilseeds as well as enhanced production and consumption of fruits, vegetables, milk, meat and egg are being tried at mass level. Initially, nutrigardens have been established at several locations in village and two mushroom units are established for live demonstration and training to farmers. Weaker sections of the society have



Fi. 5.11. Project team and farmers at Chhotka Dhakaich, Buxar

been provided livelihood support through poultry rearing. Organization of capacity building programmes like training, awareness camp, farmer-scientist interaction and workshops are conducted regularly.

The project will run for three years in the village and a Model village will be created as a success story for replication at other locations.

Standardization of hydroponic technology for horticultural crops

A foldable hydroponics structure for growing of leafy vegetables were designed and fabricated (Fig. 5.12). The main frame of the hydroponic unit was made of mild steel square pipe of size 2″x 2″. Structure is sturdy enough to withstand heavy load and can be reused for more than 5 years. The main frameswere connected to each other with the help of square pipe and nut bolts. The dimension of the structure is : Height 5.5 feet x Length 10 Feet x base width 4.3 Feet. The length of the hydroponic unit can be easily increased or decreased as the whole system is detachable. Also, the slope of the nutrient film can be changed easily with the help of adjustable screw. Lettuce seed were sown in oasis cube during October. The seedlings were ready for transplant within 20-25 days. Whereas the conventional method of growing in soil required approximately 30 days. For first picking under both condition leaves were ready for 46-47 days. Growing season of lettuce was 98 days in NFT whereas for conventional system crop required approximately 110 days. In both systems crops gave five harvests. A total of 20 germplasm of tropical radish (*Raphanus sativa*) were collected and evaluated for their suitability in hydroponics. A wide range of variation was observed with respect to fresh weight, colour and antioxidant potentials. Few unique germplasms with distinct colour were identified.



Fig. 5.12. Performance of Lettuce under NFT structure

Transformative impact and evolving research priorities

Over the past two decades, DSEE's research priorities have evolved, expanding into impact assessment and technological innovations. Scientists have conducted detailed analyses of 35 crop varieties, including 33 vegetable crops, rice variety Swarna Shreya, and makhana variety Swarna Vaidehi, through partial budgeting and economic surplus approach estimating an economic gain of ₹ 32,785 million. Additionally, ICAR-RCER has developed or refined 19 models and technologies for the Eastern region, such as Integrated Farming System models, low-cost dairy feed formulations, makhana cultivation, composite fish farming, orchard rejuvenation, and pulse seed hubs. These innovations have generated an economic impact of ₹1,22,017 million from 0.18 million hectares, contributing to a total economic gain of ₹ 1,54,803 million from ICAR-RCER's research and technological advancements.

Technologies developed

The scientist of the division has developed several technologies among them followings are approved by ICAR

Table 5.3 List of technologies approved by ICAR

Sr. No.	Technology
1	Seed based technology delivery model through farmers Producer Organization (FPO)
2	Structural and functional model for value chain analysis of makhana
3	Flood prone area identified as fruit hub in Bihar: A policy framework
4	Policy Measures for Tenant Farmers of Bihar
5	Strengthening export potential of farmer producer organizations (FPO) through One District One Product (ODOP): A Conceptual Model
6	Development of Climate Resilient Model Villages at Gaya and Buxar Districts

Teaching, Extension and Capacity Building

The division has been at the forefront of implementing capacity-building programs aimed at empowering farmers and stakeholders across various sectors. These programs are designed to enhance awareness, skills, and knowledge, enabling participants to better address opportunities and challenges in agriculture. Through targeted training sessions, farmers and other stakeholders are equipped with practical tools and technologies that drive productivity and sustainability.

Key initiatives include hands-on training, exposure visits, and Farmers' Days (Fig 5.13), where participants learn best practices, emerging technologies, and sustainable farming techniques. These events foster collaboration and encourage the adoption of modern agricultural methods. Additionally, the division organizes Kisan Melas and mass awareness campaigns that engage larger communities, phone in live program leveraging various media platforms to disseminate critical information and resources.

During the year 2009 to 2015, a weekly (every Friday) phone-in live programme was operational for the farmers and other stakeholders for which a dedicated landline telephone no. (2612-223972) was installed in the division to answer the query asked by the stakeholders including farmers (Fig 5.14).



Fig 5.13. Farmers training and exposure on Kisan Diwas



Fig. 5.14 Phone-in–live programme for the farmers

Table 5.4 Training Programs conducted by Division

Year	Farmers' training programme (nos.)	Participants (nos.)	Officials training programme (nos.)	Participants (nos.)
2001-05	98	5528	64	89
2006-10	138	6110	19	37
2010-15	169	10497	54	233
2016-20	321	6445	183	960
2021-24	247	11740	97	500
Total	**973**	**40320**	**417**	**1819**

Teaching and research guide

The division has been instrumental in fostering Human Resource Development (HRD) in agriculture through a wide range of educational and training initiatives. It actively guides students enrolled in Summer/Winter internships, the Rural Work Experience Program (RAWE), and Agribusiness programs, ensuring hands-on learning and exposure to real-world agricultural practices. The division has also significantly contributed to postgraduate education in Agricultural Extension and Agricultural Statistics (Table 5.4).

A major achievement in HRD is the division's leadership in establishing the IARI Patna Hub under ICAR's initiative to transform IARI New Delhi into a mega university. As part of this initiative, IARI Patna Hub has become a vital academic center for Eastern India, offering specialized courses in communication, sociology, psychology, farm management, research methodologies, and ethics. This hub facilitates a comprehensive academic experience, with practical exposure through research and seed production farms, as well as specialized laboratories in soil science, plant pathology, and animal sciences. In the academic year 2023-24, the IARI Patna Hub enrolled 21 undergraduate students, 2 postgraduates, and 1 PhD scholar, followed by 17 UG students in 2024-25, from diverse states including Assam, Bihar, Jharkhand, Haryana, and Maharashtra. The division's efforts have not only enhanced the quality of education but also played a pivotal role in building a skilled workforce capable of addressing the challenges of modern agriculture, ensuring the sustainability of farming practices, and contributing to agricultural research and development.

Capacity building programs

Training Programme

The details of the training programs organized and the number of trainees—both farmers and officials—during the period 2001-2024 (Fig 5.15). A total of 973 training programs were conducted for 40,320 farmers. The total number of training programs for officials was 417, with around 1,819 trainees.

Farmers' training programs accounted for about 70% of the institute's training activities, while official training accounted for around 30%. However, farmers represented 96% of the total trainees, while officials accounted for only 4% of the beneficiaries. Consequently, the institute primarily focuses on enhancing the knowledge of farmers by demonstrating improved technological practices. Additionally, some awareness programs were also conducted during the initial period from 2001 to 2005. A total of 39 awareness programs were held, with 868 farmers participating. The numbers of training and participation for farmers and officials are illustrated in Fig 5.16. There is a clear upward trend in both the number of training programs and participant numbers over time.

In addition to capacity building of farmers and stakeholder, exposure visits of different stakeholder, state govt officials, IAS probationers, school and college students including teachers have been a routine event led by the division. Model training courses for state govt. officials and other extension personnel were also conducted by the scientists of the division. During the COVID-19 period (2019-2020), although no. of farmers' training programmes were less but online webinars and workshops were conducted for different stakeholdrs.

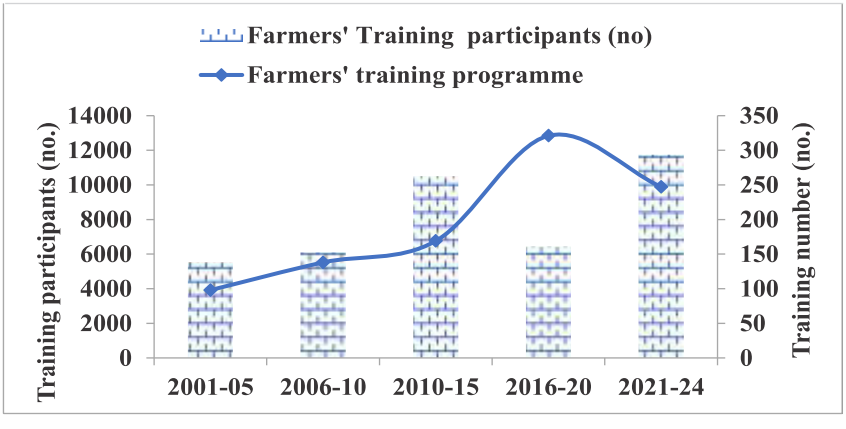

Fig 5.15. Farmers' training programme and trainees' number in an interval of five years during the period 2001 to 2023

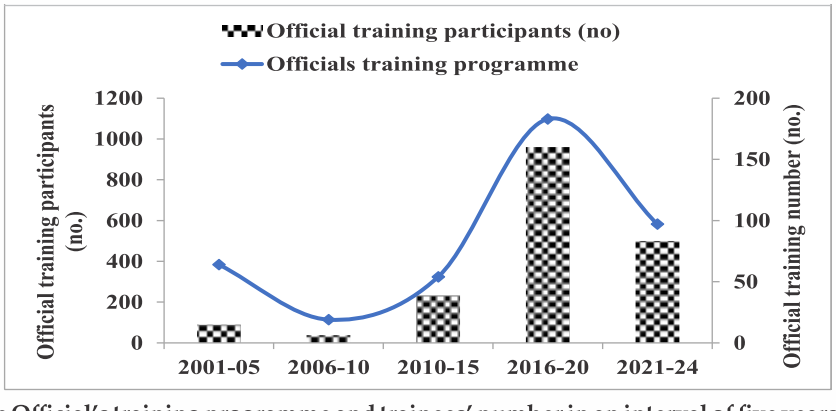

Fig 5.16. State Official's training programme and trainees' number in an interval of five years during the period 2001 to 2023

Model Training Programme

During the last 25 years the division has conducted 7 major training courses for state government and other extension functionaries in the area of participatory irrigation management, Participatory Irrigation Management, Livelihood Improvement of Rural Youth



Fig. 5.17 Model Training course conducted by DSEE in 2019



Fig. 5.18 Showcasing of Agricultural Technologies at ICAR RCER, 6-7 December, 2013

Awards, Honors and Peer Recognitions

Scientists of DSEE have received several prestigious awards, including the Swami Sahajanand Saraswati Outstanding Extension Scientist Award (2001) and the ICAR Award for Outstanding Team Research (2004). Notable recognitions also include the Jawaharlal Nehru Award for Outstanding Doctoral Thesis Research (2020) and the NABARD Researcher of the Year (2024), highlighting their contributions to agricultural extension and social sciences (Table 5.5).

Table 5.5 Awards and recognition of Scientist of DSEE

Year	Name of the award & recognition	Name of the Scientists
2001	Swami Sahajanand Saraswati Outstanding Extension Scientist Award	US Gautam
2004	"ICAR award for outstanding team research for the biennium 2001-2002"	US Gautam, S S Singh, P R Bhatnagar, Ujjwal Kumar, K Rajan and A K Sikka

2020	**Jawaharlal Neheru Award** for outstanding Doctoral Thesis Research in Agriculture and Allied Sciences 2019 for Social Science by Indian Council of Agricultural Research	Anirban Mukherjee
2022	**'NAAS Associates 2021'**, by National Academy of Agricultural Sciences, New Delhi. (Fig 5.19.)	Tanmay Kumar Koley
2024	**NABARD Researcher of the Year 2023** for outstanding research contributions in the field of Agricultural Extension on the occasion of 62nd Convocation of the IARI, New Delhi (Fig 5.20.)	Anirban Mukherjee



Fig 5.19. Dr Tanmay Kumar Koley receiving NAAS Associates in the year 2021



Fig 5.20 Dr Anirban Mukherjee receiving NABARD Research of the year 2023

Publications

Over the past twenty-five years, Social scientists have produced numerous key publications that demonstrate our commitment to advancing and sharing knowledge in the agricultural sector. The consistent increase in the number of publications over time reflects the dedication of our researchers to supporting agricultural farmers and policymakers in the country. These published works not only provide valuable insights but also contribute to broader discussions on critical issues impacting our agricultural landscape. The details of our publications are presented in Table 5.6. The publication rate increased by 66% from 2001-06 to 2006-10, by 90% from 2006-10 to 2011-15, and by more than 200% from 2011-15 to 2016-20. A total of 11 books and 12 bulletins have been also published, along with three radio talks. The contributions of research publications, radio talks, and TV shows from 2001 to 2023 are also depicted through pie chart. It was observed that research papers accounted for over 50% (approximately 53%), followed by popular articles at 31%. The contributions from books, bulletins, radio talks, and TV shows accounted for a total of 16% of the social scientists' group. Furthermore, the contribution of international research articles has been on the rise since 2020.

Table 5.6 Research papers, popular articles, books, bulletin, radio talks and TV shows during 2001 to 2024

Year	Research Paper	Popular articles	Books	Bulletin	Radio talks	TV shows
2001-05	6	20	0	1	0	1
2006-10	10	2	1	0	3	2
2011-15	19	0	6	6	2	6
2016-20	60	25	2	2	0	5
2021-24	36	27	2	3	0	8
Total	**131**	**74**	**11**	**12**	**5**	**22**

Future Research Thrust

The Division of Socio-Economics and Extension has been instrumental in bridging the knowledge gap between farmers and scientists by disseminating innovations and improved agricultural practices. With rapid advancements in technology, emerging challenges in sustainable agriculture, and the need for more data-driven decision-making, the division aims to strengthen its research in the following key areas.

- AI-driven policy and adoption analysis will utilize simulation models to assess farmer behavior, risk perception, and technology adoption for informed decision-making.
- Developing an enabling environment for farmers to adopt carbon farming practices through policy research, market integration, and participation.
- Promoting digital learning with Virtual Reality (VR) and Augmented Reality (AR) for experiential learning on modern agricultural technologies.
- Strengthening technology transfer and innovation diffusion through AI-driven decision support systems, digital platforms, and participatory approaches.
- Leveraging big data analytics, remote sensing, and AI-based tools to provide real-time market insights, climate advisory services, and risk mitigation strategies, enhancing farmers' decision-making and profitability.

Adaptive research for empowering farming communities: KVK Buxar

The Krishi Vigyan Kendra in Buxar district of Bihar was sanctioned by the Council on 31/03/2007. For this, the required land measuring 25.64 acres of Lalganj agricultural farm of Govt. of Bihar was transferred to ICAR. The foundation stone for construction of office building was laid by Honb'le Secretary DARE & DG ICAR, Dr. Mangala Rai on 23rd December, 2007.

Major activities

KVK, Buxar is doing farmers participatory location- specific research for its adaptability in the specific farming situation in addition to its mandated activities of technology assessment for its application in farmers field, frontline demonstration, skilled training to rural youth and

women. Since its establishment, around 1,10,000 farmers and extension functionaries got benefitted through training, demonstration and other extension activities of the KVK. Through capacity building programmes of the KVK, Buxar 43,000 ha wheat area was brought under Zero tillage. Following projects had been implemented by the KVK, Buxar.

Climate-resilient agricultural interventions by KVK, Buxar

KVK, Buxar implemented a project in 2011-12 to demonstrate proven technologies in crop and livestock production systems, helping farmers adapt to climate variability. The project was executed in Kukurha, Bhitihar, and Jamuaon villages, covering modules on NRM, crop production, institutional support, and livestock and fisheries (Fig. 5.21). Key interventions such as rainwater harvesting structures, farm ponds, micro irrigation systems, and watershed management significantly improved groundwater recharge, expanded irrigated acreage, and increased production by 22%. Under the NICRA project, KVK demonstrated crop residue management using a Happy Seeder on 150 hectares across 110 farmers' fields. This method added 4.2 t of residue to the soil, enhancing wheat yield (Var. HUW-234) by 13.78% (35.5 q/ha) compared to conventional practices. Additionally, it reduced cultivation costs while improving soil fertility.



Fig. 5.21. Crop residue management in wheat in Kukuraha, Buxar

Institute post office linkage project

KVK, Buxar was selected for the Institute post office linkage project in the year©2012 by ICARIARI, New Delhi. This project has unique characteristics with selecting the villages in the district and to provide the best IARI varieties to the farmers. KVK started programme in five village post offices viz. Chunni, Kukurah, Unvas, Rahtua and Buxar. Farmers got new varieties of Rice, Wheat, Gram, Mustard and Vegetable seed through respective post office of adopted villages. Rice variety, Pusa Sugandh-5 became very popular by this programme and was adopted in 100 ha area. Wheat variety HD 2967, HD 2733, HD 2824 for timely sown and HD 2985 for late sown was also popularized. The wheat variety HD 2967 covered 70% timely sown area.

Improved Rice based Rainfed Agricultural System (IRRAS) project

The project was initiated during kharif 2012 with the mandate of improving productivity and profitability of submergence and drought prone ecology of Bihar, which is essential not only for national food security, but also for the livelihood of poor and under-privileged people of the state. Promising research findings of the experiments conducted at Patna under the IRRAS project were demonstrated at KVK, Buxar (Fig. 5.22).



Fig. 5.22. Activities of IRRAS Project

Creation of seed hub for increasing indigenous production of pulses in India (Seed Hub)



Fig. 5.23. Seed hub established at KVK Buxar visited by RAC team

The programme was started from rabi season of 2016-17 with targeted production of quality seed of pulses at KVK Farm and farmer's field (Fig. 5.23). A seed processing unit costing 50 lakh has been established Seed produced on farmer's field was purchased by the KVK at 20 % higher rate than the prevailing market rate to make availability of quality pulse seeds for next season. So far, a total 1987.88 quintal seeds of different pulse crops viz. Chickpea, Lentil and Pigeonpea have been produced and provided to the farmers of the district as well as different KVKs / NGOs and allied departments including NSC. Seeds were also provided for other programmes, like CFLD on Pulses, CRA Programme, etc.

KVK-CSISA Project

Cereal Systems Initiative for South Asia project was implemented in the KVK in the year 2016. The project was led by the International Maize and Wheat Improvement Center (CIMMYT) and implemented jointly with the International Food Policy Research Institute (IFPRI) and the International Rice Research Institute (IRRI). Strengthening of the monitoring, learning and evaluation (ML&E) systems was identified as a strategic objective of the collaboration. KVK, Rice nursery was grown (21-25 days old seedlings) in two acres of land and supplied to 60 farmers and was transplanted in 64 acres land. The total cost of production for one acre was ₹14, 227 and net return of ₹11, 373 in one month. This was the success case for timely transplanting of rice nursery and harvest the higher yield of rice and boost for timely sowing of wheat. Other interventions, like zero-till wheat, cropping systems diversification, promoting directly sown rice to address labor and energy constraints to precision rice establishment, integrated weed management, irrigation scheduling for rice and wheat were implemented under the project.

Cluster frontline demonstration of oilseed & pulses

The programme was started during 2015-2016 for promotion and maximum adaptation of oilseed and pulses crop by farmers to reduce the technology gap. Best management practice and high yielding varieties of oilseeds and pulses were demonstrated for maximizing the productivity of oilseed and pulses (Fig. 5.24.).



Fig. 5.24. CFLD in Pigeon Pea

Consortia Research Platform on Farm Mechanization and Precision Farming (CRP on FM & PF)

Custom hiring centre (CHC) has been stated at KVK, Buxar under the project "CRP on FM &PF" since 2016. CHC provides improved agricultural implements (ZT, multicrop seed drill, Seed drill, MB plough, rotovator, multi crop thresher and ripper cum binder along with tractors) to the farmers of Buxar district with nominal charges. In the first year 85 farmers benefitted under by using different implements and their operation cost for cultivation was reduced. Few trainings for the farmers of different blocks were also organized to know more about the operation, use, management and benefit of the improved implements.

Climate Resilient Agriculture Programme (CRAP)

CRA Programme, a mega project of ICAR RCER Patna which is funded by Govt. of Bihar is started in the year 2020 at KVK, Buxar and executed in the five villages of district Buxar (Harikishunpur, Balapur, Churamanpur, Dalsagar & Ramobariya). The Climate Resilient Agriculture (CRA) Programme, launched in 2020 by ICAR-RCER Patna and funded by the Bihar government, is implemented in five villages of Buxar district (Fig. 5.25). It aims to reduce crop losses due to climate change impacts on soil, water, pests, diseases, and heat stress. Key initiatives include crop rotation, zero tillage, happy seeder sowing, laser land leveling, and advanced nutrient management using Green Seeker. The program has demonstrated climate resilient varieties on 595 acres in Kharif, 623 acres in Rabi, and 250 acres in summer, benefiting 1,500+ farmers annually. KVK Buxar has also leveled 375 acres and facilitated exposure visits for 12,000 farmers.





Fig. 5.25. Laser levelling under CRA Program

Upscale of Natural Farming through KVKs

The programme was implemented at KVK since 2022 with aims to involve more farmers and enhance the reach of natural farming through awareness and demonstration of natural farming. It involves set of holistic and comprehensive practices from tillage to selection of crops and varieties, raising of crops including management of on-farm inputs for realizing optimum productivity, economic advantage and improving soil health. Demonstration was undertaken at 10 farmers' field and KVK farm for Paddy, Wheat, Chickpea, Lentil and Mustard. Also, awareness (31 numbers) and skill development through training (08 numbers) were conducted with participation of more than 2000 farmers.

Skill development under Agriculture Skill Council of India (ASCI)

KVK Buxar has organized 04 numbers of skilled training programmes (more than 200 hours each) during 2017-18 & 2018-19 under ASCI mission to improve the skills of farmers, wage workers, and other workers in the agricultural sector (Table 5.7). Job role on vermicompost, quality seed grower, organic grower and Beekeeping were designed and imparted among total 80 rural youths. More than 40% percent trained rural youths established units and getting income for their livelihood.

Table 5.7 Capacity building and extension activities undertaken by KVK, Buxar

Particular	Quantity/ Area/ Location	Participants		
		M	F	Total
Training programme for practicing farmers	1555	33140	5835	38975
Training programme for rural youths	134	2445	275	2720
Training programme for extension functionaries	125	1785	95	1880
Front Line Demonstration on Crops	730 ha	1580	440	2020
Front Line Demonstration on Enterprises.	06	84	10	94
Cluster Front Line Demonstration on Oil seeds & Pulses.	580 ha	1460	180	1640
On Farm Testing	88	836	44	880
Extension activities (Kisan Mela, Goshthi, awareness programme, etc.)	760	48585	12915	61500
Total	**-**	**89,915**	**19,794**	**109,709**

Participatory research for transforming livelihoods: KVK, Ramgarh

Established by ICAR on August 26, 2014, KVK Ramgarh plays a vital role in advancing sustainable agriculture and rural livelihoods. With 19.4 acres allotted by the Jharkhand government, it promotes integrated farming, climate-resilient crops, organic practices, and water-saving technologies. The center supports allied sectors like horticulture, livestock, fisheries, and agroforestry. Through on-farm trials, training, and demonstrations, it enhances productivity and food security. KVK also empowers women and youth in agri-enterprises like food processing, mushroom cultivation, and beekeeping. Bridging research with farmers, KVK Ramgarh drives agricultural innovation, transforming small and marginal farming communities.

Empowering farming communities through capacity building

Since its inception, Krishi Vigyan Kendra (KVK) Ramgarh has been actively conducting various training programs targeting farmers, rural youth, and extension functionaries. A total of 693 training sessions reached 20,907 participants. These trainings have improved agricultural practices, leading to better crop productivity, enhanced livestock management, and the adoption of new technologies in farming. With 91 programs and 2,756 participants, the training has empowered rural youth by providing them with practical skills, enabling them to engage in agriculture-based entrepreneurship and enhancing employment opportunities in rural areas. Total 28 training programs for 820 participants have strengthened the capacity of extension workers, enhancing their ability to disseminate knowledge and agricultural innovations effectively to a broader farming community. Overall, the KVK training programs have significantly contributed to knowledge transfer, skill development, and sustainable agricultural practices in the region.

Staggered nursery-raising technique

Rice cultivation in Ramgarh has been severely impacted by erratic rainfall, leading to low yields due to delayed transplanting with over-aged seedlings (Fig. 5.26). To address this, a staggered nursery-raising technique was introduced, with nurseries sown in three phases, seven days apart. This ensured optimal seedling availability while repurposing unused seedlings as fodder. Implemented on 30 hectares, the method improved yields by 10-15% using 10-day-old seedlings. With a low cost of ₹1,480 per hectare, this approach proved a cost-effective solution, enhancing productivity and resilience in rice farming.



Fig. 5.26. Staggered Nursery

Demonstration of drought tolerant rice varieties

KVK Ramgarh has demonstrated medium-duration, drought-tolerant rice varieties to promote sustainable rice cultivation in drought-prone areas. Between 2020 and 2024, several resilient rice varieties, including Swarna Shakti Dhan, Swarna Shreya, CR Dhan 320, IR64 drt-1, and Sahbhagidhan, were introduced to farmers' fields. These varieties produced yields of 44.24, 42.89, 44.82, 39.3, and 38.7 q/ha, respectively, showing yield increases of 24.26%, 23.35%, 28.79%, 10.70%, and 9.53% over traditional farming practices. The demonstrations expanded steadily, covering 500 hectares across 1,200 farmers' fields in 24 villages of Ramgarh district. Additionally, vertical expansion efforts reached 2,500 hectares, benefiting 6,000 farmers. The successful adoption and scaling up of these drought-tolerant varieties have significantly enhanced farmers' resilience to water scarcity while boosting rice productivity in the region.

Water-efficient DSR solution for climate-resilient rice cultivation

Rice cultivation in Jharkhand relies on the monsoon, and delayed rains often disrupt nursery raising, transplanting, and subsequent crops. Traditionally, farmers used inefficient broadcast methods for Direct Seeded Rice (DSR), making weed control difficult. To address this, zerotill seed-cum-fertilizer drill machines were introduced, enabling dry sowing after land preparation. Drought-tolerant varieties like Swarna Shreya, Swarn Shakti Dhan, Swarn Samriddhi, and CR Dhan 320 were sown by 63 farmers over 25 hectares using DSR. This method reduced costs, saved labor and water, improved soil health, and lowered methane emissions, making rice farming more sustainable and efficient.

Demonstrating high drought-tolerant finger millet

The demonstration of drought-tolerant finger millet (A-404) across 20 hectares in Jharkhand, involving 62 farmers, increased yields by 23.53%, from 17.00 to 21.00 quintals per hectare. As a resilient C4 plant, finger millet thrives in rainfed conditions, making it ideal for climate variability. Its adoption reduces reliance on less drought-resistant cereals, enhancing food security and sustainability. Additionally, it improves soil health and minimizes erosion. By integrating finger millet into cropping systems, farmers gain a reliable, climate-resilient option, ensuring stable yields and promoting sustainable agriculture amid changing climatic conditions.

Enhancing pulse production in rice fallow land through CFLD Programme

The CFLD (Cluster Front Line Demonstration) Programme has significantly enhanced pulse production in rainfed rice fallow lands in Ramgarh, Jharkhand, demonstrating considerable impact on both vertical and horizontal expansion. With varieties such as KPG-59 chickpeas planted across 20 hectares, average farmer yields reached 10.76 q/ha, while demo yields soared to 13.52 q/ha, resulting in a yield increase of 25.65%. This upward trend was mirrored by Pusa-547, yielding an average of 10.64 q/ha against a demo yield of 12.97 q/ha, leading to a 21.90% increase. Lentils like HUL-57 and Pusa Ageti 4717 also displayed impressive results, with yield increases ranging from 18.54% to 29.90%. The programme encourages vertical expansion by boosting existing farmers' productivity, providing them with knowledge and resources to maximize yields. It also fosters horizontal expansion by inspiring neighbouring farmers to adopt similar practices, increasing the area under pulse cultivation in the region. This diversification enhances food security and soil health, essential for sustainable agriculture. Ultimately, the CFLD Programme is transforming Ramgarh's agricultural landscape, empowering farmers and promoting resilience in rainfed farming systems while contributing to economic stability and environmental sustainability.

Enhancing oil seed production in rice fallow land through CFLD Programme

The Enhancing Oilseed Production in Rice Fallow Land through the CFLD Programme has significantly impacted oilseed cultivation, particularly mustard and linseed, in the targeted villages. Conducted across 220 hectares with 557 farmers in 47 villages, the program demonstrated the potential of improved oilseed varieties to boost yields and profitability for farmers. Mustard, cultivated using varieties like Pusa-30, PM-30, and BBM1, saw notable yield increases. For example, the PM-30 variety recorded a 31.71% yield increase, improving from

10.25 q/ha to 13.50 q/ha. Similarly, the BBM1 variety demonstrated a 19.66% increase in yields, from 11.70 q/ha to 14.00 q/ha. These improvements highlight the effectiveness of advanced varieties in optimizing productivity on rice fallow land. Linseed, grown using the Priyem variety, also showed significant results. Yields increased by 19.80% to 20.57%, with average farmer yields improving from 10.10 q/ha to 12.60 q/ha in demonstration plots. Overall, the CFLD programme has successfully showcased the benefits of utilizing rice fallow land for oilseed production, enhancing food security and boosting farmers' incomes through improved crop varieties and management practices.

Demonstration of pigeon pea in upland under CFLD programme

The demonstration of pigeon pea cultivation under the CFLD (Cluster Front Line Demonstration) Programme has significantly impacted agricultural productivity in upland regions while effectively utilizing barren land. By encouraging the cultivation of pigeon pea in areas previously deemed unproductive, the program promotes sustainable land management and optimizes resource use. Notable yield improvements across various pigeon peas varieties underscore the program's effectiveness. The Asha variety, cultivated on 30 hectares by 273 farmers in 6 villages, achieved an average farmer yield of 9.20 q/ha, with a demo yield of 11.20 q/ha, resulting in a yield increase of 21.74%. Another demonstration of Asha (30 ha, 273 farmers, 5 villages) recorded a 12.22% increase with yields of 9.00 q/ha compared to 10.10 q/ha. The NDA-2 variety on 40 hectares, involving 107 farmers from 8 villages, recorded an average farmer yield of 10.6 q/ha against a demo yield of 12.10 q/ha, reflecting a 14.15% increase. Similarly, the IPA 203 variety, planted on 50 hectares by 308 farmers, achieved average yields of 13.36 q/ha and demo yields of 15.80 q/ha, leading to an 18.26% increase.

These improvements enhance farmers' incomes, promote food security, and foster sustainable farming practices, ultimately contributing to the resilience of upland agriculture and the effective utilization of barren land in the region.

Scaling up contingent cropping

The demonstration of contingent crops like Niger and Horse Gram in Jharkhand has shown remarkable success in boosting agricultural resilience in rainfed farming systems. Conducted over 260 hectares, the program engaged 344 farmers for Niger and 643 for Horse Gram across 69 villages. This initiative has not only led to improved yields but also highlighted the importance of climate-resilient crops in mitigating the risks associated with unpredictable rainfall. Niger, a drought-tolerant oilseed crop, demonstrated impressive results. Varieties like Birsa Niger-1 and BN-1 saw farmer yields ranging from 5.80 to 6.40 q/ha, while demo plots achieved up to a 27.12% increase. For instance, BN-1 showed a yield jump from 5.90 to 7.50 q/ha, offering a robust solution against drought-induced crop failures. Similarly, Horse Gram, a drought-adapted legume, was demonstrated using Birsa Kulthi-1. With farmer yields ranging from 8.75 to 9.60 q/ha and demo plots showing up to 15.74% yield increases, Horse Gram has proven effective in providing stable harvests in dry conditions. These demonstrations have improved food security, raised farmers' incomes, and fostered resilience in Jharkhand’s rainfed areas, reinforcing the importance of contingent crops in addressing the challenges of climate change.

Crop diversification

Crop diversity in rainfed farming systems, such as those in Ramgarh, Jharkhand, has proven to be a crucial strategy for improving agricultural productivity and resilience. The cultivation of various crops, including Black Gram, Maize, Field Pea, Groundnut, and Sesame, has demonstrated significant yield improvements through the adoption of advanced varieties and better management practices. For instance, Black Gram, using varieties like PU-31 and IPU 02-043, showed yield increases between 16.03% and 18.39%, with demo yields reaching 10.40 q/ha. Similarly, Maize (Bio 9544) demonstrated a 17.07% yield improvement, while Field Pea (IPF-4-9) saw an impressive 22.96% increase, with yields rising from 11.89 to 14.62 q/ha. Groundnut (Dharani) and Sesame (RT-351 and Gujrat Til-1) also recorded substantial yield improvements. Groundnut saw yield boosts up to 26.75%, and Sesame varieties exhibited increases between 12.98% and 30.68%, highlighting the advantages of crop diversity in maximizing land use and enhancing farmers' incomes. The impact of crop diversity in Ramgarh has been transformative, ensuring better food security, improving soil health, and reducing risks associated with reliance on a single crop, especially in rainfed conditions where water availability is unpredictable. This strategy has proven beneficial for farmers in building resilience against climate variability.

Vegetable cultivation through raised bed poly mulching and drip irrigation

In Ramgarh, Jharkhand, the introduction of vegetable cultivation using raised bed poly mulching and drip irrigation has significantly improved crop yields and farmer incomes (Fig. 5.27). This innovative method not only conserves water but also reduces weed growth and improves plant health. High-yielding and disease-resistant varieties of vegetables, such as tomato and brinjal, were cultivated across 16 hectares, involving 100 farmers in 54 villages. Tomato, grown using the high-yielding variety Swarna Sampada, showed yield increases of up to 23.51%, with demo plots yielding 646 q/ha compared to the average farmer yield of 523 q/ha. Brinjal, using the disease-resistant Swarna Shyamali variety, demonstrated yield increases of up to 15.75%, with demo yields reaching 445 q/ha compared to the average farmer yield of 385 q/ha. Swarna Pratibha, another brinjal variety, delivered even more significant yield gains, with a 26.13% increase in yield, boosting production from 310 q/ha to 391 q/ha. These results underline the advantages of using advanced cultivation techniques and high-yielding varieties. The efficient use of resources and disease-resistant varieties have helped enhance productivity, making vegetable farming a profitable and sustainable venture in Ramgarh.



Fig. 5.27. Performance of Brinjal (cv. Swarna Shyamali) under raised bed

Demonstration of high yield verities of vegetables

The demonstration of high-yielding vegetable varieties across 21 villages in Ramgarh, Jharkhand, significantly boosted productivity and farmer incomes. Conducted on 60 hectares Fig. 5.27. Performance of Brinjal (cv. Swarna Shyamali) under raised bed poly-mulch with 45

farmers, the initiative showcased improved varieties like Swarna Sneha (Bottle Gourd), Swarna Prabha (Sponge Gourd), Swarna Yamini (Bitter Gourd), Swarna Mukut (Cowpea), Arkel (Vegetable Pea), and Arka Niketan (Onion). Yield increases ranged from 15.73% to 27.61%, enhancing production and profitability. These demonstrations underscored the benefits of disease-resistant, high-yield varieties, promoting modern agricultural practices that improve livelihoods and food security in the region (Fig. 5.28 and Fig. 5.29).



Fig. 5.28. Performance of Sponge Gourd cv. Swarna Prabha in the



Fig. 5.29. Performance of Chilli cv. Swarna Prafulya in the farmer's field

Demonstration of Peste des Petits Ruminants (PPR) vaccine

The Peste des Petits Ruminants (PPR) vaccine demonstration in 26 villages of Ramgarh district significantly improved livestock health and the local economy. PPR, a highly contagious disease in goats, previously caused severe losses. Vaccinating 4,200 goats drastically reduced mortality, boosting herd sizes and farmer incomes. Healthier goats led to increased milk and meat production, enhancing economic stability for small farmers. The initiative also lowered veterinary costs and strengthened community resilience. This program highlighted the vital role of proactive disease management in sustaining livelihoods, demonstrating the long-term benefits of vaccination for livestock-dependent rural households (Fig 5.30).



Fig. 5.30. Goat vaccination camp at Lodhma village

Demonstration of Dewormer and Mineral mixture supplementation In Livestock

The demonstration of mineral mixture supplementation for enhancing yield and improving the overall health condition of dairy cows in Ramgarh, Jharkhand, has significantly impacted local livestock management since the inception of the Krishi Vigyan Kendra (KVK) Ramgarh. Covering 27 villages, this initiative has reached approximately 2,800 livestock, demonstrating

the vital role of minerals in dairy nutrition. The inclusion of a balanced mineral mixture in the diet has led to notable increases in milk production, with farmers reporting enhancements of 15-20%. Essential minerals like calcium, phosphorus, and magnesium contribute to better reproductive performance and overall vitality. Additionally, regular deworming has proven crucial in preventing parasitic infections, which can severely affect the health and productivity of dairy cattle. Farmers have observed improved health conditions, including reduced incidence of diseases such as mastitis and digestive disorders. The dual approach of mineral supplementation and deworming not only boost milk yields but also improves the overall well being of the cows, resulting in better economic returns for dairy farmers.

GKMS-DAMU Scheme

The GKMS-DAMU Scheme was started in 2019 at KVK, Ramgarh. Twelve numbers of whatsapp groups with 4750 nos of beneficiaries were created. Under this scheme. during the period 2019-24 weather forecast data received from IMD twice in a week (Tuesday & Friday) and prepared location specific agromet bulletin in bilingual for the farmers of the district. During the period 3456 numbers of Bi weekly agromet bulletins and 77 numbers of special agromet bulletins were issued for 06 blocks (Ramgarh, Gola, Chitarpur, Mandu, Patratu and Dulmi) of the district.. Farmers Awareness program (97 nos) were organized for more than 4,680 farmers. More than 16,500 farmers are getting agromet bulletin through Whatsapp, Print media, Social media, Notice boards in block offices etc. In this period farmers got benefits of weather forecast (effects of rain, temperature, cyclone, frost, hail strom etc.) and farmers were prepared for protect their crops from damage by the nature (Fig 5.31).



Fig. 5.31. Agromet unit at KVK, Ramgarh

Hi-tech model nursery

Hi-tech nursery for horticultural crops has been established in collaboration with CCL, Ranchi & NABRAD, Ranchi at KVK, Ramgarh and inaugurated by Dr. Himanshu Pathak, Hon'ble Secretary DARE and DG, ICAR, New Delhi in virtual mode in the physically presence of Dr. S.K. Chaudhary, DDG, NRM, New Delhi and Dr. U.S. Gautam, DDG, Extension, New Delhi on 30 Oct, 2023 for production of quality planting material of fruits and vegetable. 7000 nos. of mango plants (variety-Amrapali, Jardalu, Malda, Himsagar, Malika, Lagda, Dasehri), 100 nos. Guava (variety-L49 and Lalit), 50 nos. of Lemon (Variety- Kagzi Kalan), 500 nos of Papaya plant (variety-Red lady), 500 nos. Drum stick plant (variety-PKM1) and 6000 nos. Of tomato seedling, 6000 nos. of Chilli seedling, 1000 nos. of Brinjal seedling, 1000 nos. of ridge guard etc. under selling and approximately 18000 root stock of Mango, 350 nos. of guava, 100 of jackfruit are ready for propagation during 2023-24. Timber species and annuals/seasonal are also growing in the nursery.

Capacity Building

KVK, Ramgarh has been playing important role in capacity building of farmers. Till date 98,409 farmers have been trained through KVK (Table 5.8) (Fig. 5.32).

Table 5.8 Capacity building and extension activities undertaken by KVK, Ramgarh

Particular	Quantity/ Area/ Location	Participants		
		Male	Female	Total
Training programme for practicing farmers	693	14122	6785	20907
Training programme for rural youths	91	2173	583	2756
Training programme for extension functionaries	28	431	389	820
Skill Development Training Programme	23	303	528	831
Training programme for PACs, FPOs, Input Deal ers, and Rural youth	12	189	299	488
Extension activities (Kisan Mela, Goshthi, awareness programme, etc.)	475	28917	43690	72607
Total	**1322**	**46135**	**52274**	**98409**





Fig. 5.32. Training programs conducted at KVK Ramgarh

Linkages developed by KVKs

KVKs have established strong linkages with various organizations to collaborate on aspects of capacity building, participatory evaluation of technologies and implementation of developmental projects. Major collaborators include national and internation organizations, state departments, NGOs and financing institutions (Fig 5.33).



Fig. 5.33 Linkages developed by KVKs

Science & Innovations for Empowering Farmers

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Farming System Research Centre for Hill and Plateau Region, Ranchi

Background

The Farming System Research Centre for Hill and Plateau Region located at Ranchi, was established on 8th May 1979 with the name "Central Horticultural Experiment Station (CHES)" under the aegis of the ICAR-Indian Institute of Horticultural Research Institute, Bengaluru. Geographically, it is located at 23º 45' N latitude, 85º 30' E longitude, elevation 620 m above mean sea level. Initially, the Centre had a total area of 227 ha divided into three farms located at Plandu, Churu and Garkhatanga in the Ranchi district of Jharkhand. The primary goal of the Centre was to harness the horticultural potential of tribal areas in Eastern India through strategic development.

Mandate of the Centre

1. Development and breeding of improved varieties of horticultural crops resistant to biotic and abiotic stresses for the region.
2. Developing packages of practices suitable for the tribal farmers of the tract.
3. Standardization of pest and disease management.
4. Supply of genuine planting material of different fruits and vegetables in a large scale.

The focus was on improving fruits and vegetables, developing production technologies tailored to tribal farming, standardizing pest and disease management techniques, and providing genuine planting materials for various fruit and vegetable crops. During this phase, germplasms of various vegetable and fruit crops were collected from different parts of India and the world, and orchards were established. Farms II and III were developed as a 'National Repository for mango and litchi germplasm.

On April 1, 2001, the Centre merged with ICAR RCER, Patna, and was renamed the 'Horticulture and Agro-forestry Research Programme (HARP)'. This change incorporated natural resource management technologies into the horticultural and agro-forestry research programs, alongside the existing mandates. New research areas, such as land and water management, were added to its scope. In 2010, to expand its research focus and address the growing complexity of its mandates, the Centre was renamed 'ICAR RCER, Research Centre, Ranchi'. The Centre's research emphasis was realigned to address diverse issues related to land and water resource management, horticulture, agro-processing, plant protection, and socio economic aspects, following a farming system approach to enhance agricultural productivity and sustainability in eastern India. In 2019, the Centre was further renamed 'ICAR RCER, Farming System Research Centre for Hill and Plateau Region (FSRCHPR), Ranchi'. The vision of

Das A, Kumar A , Naik SK, Kumar P, Mali SS, Dubey R. and Mukherjee A. (2025). ICAR RCER: 25 Years of Glorious Journey of Innovation and Excellence. ICAR RCER, Patna

the FSRCHPR is to enhance agricultural productivity and sustainability in Eastern India, particularly in tribal areas, through integrated research and innovative farming systems. Its mission focuses on advancing horticultural and agro-forestry research, improving land and water resource management, and promoting sustainable practices and enhancing livestock improvement.

Table. 6.1 Chronology of Heads of the FSRCHPR, Ranchi

Name	Designation	Tenure	
		From	To
Dr. I S Yadav	Head	07/06/1979	23/06/1982
Dr. D P Singh	Head	28/07/1982	12/04/1994
Dr. A B Pal	Head	13/04/1994	30/11/1995
Dr. K K Kumar	Head (Acting)	01/12/1995	25/12/1996
Dr. Mathura Rai	Head	26/12/1996	03/01/2003
Dr. Shivendra Kumar	Head	04/01/2003	31/01/2014
Dr. Arun Kumar Singh	Head(In-charge)	01/02/2014	04/11/2014
Dr. Arun Kumar Singh	Head	05.11.2014	05.11.2019
Dr. Arun Kumar Singh	Head (Acting)	06.11.2019	17.01.2023
Dr. Rabi Sankar Pan	Head (Acting)	18/01/2023	03/05/2023
Dr. Arun Kumar Singh	Head	04/05/2023	30/11/2024
Dr. Rabi Sankar Pan	Head (Acting)	01/12/2024	Present

Infrastructure and facilities

Research farms

Currently, the Centre has two research farms and one nursery block covering an area of 416



Fig. 6.1. Maps of research farms and residential areas

acres. Farm-I, located in Plandu Village, spans 164.1 acres and houses the Research cum Administrative Building. This farm features a picturesque landscape with well-designed

orchards, as well as nursery plots, a farmers' hostel, and a residential campus nearby. Farm-II, situated about 10 km from Farm-I near Churu village, covers 236.54 acres. Additionally, an 18.73 acre animal-cum-nursery farm is located near Farm-I. Over the past forty years, the farm has conserved 298 mango and 39 litchi germplasm accessions. Various research activities are currently operational, including multiple uses of water bodies, animal husbandry, orchards, integrated farming systems, natural and organic farming, conservation agriculture, agri photovoltaic systems, fruit-based multi-tier cropping systems, and agro-forestry blocks.

Laboratories and facilities

Laboratories: The Centre has well equipped Soil Science, Fruit quality Analysis, Post Harvest and Plant Protection laboratories.

*Livestock unit***:** The centre houses T&D crossbred pigs and Jharkhand chicken germplasm for genetic studies and performance improvement. With a hatchery capacity of 2,000 eggs, the centre supplies chicks, live chickens, and fertile eggs to farmers, contributing to improved poultry production.



Fig. 6.2. Poultry shed



Fig. 6.3. Pig unit

Library: Library houses a total of 4952 publications, 1952 reference books, CAB CD ROM's, 1075 numbers of bound volumes of technical journals, Annual reports and other references materials. Library references are computerized using library software package with quick search facility.

Quality Seed and Planting Materials Production Facilities: The centre has facilities for largescale production of seeds, planting material and mushroom spawn. On an average, 5.0 tonnes of breeder seeds of different vegetable crops, 60000 saplings of different fruit plants and 5.0 tonnes of mushroom spawn are made available to the farmers every year.

Meteorological observatory: The Centre has a metrological observatory for recording weather data. It has well well-equipped workshop with basic facilities for the maintenance of farm machinery and farm implements. The Centre has a well-furnished committee room and conference room for conducting various scientific meetings. A well-furnished farmers' hostel, "Swarnarekha Kisan Bhawan" is also available at the centre for the accommodation of trainee farmers.

Table. 6.2. Personnel strength of the centre

Cateogry	Staff in position
Scientist	14
Administrative	04
Technical	13
Supporting	23

Research Contributions

Fruit and vegetables

Crop improvement in cucurbitaceous vegetables

Crop improvement in cucurbits began in 1986 under CHES, ICAR-IIHR, and continued under ICAR RCER. Germplasm characterisation was the first step carried out for varietal development in cucurbitaceous vegetables. Swarna Poorna (CH-20-3-2-1) of cucumber, Swarna Manjari (CHRG-1) were developed through collection and single plant selection. Mutation breeding of cucumber at IIHR, Benguluru using 5kr, 10kr and 15kr resulted in Swarna Sheetal (CHC-1) and Swarna Ageti (CHC-2) which were popular among the farming community due to juicy texture and absence of placental hollowness in the fruits. Germplasm collection from Bihar, Uttar Pradesh, Odisha, Chhattisgarh and their characterisation lead for identification of three varieties of pointed gourd viz., Swarna Rekha with distinct white stripes; Swarna Alaukik, light greenish fruits without stripes and Swarna Suruchi with light greenish fruits through clonal selection. Swarna Sneha of bottle gourd, Swarna Manjari and Swarna Sawani of ridge gourd, Swarna Sawani of sponge gourd and Swarna Amrit of pumpkin were developed through germplasm collection and single plant selection and became more popular among the farming community due to suitability of cultivation in both the seasons and acceptable market size and colour of the fruits. Interspecific crosses with Cucumis hardwickii for incorporation of abiotic stress tolerance resulted in identification of RCCV-158 and was evaluated under multilocation testing in AICRP-VC.



Fig. 6.4. Pointed gourd variety: Swarna Alaukik



Fig. 6.5. Ridge gourd variety: Swarna Uphar

Breeding for bacterial wilt resistance in solanaceous vegetables

Promising varieties of brinjal and tomato were developed through selection from segregating populations after multilocational testing under AICRP on Vegetable Crops. Swarna Shyamli, Swarna Pratibha, Swarna Shree, Swarna Shobha varieties of brinjal and Swarna Lalima, Swarna Naveen varieties of tomato were developed through single plant selections made from local collections. Swarna Mani of brinjal was developed from segregating populations of a cross between CH-82, which was wilt resistant. The programme of development of F1 hybrids in brinjal and tomato was undertaken under the NATP project on "Development of hybrids in vegetable crops". Crosses were made amongst promising lines through Line x Tester and Diallel mating design. Experiences from farmers' fields had indicated the need for improvement of existing varieties released from the centre. The low keeping quality of bacterial wilt resistant variety Swarna Lalima was found to be one of the main characters that required improvement. Thus, the line HAT-193 was used as one of the parents for high keeping quality of tomato fruits. For development of bacterial wilt resistant tomato variety with small sized fruits and high acidity, the bacterial wilt resistant line HADT-1 having small sized fruits (30-40g) was crossed with the line HAT-180 having fruits with high acidity leading to F1 hybrid Swarna Vijaya. Best cross Swarna Lalima x HAT-193 (Swarna Sampada) was identified to be superior among the half diallel crosses involving eight tomato lines with respect to resistance and yield in bacterial sick plot. In brinjal, for improving yield and fruit quality, low yielding, dark colored and round fruited variety Swarna Mani, was crossed with high yielding, purple colored line HABR-6, resulting in identification of F1 hybrid Swarna Neelima with attractive dark purple round fruits. F1 hybrid Swarna Mohit with attractive light purple fruits was developed by crossing CH-381 with Swarna Mani. For improvement in fruit colour of bacterial wilt resistant cultivar Swarna Shyamli (light green with white striped fruits), crosses were made between Swarna Shyamli x HAB-792 (highly pigmented fruit) and the best F1 was identified as Swarna Ajay, with attractive purple oblong fruits. Purple oblong fruits in Swarna Pratibha was improved by crossing with Swarna Shree and F1 hybrid Swarna Shakti was developed having shiny light purple fruits. Best promising combinations were tested through AICRP on Vegetable Crops for three years at different locations. Keeping in view of the recent demands, varieties/hybrids for special purpose were developed using the exotic collections. Bacterial wilt resistant tomato hybrid, Swarna Anmol (Swarna Lalima x EC-596747) having indeterminate plant habit was developed for protected cultivation. Swarna Ratan, Cherry tomato variety and Swarna Kanchan, for processing were developed and popularised. On the recommendation of the group meeting organized under AICRP on Vegetable Crops the promising varieties/hybrids were identified for release through Central Variety Release Committee. 22 varieties/ hybrids of tomato and brinjal which are high yielding and bacterial wilt resistant were released and notified under CVRC/SVRC/IVRC.

Improvement of French bean for disease resistance

At FSRCHPR, a comprehensive evaluation of 72 accessions of French bean was conducted to assess major disease reactions and qualitative and quantitative economic traits. Among these, four genotypes-RCFB6, RCFB14, RCFB15 and RCFB37 were identified as highly resistant to rust during the spring-summer season, scoring 0 on a 0-5 disease resistance scale. These genotypes

are bush-type and exhibit round-podded characteristics, except for RCFB 14, which is flat-podded. Pod lengths ranged from 14.0 to 15.6 cm, with a light green to dark green color and a stringless trait. RCFB 6 emerged as the highest-yielding genotype, producing 5.5 t/ha of green pods in 90 days, while the other three genotypes achieved yields ranging from 4.0 to 5.2 t/ha. Furthermore, under controlled conditions, these genotypes were artificially inoculated with rust sporulation and demonstrated an immune reaction, confirming their robust resistance to rust. These findings highlight the potential of these genotypes for high-yielding, diseaseresistant cultivation in the region.

Evaluation of potential wild edibles crops

Twelve surveys were conducted in tribal dominated districts like Chatra, Latehar, Garhwa, Palamau, Jamtara, Dumka, Khunti, Lohardaga, West Singhbhum and Ranchi in Jharkhand, Uttar Bastar Kanker in Chhattisgarh, Bhubaneswar and Kalahandi in Odisha and Birbhum, Bankura, Purulia and West Midnapore in West Bengal. A special survey was conducted in nine districts of Nagaland namely, Dimapur, Peren, Kohima, Phek, Zunheboto, Wokha, Mokokchung, Mon and Longleng, where 40 new germplasm of taro were collected. Totally, 256 germplasm were collected and multiplied in the field for characterization and evaluation. These include germplasm of Dioscorea spp. (56), Ipomoea batatas (12), Maranta arundinacea (3), Colocasia spp. (112), Amorphophallus spp. (47), Alocasia spp. (7), Manihot spp. (7), Xanthosoma spp. (5) and Cucumis melo var. agrestis (7).



Fig. 6.6. Wild tuber crops in farmers field

Sweet potato

Eleven germplasm lines were evaluated for 12 yield and nutritional traits. On the basis of ORSI values of genotypes, corm size and shape, ACC-161 (a collection from Silli block of Ranchi; ORSI value 0.78; tuber yield 8.25 t/ha; tuber carbohydrate 17.09 g/100g; total mineral 672.92 mg/100g; anti-oxidant activity 186.89 mg AEAC/100g; beta carotene 7775.28 mg/100g; total sugar 3.86%), ACC-229 (a collection from Rampur block of Kalahandi district; ORSI value 0.68; tuber yield 13.20 t/ha; tuber carbohydrate 14.48 g/100g; total mineral 844.7 mg/100g; anti-oxidant activity 196.90 mg AEAC/100g; beta carotene 1523.82 mg/100g; total sugar 3.13%) and ACC-183 (a collection from Ilambazar block of Birbhum district; ORSI value 0.59; tuber yield 13.70 t/ha; tuber carbohydrate 15.96 g/100g; total mineral 707.19 mg/100g; anti-oxidant activity 171.78 mg AEAC/100g; beta carotene 3228.76 mg/100g; total sugar 2.69%) were identified promising for further multiplication and promotion as pre-released varieties.



Fig. 6.7. ACC161

Taro/Colocasia

Forty five genotypes of taro were evaluated for 32 yield, nutritional, anti-nutritional and biotic stress traits. On the basis of ORSI values of genotypes, corm size and shape, ACC-60 (a collection from Jama block of Dumka district; ORSI value 0.19; corm yield 748.50 g/plant; 37.42 t/ha; corm carbohydrate 39.29 g/100g; total mineral 1.604g/100g; anti-oxidant activity 284.01 mg AEAC/100g; leaf oxalate 67.47 mg/100g; corm oxalate 45.66 mg/100g; petiole oxalate 10.69 mg/100g), ACC-118 (a collection from Kanker block of Uttar Bastar Kanker district; ORSI value 0.17; corm yield 889.04 g/plant; 44.45 t/ha; corm carbohydrate 35.54 g/100g; total mineral 1.447g/100g; anti-oxidant activity 229.30 mg AEAC/100g; leaf oxalate 61.41 mg/100g; corm oxalate 50.30 mg/100g; petiole oxalate 8.38 mg/100g) and ACC-280 (a collection from Wakching block of Mon district of Nagaland; ORSI value 0.17; corm yield 2052.50 g/plant; 51.25 t/ha; corm carbohydrate 25.74 g/100g; total mineral 1.732 g/100g; antioxidant activity 310.10 mg AEAC/100g; leaf oxalate 86.75 mg/100g; corm oxalate 37.99 mg/100g; petiole oxalate 4.23 mg/100g) were identified promising genotypes for further multiplication and promotion as pre-released varieties.

Elephant foot yam

Ten germplasm lines were evaluated for 19 yield and nutritional traits. Considering five important traits. On the basis of ORSI values, corm size and shape, ACC-136 (a collection from Bandgaon block of West Singhbhum district; ORSI value 0.61; corm yield 2.63 kg/plant; 32.87 t/ha; corm carbohydrate 24.36 g/100g; total mineral 503.09 mg/100g; anti-oxidant activity 50.31 mg AEAC/100g; oxalate 9.22 mg/100g), ACC-204 (a collection from Hura block of Purulia district of West Bengal; ORSI value 0.60; corm yield 1.49 kg/plant; 18.62 t/ha; corm carbohydrate 26.15 g/100g; total mineral 532.98 mg/100g; anti-oxidant activity 230.42 mg AEAC/100g; oxalate 7.84 mg/100g) and ACC-85 (a collection from Itki block of Ranchi district; ORSI value 0.54; corm yield 2.89 kg/plant; 36.12 t/ha; corm carbohydrate 22.75 g/100g; total mineral 569.52 mg/100g; anti-oxidant activity 110.95 mg AEAC/100g; oxalate 10.18 mg/100g) were identified promising genotypes for further multiplication and promotion as pre-released varieties.



Fig. 6.8. ACC-136

Cassava

Six germplasm lines of cassava were evaluated for 16 yield and quality related traits. Considering four important traits, ORSI values of these six genotypes were calculated. On the basis of ORSI values, tuber size and shape, ACC-139 (a collection from Bandgaon block of West Singhbhum district; ORSI value 0.81; tuber yield 19.75 t/ha; tuber carbohydrate 30.68 g/100g; total mineral 751.89 mg/100g; anti-oxidant activity 297.71 mg AEAC/100g) and ACC-53 (a collection from Dumka block of Dumka district; ORSI value 0.81; tuber yield 27.25 t/ha; tuber carbohydrate 38.68 g/100g; total mineral 766.92 mg/100g; anti-oxidant activity 89.94 mg

AEAC/100g) were identified promising genotypes for further multiplication and promotion as pre-released varieties.



Fig. 6.9. ACC-28

Potato/Aerial yam

Six germplasm lines of potato/aerial yam were evaluated for 16 yield and quality related traits. On the basis of ORSI values, aerial tuber size and shape, ACC-28 (a collection from Katud nichetola village under Khunti block of Khunti district of Jharkhand; ORSI value 1.77; aerial tuber yield 9.18 t/ha; tuber carbohydrate 17.01 g/100g; protein 5.05 g/100g; total mineral 1.8 g/100g; anti-oxidant activity 65.64 mg AEAC/100g) and ACC-123 (a collection from Kanker block of Uttar Bastar Kanker district; ORSI value 0.96; aerial tuber yield 9.48 t/ha; tuber carbohydrate 7.19 g/100g; protein 5.45 g/100g; total mineral 1.3 g/100g; anti-oxidant activity 31.50 mg AEAC/100g) were identified promising genotypes for further multiplication and promotion.



Fig. 6.10. ACC-34

Greater yam

Seven germplasm lines of greater yam were evaluated for 16 yield and quality related traits. On the basis of ORSI values of these seven genotypes, tuber size and shape, ACC-113 (a collection from Amajhola village under Kanker block of Uttar Bastar Kanker district of Chhattisgarh; ORSI value 0.73; tuber yield 16.02 t/ha; tuber carbohydrate 27.19 g/100g; total mineral 1156.95 mg/100g; antioxidant activity 190.97 mg AEAC/100g) and ACC-34 (a collection from Tunko village under Namkum block of Ranchi district of Jharkhand; ORSI value 0.55; tuber yield 42.77 t/ha; tuber carbohydrate 15.61 g/100g; total mineral 642.13 mg/100g; anti-oxidant activity 102.76 mg AEAC/100g) were identified promising genotypes for further multiplication and promotion as pre-released varieties.

Lesser yam

Seven germplasm lines of lesser yam were evaluated for 16 yield and quality related traits. On the basis of ORSI values these genotypes, tuber size and shape, Lotni (a variety from Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar; ORSI value 0.91; tuber yield 30.77 t/ha; tuber carbohydrate 22.24 g/100g; total mineral 516.50 mg/100g; anti-oxidant activity 187.95 mg AEAC/100g) and Adamoul-4 (ORSI value 0.79; tuber yield 29.79 t/ha; tuber carbohydrate 25.15 g/100g; total mineral 613.11 mg/100g; anti-oxidant activity 76.91 mg AEAC/100g) were identified promising genotypes for further multiplication and promotion.



Fig. 6.11. Lotni

Wild muskmelon/Kachri

Six germplasm lines of wild muskmelon/kachri were evaluated for five yield and quality related traits. On the basis of ORSI values these six genotypes, the genotypes HAWMM-1 (ORSI value 1.21; fruit yield 3.32 t/ha; fruit carbohydrate 1.94 g/100g; protein 1.21 g/100g; total mineral 2.99 g/100g; anti-oxidant activity 866.67 mg AEAC/100g) and HAWMM-3 (ORSI value 0.88; fruit yield 3.76 t/ha; fruit carbohydrate 0.82 g/100g; protein 1.33 g/100g; total mineral 1.97 g/100g; anti-oxidant activity 1043.75 mg AEAC/100g) were identified promising genotypes for further multiplication and promotion as pre-released varieties.



Fig. 6.12. HAWMM-1

Yam bean

Out of seven genotypes including check evaluated, HAYB-1 (A collection from village Khirpai of Pashchim Medinipur district of West Bengal; 52.22 t/ha) and DPH-88 (46.57 t/ha) performed better than the check variety Rajendra Mishrikand-1 (42.66 t/ha) and were at par with each other in respect of tuber yield.



Fig. 6.13. HAYB-1

Development of biofortified vegetable varieties

At FSRCHPR, a pre-breeding initiative was undertaken to enhance the genetic diversity of edible podded pea by crossing RCEP 2, a green-podded snap pea with short stature, white flowers, sweet seeds, and thick pod walls, with EC598581, a purple-podded pea featuring pink flowers, vigorous growth habit, non-sweet seeds, and thin pod walls. This strategic crossing aimed to introgress desirable traits from wild germplasm into cultivated varieties. Edible podded pea (RCEP 2; green podded snap pea, short stature, white flowered, sweet seeds) was crossed with EC598581 (purple podded, pink flowered, vigorous growth habit, seed not sweet, thin pod wall) as a pre-breeding approach of utilizing wild germplasm for introgression of desirable traits. Based on sale of seeds from our Centre, the estimated total area covered till date by these developed improved leguminous vegetable varieties was 1235.426 ha which resulted in receipt of ₹ 17.18 crore as net income of farmers and ₹ 17.16 crore as increase in income of farmers over the traditional varieties.

Nutritional potential of underutilized leafy vegetables of Jharkhand

Jharkhand is very rich with respect to the diversity of underutilized green leafy vegetables that are commonly consumed by the natives. These underutilized leafy vegetable species are nutritionally rich and adapted to low input agriculture. A sizable proportion of these underutilized leafy vegetables is not cultivated and is collected from wild. During peak season a large quantity of these leafy vegetables are harvested and dried by local people. The potential underutilized fresh leafy vegetables of Jharkhand based on their availability as well as their

antioxidative and nutritional potential were found to be; A. gangeticus L., A. viridis L., A. spinosus L., I. aquatica L., C. album L. and B. alba L., whereas those which are sold in dried form were C. tora L., I. batatas (L.) Lam. and V. spinosa (Roxb. ex Link) Roxb. Consumption of such valuable vegetables should be encouraged through awareness so that larger section of population could include these vegetables in their dietary menu to get the nutritional as well as health benefits. Majority of these leafy vegetables contain lower amount of antinutrient components (oxalate, nitrate and tannins) and higher antioxidant potential as compared to commonly consumed leafy vegetables.

Major underutilized leafy vegetables sold in fresh form in tribal markets of Jharkhand



a) *Amaranthus gangeticus* L. b) *Hygrophylla spinosa* T. Anders c) *Ipomoea aquatica* L.

d) *Marsilea minuta* L. e) *Ficus geniculata* Kurz f) *Bauhinia variegate* L.

g) *Bauhinia variegate* L. (Flower buds) h) *Crotolaria juncea* L. i) *Indigofera pulchella* Roxb.

Fig. 6.14. Underutilized leafy vegetables of Eastern Plateau and Hill Region

Natural resources management

Integrated Farming System (IFS) model for rainfed areas

More than 80% of the rural population of Eastern hill and plateau region mainly depends on agriculture. IFS model with aim to optimize the components of (cereals, pulses, fruits, fodder

crops, fish pond, and cattle) established on a 0.75-acre rainfed farm to maximize gross returns while fulfilling the nutritional requirements of a family. The 0.75-acre rainfed IFS model integrates livestock (2 cows and 1 calf) and fruits (guava and papaya) with cropping systems that include rice, ragi, combined with black gram and horse gram. To reinforce the field bunds and provide additional income, tephrosia, pigeon pea, and black gram were planted around the bunds alongside trees like drumstick and bakain (Melia azedarach), which helped in reducing erosion. This model yielded a gross return of ₹ 84,742 and a net return of ₹ 44,957 with employment generation of 110–130-man days. Rice equivalent yield (REY) was 4 times higher (6 to 9.5 t/ha in different years) over conventional rice-fallow system. Nutrient recycling within this system is substantial, with vermicompost (0.75 ton) and FYM (3.44 ton) supplying nutrients equivalent to 23.9 kg of nitrogen (N), 9.4 kg of phosphorus (P), and 24.2 kg of potassium (K). Additionally, recycling 1.2 tons of crop residue biomass contributed an extra 6.2 kg of N, 2.5 kg of P, and 5.1 kg of K back into the system. The optimal plan produced an annual gross return of ₹1,03,448/- from 0.75-acre model. The model is optimal to meet the nutritional needs of a family of 2 adults + 2 kids.



Fig. 6.15. Hort+Dairy+Agri based IFS model for hill and plateau region

Crop diversification of existing upland production systems

Crop diversification can help address these challenges by introducing a variety of crops that are better suited to the region's conditions and provide multiple income sources for farmers. Rice, finger millet, colocasia, and sweet potato were grown as sole crops. The sole crop of sweet potato recorded the highest rice equivalent yield of 14.24 t/ha, followed by colocasia (7.57 t/ha) and finger millet (6.11 t/ha). The sole crop of rice recorded a yield of only 2.43 t/ha. The energy productivity of sweet potato (0.90 kg/MJ) was the highest, followed by finger millet (0.83 kg/MJ), colocasia (0.62 kg/MJ), and rice (0.29 kg/MJ). Crop diversification involving vegetables, pulses, and millets is an important strategy for enhancing agricultural sustainability, improving farm income, and promoting food security in the Eastern Plateau and Hill region of India. Among the different crop diversion options, vegetable cowpea (10.42 t/ha) followed by pigeonpea (8.71 t/ha), finger millet +horsegram (5.55 t/ha), produced REY as against sole rice (1.29 t/ha) in the rainfed upland.

Phosphate solubilizing fungi identified for management of acid soils

The potentiality of three fungal species isolated from the acid soils of Jharkhand, India, were evaluated for their efficiency of release of phosphorus from inorganic phosphorus compounds Fig. 6. 15. Hort+ Dairy +Agri based IFS model for hill and plateau region and acid phosphatase

activity. Isolated 3 potential phosphate solubilizing fungi (PSF) namely Aspergillus niger, Penicillium chrysogenum and Trichoderma viride from the acid soils of Jharkhand. Among the strains, Aspergillus niger was found to be most efficient strains in mobilizing P from tricalcium phosphate (75%) and ferric phosphate (77%). The highest acid phosphatase activity of 73U was induced both by Aspergillus niger and Trichoderma viride.

Soil organic carbon stock in multipurpose trees (MPTs) in eastern plateau and hill region of India

The soil organic carbon (SOC) stock in multipurpose trees (MPTs) in the Eastern Plateau and Hill region of India plays a crucial role in improving soil fertility, enhancing agricultural productivity, and combating climate change. The MPTs contribute significantly to the SOC stock, benefiting both the environment and the farming community. The total SOC in different soil depths of 0-0.15, 0.15-0.30, 0.30-0.45, 0.45-0.60 and 0.60-0.90 m under 9 year old plantations of ber, kusum and palas in eastern plateau and hill region were determined. The highest Ctot (TSOC) in 0-0.90 m depth was 65.32 t/ha under kusum plantations, which was 24.5% higher than that obtained under control and followed trend as, kusum> ber> palas> control.

Carbon sequestration potential of agroforestry systems

Tree-based agroforestry systems offer several benefits for rainfed upland areas, where agricultural productivity is often constrained by irregular rainfall, soil fertility challenges, and limited access to irrigation. Leucaena leucocephala based AFS had the highest estimated annual carbon sequestration potential (8.678 t C/ha/yr) followed by Emblica officinalis (8.658 t C/ha/yr) and the lowest was for Sapindus mukorossi (2.489 t C/ha/yr). The per cent change in carbon sequestration potential of fast-growing tree based AFS were impacted by annual rainfall and temperature.

Carbon foot print in Rice production system of Eastern Plateau and Hill Region

The carbon footprint is a measure of the total greenhouse gas (GHG) emissions produced by agricultural systems, and it is a critical factor in understanding the environmental sustainability of different farming practices. In the context of the Eastern Plateau and Hill Region of India, the comparison between Conservation Agriculture (CA) and conventional farming systems can provide insights into how different agricultural practices influence carbon emissions and overall environmental health. The C-footprint in spatial scales (CFs), C-footprints in yield scales (CFy), in rice, mustard and blackgram had markedly influenced by different cultivation practice. CFs was significantly highest in rice (1670 CO_2-e kg/ha), mustard (615 CO_2-e kg/ha) and blackgram (458 CO_2-e kg/ha) in conventional practice (CP) compared to conservation agriculture based approach. System-based production showed markedly minimum CFs of 2311 CO_2-e kg/ha in CA system compared to CP. The system CFy was lowest of 465 CO_2-e kg/t in CA system and registered 26.6% decrease over CP.

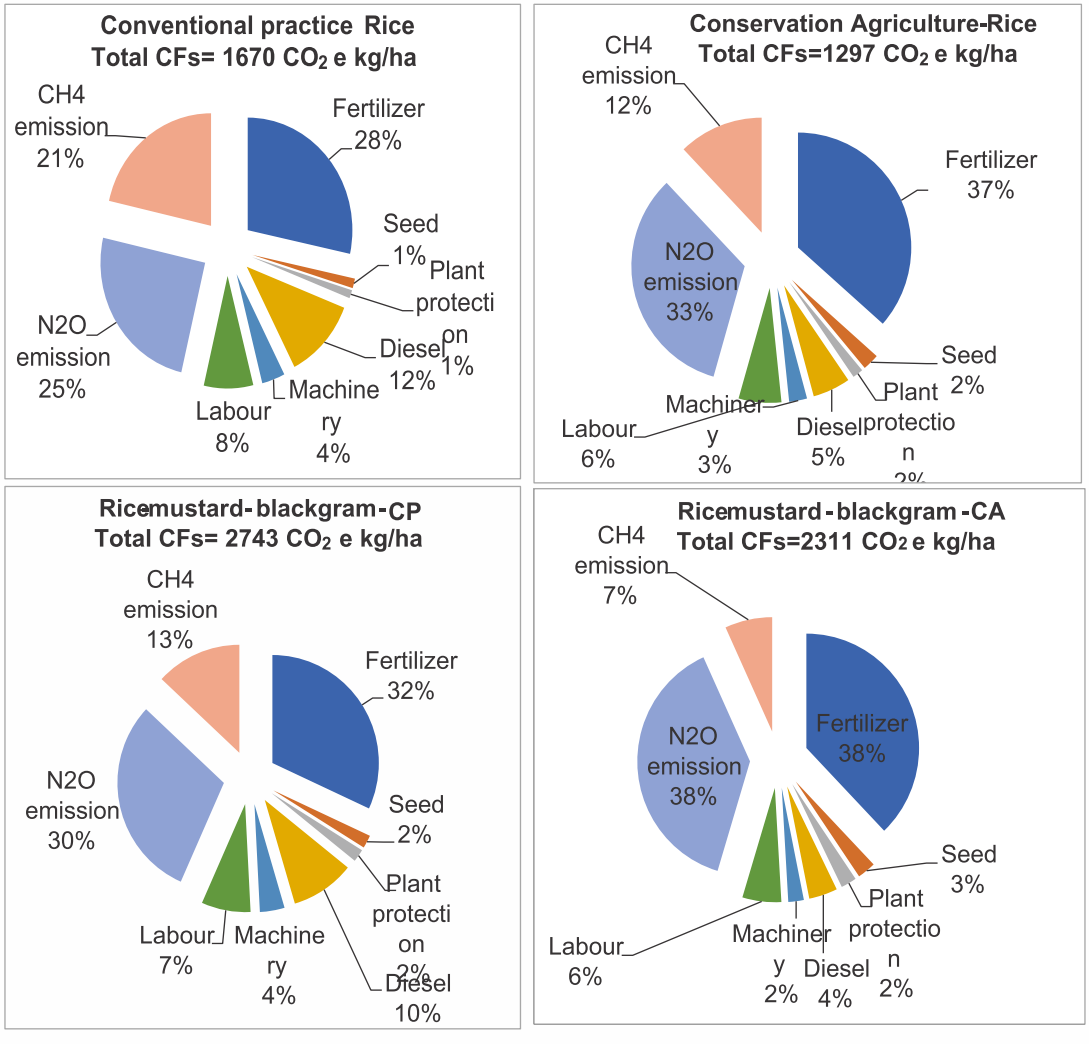

Fig. 6.16. Carbon foot print in rice production systems of Eastern Plateau and Hill Region

Degradation and nutrient release pattern of various crop residues

In Eastern hill and plateau region, where sustainable agriculture relies on effective management of crop residues to enhance soil health and fertility, research on the degradation and nutrient release patterns of residues is essential to optimize residue incorporation practices. The decomposition pattern of different Crop residues viz. paddy, rice, ragi, maize, blackgram and niger straw have been estimated through litter bag techniques and observed that ragi straw has the slow decomposition rate while blackgram straw has highest (T99= 12.25 months) decomposition rate. In all the crop residues the nutrient release pattern shows the order as, K > P > N. These findings provide critical insights for optimizing crop residue management to improve nutrient cycling, soil organic matter, and productivity in Jharkhand's agricultural systems.

Unveiling lignocellulose-degrading microbes in acidic soil

In Eastern hill and plateau region, where agriculture relies heavily on crop residues and organic matter for soil fertility, research on lignocellulose-decomposing microbes is crucial to address challenges of residue management and soil health. Screening on carboxymethylcellulose (CMC) and tannic acid (TA) agar identified 5 fungi and 2 bacteria with significant cellulose and lignin-decomposing capabilities. Quantitative enzyme assays revealed that fungal strains identified as Trichoderma and Aspergillus species exhibited the highest CMCase and filter paperase activity. These strains hold potential for enhancing lignocellulose decomposition, offering an eco-friendly solution for managing crop residues, improving soil organic matter, and promoting sustainable farming practices.

Crop residues for sustainable nutrient recycling

In Jharkhand's rice-wheat cropping systems, where low soil fertility and reliance on chemical fertilizers are a persistent challenges, research on crop residue recycling has shown significant potential for sustainable nutrient management. Applying paddy, wheat, and maize straw at 5 tons/ha after one month of paddy sowing recycled 111, 107, and 105 kg/ha NPK, respectively. Wheat straw decomposed faster (7 months) compared to maize (9 months) and paddy straw (10 months), ensuring quicker nutrient mineralization and availability. This practice enhances soil organic matter, reduces residue burning, and supports higher crop productivity, making it

an eco-friendly and cost-effective strategy for Jharkhand's resource-constrained farming systems.



Maize straw application Wheat straw application Paddy straw application

Fig. 6.17. Crop residue application in Cereals

In-situ crop residue management with microbial inoculation and nitrogen supplementation

The Jharkhand, where low-input farming systems dominate, research on in-situ crop residue management with microbial inoculation and nitrogen supplementation is vital to address challenges of residue disposal, soil fertility, and productivity. Adding crop residues paddy or ragi straw @ 5.0 t/ha along with Inoculation of Trichoderma spp. and Aspergillus spp. cultures (@2 kg/t of crop residue) with 1% nitrogen supplementation accelerated residue decomposition, enhanced soil fertility, and increased crop yields. This practice boosted the yields of field pea, moong bean, and maize by 8-12%, improved soil parameters like organic carbon, available NPK, DTPA-Fe, Mn, Cu, Zn, microbial count, and enzyme activity (dehydrogenase, phosphates and FDA).



Fig. 6.18. Crop residue management with microbial inoculation

Phosphorus solubilization in acidic soil through organic amendments

In Jharkhand, where acidic soils dominate and phosphorus fixation limits crop productivity, research on enhancing phosphorus availability through organic amendments is essential to improve soil fertility and sustainability. The study demonstrated that organic amendments like vermicompost (7 t/ha) and PSB (7 kg/ha) effectively mobilized fixed phosphorus by stimulating microbial activity and organic acid production, increasing Saloid-bound phosphorus (5-10% of total P) and improving phosphorus availability.

Subsurface Drip Irrigation in Vegetable Crops

Cucumber

Subsurface drip irrigation (SSDI) enhances water distribution, nutrient delivery, and crop performance by placing lateral lines below the soil surface, minimizing evaporation losses and ensuring efficient water and nutrient supply to the active root zone. A study on cucumber crops in sandy loam soils of India's eastern plateau region assessed lateral placements at 5 cm, 10 cm, and 15 cm depths, combined with four fertigation levels, over three cropping seasons. SSDI improved soil moisture distribution, with deeper placements providing better water uniformity. The best vine growth was achieved with 120:90:90 N:P:K fertigation and a 10 cm lateral depth, while the highest yield of 32.9 t/ha occurred at a 15 cm depth. The 10 cm depth, paired with balanced fertigation, consistently resulted in higher yields and improved water use efficiency, ranging from 0.47 to 0.83 t/ha/mm.



Fig. 6.19. Sub surface drip irrigation

Bitter gourd

Treatments with lateral placements at 10 cm and 15 cm depths maintained drier soil surfaces while offering better water access, enhancing plant growth. The highest yield of 35.4 t/ha and irrigation water use efficiency of 6.33 t/ha/mm were achieved with 10 cm lateral depth and high fertigation (150:120:120 kg NPK/ha). For bitter gourd cultivation in sandy loam soils of India's eastern plateau region, placing laterals at 10 cm depth with high fertigation is the most effective strategy for optimizing yield and water management.

Solar-Powered Irrigation for Livelihood Improvement

The solar-based collective farming model, implemented across the Eastern Gangetic Plains from 2015 to 2019 with funding from ACIAR, Australia, aimed at improving irrigation access and agricultural productivity for small and marginal farmers in Bihar. Key interventions included solar pumps, drip and sprinkler irrigation, and plastic mulching, along with the formation of farmer collectives. These efforts led to a significant increase in cropping intensity from 110% to over 230%, with the introduction of profitable rabi and summer crops such as tomato, brinjal, and okra. Economic analysis highlighted the profitability of crops like wheat and potatoes, while solar-powered irrigation systems improved water access and efficiency. This model not only improved cropping patterns and incomes but also addressed groundwater management, significantly boosting the livelihoods and resilience of farmers.



Fig. 6.20. Solar-powered irrigation

Water requirements for mushroom

The mushrooms [*Pleurotus florida* and *Hypsyzigus ulmarius* (Blue Oyster)] were cultivated on paddy straw substrate during October and November. The bags were hung on steel racks in December under controlled conditions, with daily temperature and humidity monitored. The study revealed that water use efficiency (WUE) for Pleurotus Florida ranged from 0.2 to 0.24 kg/liter, and for *Hypsyzigus ulmarius*, it ranged from 0.18 to 0.24 kg/L. This indicated that producing 1 kg of *Pleurotus florida* required 4.16 to 5.0 liters of water, while Blue Oyster production required 4.16 to 5.5 liters.

Plant protection techniques

Resistant sources for mango shoot gall psylla management

Mango shoot gall psylla, *Apsylla cistellata* Buckton (Psyllidae: Homoptera) is one of the region-specific serious pests of mango in India. The pest forms hard conical shaped green shoot galls in place of axillary and apical buds which hampers the initiation of inflorescences and retard the growth. The research was initiated to screen and evaluate the resistant sources against shoot gall psylla at the centre. Screening of mango genotypes in the early 90s showed that varieties Amrapali, Latara, Baramasia have field tolerance against shoot galls. During 2012-2016, genotypes Himayuddin, Lal Sinduria, Mulgoa Hill and Hybrid- 11/4 were recorded as resistant continuously from four years of data against MSGP in field conditions. Resistance

sources can be used for resistance breeding programs and to develop more handy and sustainable resistant mango varieties.

Gut bacteria-based female-biased bait trap for peach fruit fly, *Bactrocera Zonata*

Cultivable gut bacteria-based female-biased fruit fly bait trapping was developed for the management of peach fruit fly, *Bactrocera zonata*. The combination of *Klebsiella oxytoca* based trap captured significantly higher numbers of female flies than male flies. Widely used methyl eugenol-based para pheromone traps attract only male flies. This is the first description of gut isolated bacteria (*K. oxytoca*) attractancy potential of *B. zonata* in open field conditions, attracting a greater number of female flies along with male flies.

Genotypes resistant against melon fruit fly in pointed gourd

Fruit flies are the major pest of pointed gourd and are difficult to manage through chemical sprays. The screening of pointed gourd genotypes was initiated against fruit flies for host plant resistant. The genotypes HAP-88 and HAP-65 were designated as a resistant source against melon fruit flies. The relationship was established between fruit fly infestation and allelochemical (phenol and tannin) antixenotic (length of pubescence and rind hardness) fruit traits in pointed gourd varieties/ genotypes to test the validity of the hypothesis for highly influencing factors.

Climate change impacts on insect pests of horticultural crops

- A temperature-dependent growth and development model was developed for peach fruit fly, *Bactrocera zonata* (Saunders) (Diptera: Tephritidae) using a process-based phenology modeling centered on rate summation and cohort updating approach. The phenology models of life table parameters of *B. zonata* using ILCYM software were estimated at constant and fluctuating temperatures to reflect its growth potential in response to changes in temperature regimes. The phenology model developed for *B. zonata* can be linked with Geographic Information Systems (GIS) for mapping pest population distribution, damage activity, and population build-up in response to climate change scenarios.
- Statistical models for forewarning of cowpea thrips, *Scirtothrips dorsalis* and mites, *Polyphagotarsonemus latus* and whitefly, *Bemisia tabaci* dynamics model on capsicum were standardized. Regression-based statistical models were developed to explain the variability in population development of thrips and mites on summer-season cowpeas and whiteflies on capsicum. The model explains that temperature and rainfall significantly affect the pest dynamics in cowpeas in the Eastern Plateau and Hill region. The statistical regression model developed can be used for weather-based forecasting and can save a considerable amount of crop losses by successfully developing and implementing pest management strategies.
- Conceptualized and predicted future spatio-temporal variations in population abundance and distribution of peach fruit fly, *Bactrocera zonata* (Saunders), based on temperature driven phenology models under different climate change scenarios. The possibilities of changes in abundance and distribution of *B. zonata*, temperature-driven process based phenology models were linked with climatic data of multiple General Circulation Models (eight models) and climate change scenarios (RCP 2.6, 4.5, 6.0 and 8.5) using the Insect Life

Cycle Modeling (ILCYM) software. The risk indices (establishment, generation, and activity index) were mapped and quantified the changes in respect to locations, scenarios, models and times (2050 & 2070). The study results showed that changes in future predicted temperature due to climate change will increase the activity of B. zonata with higher generations and thus lead to increased suitable areas under this pest in India.

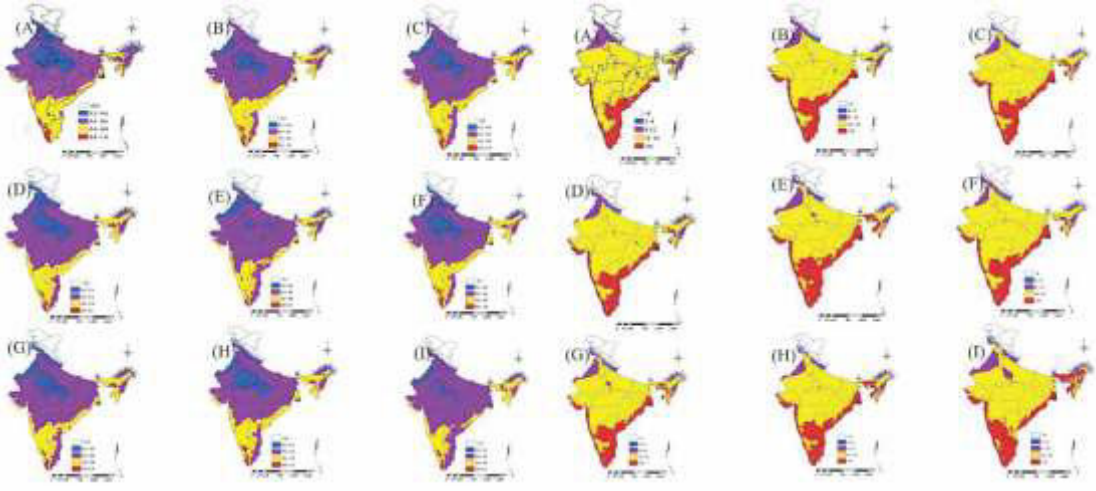

Fig. 6.21. Current (1950–2000) (A) and ensemble average of eight GCMs of each future scenarios (B = 2.6/2050; C = 4.5/2050; D = 6.0/2050; E = 8.5/2050; F = 2.6/2070; G = 4.5/2070; H = 6.0/2.070; I = 8.5/2070) establishment of *Bactrocera zonata* in India based on phenologybased model prediction of establishment risk index (ERI) and activity index (AI).

New reports of insect pests and their natural enemies

- New report of an entomopathogenic fungus belonging to the genus *Hirsutella* infecting the mango hopper, *Idioscopus clypealis* (Lethierry) (Hemiptera: Cicadellidae). An entomopathogenic fungus belonging to the genus *Hirsutella* was found infecting the mango hopper, *Idioscopus clypealis* (Lethierry) (Hemiptera: Cicadellidae), for the first time in India. The report of a natural control agent of mango hopper during the off-season has special significance because its outbreak depends upon its residual hibernating population.



Fig. 6.22. Dead mango hopper infected with *Hirsutella* sp. on mango twig.

- New record of the litchi stink bug, Tessaratoma javanica (thunberg) egg parasitoids from India. Three egg parasitoids of litchi stink bug were recorded, two were from the family Eupelmidae and one was from the family Encyrtidae of order Hymenoptera. The parasitoids that were reported were, Anastatus bangalorensis and Anastatus acherontiae.



Fig. 6.23. Adult female of *Anastatus bangalorensis* Mani and Kurian (1953) and *Anastatus acherotiae* Narayanan et al. (1960)

Complete mitochondrial genome sequencing

Complete mitochondrial genome sequencing of two agriculturally important insect species has been designed, conceived, sequenced, assembled/annotated. Sequencing of first complete mitochondrial genome of two agriculturally important insect species viz., peach fruit fly, *Bactrocera zonata* (Diptera: Tephritidae) and mango hopper, *Idioscopus nitidulus* (Hemiptera: Cicadellidae) (NCBI database: KP296150 & KR024406 as vide accession numbers, respectively, available at https://blast.ncbi.nlm.nih.gov/Blast.cgi). The complete circular mitochondrial genomes of *B. zonata* and *I. nitidulus* were determined to be 15,935 & 15,287 bp long, respectively. This is to note that both insect mitogenomes are the world's first complete/whole mitogenomes.

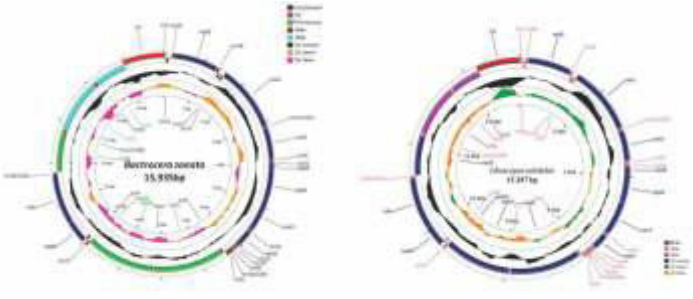

Fig. 6.24. Mitochondrial genome maps of *B. zonata* and *I. nitidulus*

Barcode sequences for rapid identification of horticultural insect pests

Barcode region sequences for quick and reliable identification have been generated for horticultural insect pests. Barcode region sequences of mango hopper (*Amritodus atkinsoni*), mango fruit flies (*Bactrocera zonata, Bactrocera dorsalis, Bactrocera caryeae*), Vegetable fruit fly (*Bactrocera caudata*), litchi stink bug (*Tessaratoma javanica*) and litchi fruit borers (*Conopomorpha sinensis, C. litchiella, Cryptophlebia ombrodelta, Gatesclarkeana spp.*) was developed and deposited

in GenBank repositories. NCBI vide Accession nos.: KY084430-KY084442; KY367445–KY367487; KT119929-KT119946; KF534917- KF534924; KP997222- KP997226; KT989670- KT989677; KU041685- KU041688; KX831081-KX831092; BOLD vide Accession Nos.:JAIPU001-14-JAIPU004-14; JAIPU003- 14; TESSA001- 13 available at https://blast.ncbi.nlm.nih.gov/Blast.cgi). The sequences are in the public domain and can be used by officials with minimum technical knowledge for reliable and quick identification.

Characterization of fruit flies and mango hopper

Conceptualized genetic diversity, demographic pattern and phylogenetic analysis of Indian population of fruit flies (*Bactrocera dorsalis; B. zonata*), and mango hopper (*Amritodus atkinsoni*). Evidence suggested that the distant population of fruit flies may be mating compatible with no cryptic species present and suitable for management through the area-wide management program with proper inclusion of the Sterile Insect Technique (SIT). Phylogenetic relationships of tephritid (Fruit fly) species have been resolved using whole mitochondrial DNA sequences.

Bacterial diversity assessment in insect pest species

- Taxonomic and functional characterization of bacterial community associated with different developmental stages of melon fly, *Zeugodacus cucurbitae* and peach fruit fly, Bactrocera zonata has been done using 16S ribosomal RNA (rRNA) gene amplicons metagenomics. Functional prediction of metabolic activities revealed that stage-associated microbiota was involved in membrane transport, carbohydrate metabolism, amino acid metabolism, energy metabolism, replication, and repair processes, as well as cellular processes and signaling.
- Decoded bacterial communities associated with the life stages of invasive C strain fall armyworm, *Spodoptera frugiperda*. The taxonomic analysis of highly variable V3-V4 region of bacterial 16S rRNA gene sequencing indicated that the bacterial community associated with *Spodoptera frugiperda* were dominated by Firmicutes and Proteobacteria across all developmental stages.
- Bacterial diversity associated with developmental stages of litchi stink bug, *Tessaratoma javanica* (Thunberg) (Hemiptera: Tessaratomidae) has been determined. The phyla Proteobacteria followed by Firmicutes, Bacteriodetes, and Actinobacteria, exhibited the highest levels of abundance across all the developmental stages of *T. javanica*. The documentation and information on symbiotic bacteria across *T. javanica* life stages will prompt the development of novel biological management strategies.

Mushroom strains collected, characterized, and preserved

A total number of 86 wild mushroom germplasm were collected from different districts of Jharkhand under the AICRP (Mushroom) since its inception. The specimens were preserved in dry and wet forms and identified on morphological and molecular basis. Some of the strains of mushrooms collected, characterized, and preserved are as follows:



Pleurotus pulmonarius



Clitocybe candicans



Termitomyces clypeatus



Rugra (Pisolithus arrhizus)



Termitomyces medius or radicatus



Jamun Khukhri (Boletus edulis)



Ganoderma lucidum



Funalia subgallica

Fig. 6.25. Strains of mushroom collected, characterized, and preserved

A total of 41 research trials were conducted in different years on oyster mushroom, milky mushroom, and paddy straw mushroom production and improvement after the inception of the project.

- Supplementation @ 2% with wheat bran significantly enhanced the yield in *P. florida* (48.3 %), *P. sajor-caju* (44.9 %) and *P. ostreatus* (48.1 %) over control.
- Spray of mushroom beds with 0.1M solution of K2HPO4 significantly increased the yield of *P. sajor-caju*.
- Spraying of 10 % neem leaf extract on the pasteurized paddy straw before spawning showed maximum efficacy against *Trichoderma harzianum* causal agent of the green mold of oyster mushroom and minimum inhibition against oyster mushroom (P. ostreatus) and maximum yield of mushroom (723.3 g/kg dry substrate) closely followed with karanj leaf extract.
- Four mushroom varieties namely, Oyster mushroom (*Pleurotus* spp.) grown from July to February, Milky mushroom (*Calocybe indica*) grown from March to June, Paddy straw mushroom (*Volvariella* spp.) grown from July to September and Button mushroom (*Agaricus bisporus*) grown during November to February under natural conditions have been recommended for round-the-year cultivation in Jharkhand.

Management of wilt disease of guava through VA-Mycorrhiza

A replicated field trial was conducted with twelve-year-old guava trees of cv. Sardar, using three levels of Glomus mosseae Gerd. and Trappe (2.5, 5.0, and 10 kg of symbiont mixed with farmyard manure, FYM), with and without FYM. The results revealed that VAM interacts with the host-pathogen system in a subtle manner. Root bit infection and colonization of VAM were observed at 75 to 85% in treated plants and 50 to 20% in the two control groups,

respectively. Based on overall performance, using the VAM symbiont at a 5 kg/tree rate appeared to be beneficial.

Integrated management of wilt of bottle gourd

Integrated management using soil amendment with neem cake at 50 g/pot, seed treatment with the biocontrol agent *T. asperellum* at 10 g/kg seed, and soil drenching with Carbendazim at 1.0 g/liter of water resulted in the maximum disease reduction (58.2%) of Fusarium wilt in bottle gourd. This was followed by soil amendment with neem cake at 50 g/pot, seed treatment with *T. asperellum* at 10 g/kg seed, and soil drenching with a mixture of Captan 70% + Hexaconazole 5% at 1.0 g/L of water, which resulted in 50.3% disease reduction.

Livestock & Poultry

Genetic Resource Documentation of the livestock & poultry

The study focuses on the comprehensive evaluation of Jharkhand's indigenous livestock and poultry populations, such as 'Jharkhandi cattle', 'Palamu goat', 'Chotanagpuri buffaloes', 'Kodo ducks', and 'Mala chicken'. It examines their unique physical traits, growth patterns, productivity, and reproductive efficiency to support their official recognition and conservation. Indigenous 'Jharkhandi Cattle' populations of Jharkhand:

The Jharkhandi cattle, identified through the study, are small-sized animals with a predominantly grey coat, though 9.4% exhibit a dark brown shade. Adult cattle in this population have a pooled height at the withers of 95.32 cm, body length of 82.17 cm, and chest girth of 127.24 cm. Minor body measurements, including face length (37.81 cm), horn length (10.12 cm), and tail length (63.15 cm), were also recorded for both sexes. Body weight estimates, according to Shaeffer's formula, were found to be 139.40 kg for males and 117.23 kg for females. Peak milk yield ranged between 2.5 and 6.5 kg/day.



Fig. 6.26. Jharkhandi cattle

Palamu goat

The newly identified Palamu goat population in Jharkhand exhibits distinct characteristics, differentiating it from the Black Bengal breed. These goats have a black coat color, slender bodies, and medium height, with only sparse occurrences of white and brown coat color variants. The herd size typically ranges from 1 to 27 goats, as reared by local farmers. Adult Jharkhand Medni goats have a height at the withers of 65.12 cm, body length of 66.28 cm, and chest girth of 72.45 cm. The body weights at different ages (3, 6, 9, and 12 months) were found to be 6.88, 8.92, 12.54, and 16.11 kg, respectively. The goats' age at first kidding was recorded as 12.32±0.76 months, with a kidding interval of 8.67±0.53 months. The average litter size was found to be 1.26, indicating moderate reproductive efficiency.



Fig. 6.27. Palamu goat

Indigenous 'Kodo Duck' populations of Jharkhand



Fig. 6.28. Indigenous Kodo Duck

The study focused on the phenotypic characterization of Jharkhand ducks locally called 'Kodo', surveyed across four districts: West Singhbhum, Saraikela-Kharsawan, Ranchi, and Pakur, with an estimated population of approximately 40,000. The research revealed unique plumage patterns, notably the striking black-and-white coloration of Kodo ducks, and variations in bill, eye, shank, and web colors. Drakes predominantly displayed greenish-black bills (56.25%), while ducks had black bills (58.67%), with brown being the dominant eye color in both sexes. Orange shank and web colors were prevalent in drakes (65.0%) and ducks (68.0%). Jharkhand ducks demonstrated remarkable adaptability to local agro-climatic conditions, requiring minimal inputs from farmers due to their natural hatching and brooding abilities. Their production traits were notable, with an average egg yield of 66.92 ± 2.00 eggs annually and adult body weights of 1.64 ± 23.19 kg for drakes and 1.51 ± 30.09 kg for ducks.

Indigenous Mala chicken



Fig. 6.29. Indigenous Mala Chicken

The study aimed to describe the phenotypic characteristics, production performance, and behavioral traits of indigenous chickens from the Chotanagpur plateau of India. A total of 736 adult chickens were characterized for 17 quantitative traits and 438 for 10 qualitative traits under field conditions. Male chickens exhibited rich golden-yellow hackle and saddle feathers forming a mala (garland-like) pattern with lacing which is why they are locally known as "Mala" in the region. The native chickens predominantly possessed white skin (73.28%), red earlobes (55.92%), and yellow shanks (64.46%). Average body weights were 1.86 ± 0.04 kg for males and 1.09 ± 0.02 kg for females.

This study provides baseline data on the phenotypic, production, and behavioral traits of native chicken germplasm in the Chotanagpur plateau, emphasizing the need for conservation and improvement efforts.



Fig. 6.30. Chotanagpuri Male Buffalo

Indigenous 'Chotanagpuri' buffalo of the Jharkhand

Surveys were conducted in various districts of Jharkhand, including Ranchi, Gumla, Khunti, Pakur, and adjoining areas. The buffalo referred to as the Santhali buffalo, Dhanbadi buffalo, Desi Kadha, and Jharkhandi buffalo is known for its hardiness. These buffaloes are primarily raised by tribal communities mainly for draught purposes, followed by milk and manure production. The size of buffalo was medium with compact body and had black coat colour with brown to blackish hairs. The overall least square means for age at first calving (months), calving interval (days), average daily milk yield (lit), peak milk yield (lit), lactation length (days), dry period (days) and

lactation yield (lit.) were 49.48±0.75, 440.78±2.73, 3.66±0.04 litres, 4.69±0.07, 191.56±2.23, 241.08±2.82 and 844.91±15.44 respectively.

Social Sciences

Farmers Producer Organization (FPO) based Safe food based technology delivery model

The FPO-based Safe Food Technology Delivery Model (SFTDM) was developed and validated under the ICAR-NASF project titled "Development and Validation of Need-based Technology Delivery Model through FPOs in the Eastern Region of India" (2019-2022). The aim was to address challenges related to accessing improved agricultural varieties, enhance farmers' productivity, and promote the sustainability and growth of FPOs in the targeted eastern region of India.

Experiments on safe food cultivation of pointed gourd, dolichos bean, and grafted tomato were conducted in both FPO and non-FPO settings. The percentage increase in yield and income due to the FPO-based SFTDM ranged from 9 to 27% and 27 to 33%, respectively. The effectiveness level of SFTDM in Greenary Agro Tech Producer Company Limited was 62.10%.

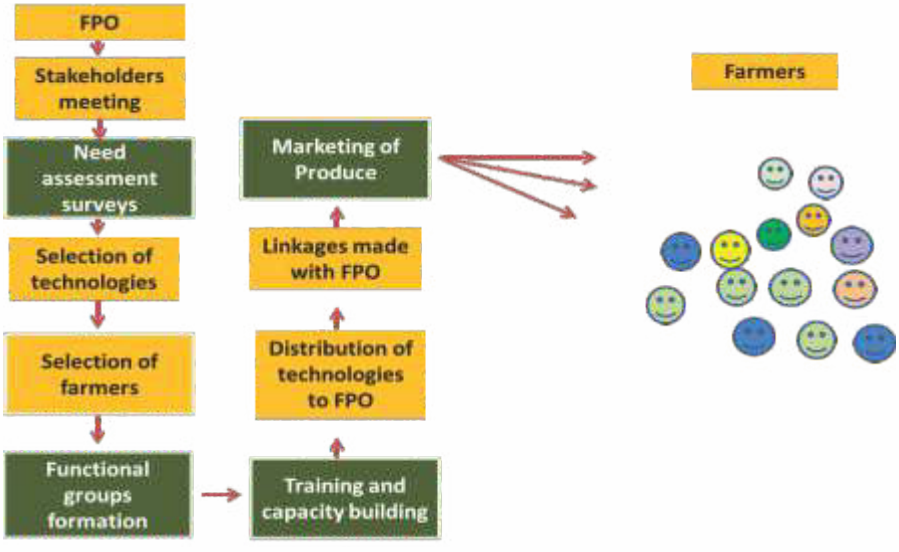

Fig. 6.31. Process of working of FPO based safe food technology delivery model

Socio-economic characterization of farmers in Bihar and Jharkhand

The study, initiated in 2017, aimed to develop a modified socio-economic scale for farmers in Bihar and Jharkhand and classify them based on socio-economic status (SES). Using the M-K-J-B-D multidimensional scaling method, data from 492 farmers across both states was collected. Factor analysis identified ten key factors that explained 93% of the variance, leading to a scale with 10 factors and 17 variables. The scale demonstrated high reliability (correlation coefficient 0.96, reliability coefficient 0.97) and validity ($p<0.001$). The findings revealed that lower middle-class farmers dominate both states. In Bihar, 40.64% were lower middle class, followed by middle class (39.44%) and upper middle class (9.96%). In Jharkhand, lower middle-class farmers were followed by lower class, middle class, upper class, and upper middle class.

Technologies developed

Fruit and vegetables

Interspecific grafting in solanaceous vegetables for bacterial wilt management

Bacterial wilt, caused by *Rhizoctonia solanacearum*, is a soil-borne pathogen that leads to significant losses (11.7% to 96.7%). Efforts have been made to identify resistant rootstocks of brinjal and standardize an interspecific grafting technique for solanaceous vegetables, particularly for cultivation during the rainy season. The grafting technology for high-yielding tomato hybrid *Swarna Baibhav* onto bacterial wilt-resistant brinjal rootstocks, such as HAB-901, HAB-921, HAB-928, and HAB930, was standardized, resulting in 90-95% plant survival. The average yield of grafted tomatoes was 127.7 t/ha, which is 2.17 times the yield of ungrafted plants. The net returns per hectare were ₹ 14,39,000, with a benefit-to-cost (B:C) ratio of 1:2.29.



Fig. 6.32. Field demonstration of grafted tomato in farmer's field

High-density planting of mango cv. Amrapali

The rational of the study was to standardize the optimum planting density of mango cv. Amrapali for higher productivity. The planting of mango cv. Amrapali at 2.5 m x 2.5 m spacing was found to be more productive in terms of cumulative yield of ten years (728.48 q/ha). Proper canopy management practices required after 12 years of planting in case of closer spacing (2.5 x 2.5 m). The Jharkhand Government's flagship programme "Birsa Harit Gram Yojna" and NABARD's "Wadi" programme adopted this technology where mango is promoted under normal spacing.



Fig. 6.33. Mango flowering under HDP

Mango based multitier system

The multitier system consists of mango plants spaced at 10 m x 10 m, accommodating 100 plants per hectare. In addition, precocious and smaller canopy fruit plants like guava are planted at a spacing of 5 m x 5 m between the mango plants and between the rows of mango, accommodating 300 plants per hectare. Rainfed intercrops are grown in the interspaces. In this system, a paddy equivalent yield of 8 t/ha can be obtained from rainfed uplands, compared to nearly 1.2 t/ha yield of paddy from the same rainfed uplands. This model has been adopted in the Wadi programme of NABARD, and several NGOs, including PRADAN, BAIF, and TRIF, have promoted it in farmers' fields, covering over 5,000 hectares.



Fig. 6.34. Mango+guava based multitier system

Rejuvenation of old and senile mango orchards

Old and senile orchards are primarily characterized by the prevalence of long, unfruitful branches with a tip-bearing habit. The overcrowding of branches on the inner side of the canopy restricts sunlight penetration, leading to competition among branches for light and limited fruiting. The rejuvenation technique provides an alternative for improving the productivity of these orchards within a period of three years. Rejuvenation pruning of old and unproductive mango plants at a height of 1.5 m and maintaining the lengths of the primary shoot emerged after pruning (3-4 number per branch) to a length of 60 cm can result in initiation of fruiting after two years and maintenance of productivity for longer period without overcrowding of branches in the plant canopy. Optimum productivity of the plants can be attained after 6 years. This technology is adopted under the NHM and other state-run programmes.



Fig. 6.35. Rejuvenation of old and senile orchards

Ultra-high density orcharding in guava

Traditional guava cultivation is less remunerative under Eastern Plateau condition. The Ultra high density system of planting is recommended at a spacing of 1 m x 2 m accommodating 5000 plants per ha and pruning of current year shoots in May, October and March to 50% of the shoot length resulted in more than 2.5 times increase in fruit yield over that of traditional method of planting. This is a bankable technology of the National Bank for Agriculture and Rural Development (NABARD), Ranchi.



Fig. 6.36. Ultra High Density in Guava

High density orcharding in mango

The technology involves planting of mango plants cv Amrapali at a spacing of 2.5 m x 2.5 m accommodating 1600 plants as compared to 100 plants per ha in case of traditional method of planting. After every four years, severe pruning should be done in bearing plants to avoid overcrowding. A yield level of 16-20 t/ha can be obtained from high density orchard as against 5-6 t/ha under existing poorly managed systems.



Fig. 6.37. High Denisty in Mango

Tephrosia biomass mulching for improving productivity of fruit orchards

To address issues such as low soil organic carbon content and the poor availability of organic manures, an alternative biomass-yielding plant, *Tephrosia*, was evaluated. *Tephrosia* is a leguminous perennial shrub with a high biomass production capacity (4.0-5.0 kg dry biomass/m^2). Application of *Tephrosia* biomass at 3.0 kg dry weight/m^2 resulted in improvements in soil properties, including total soil organic carbon (TSOC) (18.43-21.32%), available nitrogen (13.68-23.02%), available phosphorus (73.18-96.76%), and exchangeable potassium (41.60-47.47%) as well as enhanced fruit yield (mango 25.03%, guava 42.25%). This technology has been recommended for the On-Farm Testing (OFT) by ATARI Patna for the KVKs in Bihar and Jharkhand.



Fig. 6.38. Mango production under Tephrosia mulch

Multitier cropping system for rainfed uplands of Eastern India



Fig. 6.39. View of multitier system with timber tree, fruit plants and intercorp

Growing of cereal crops addresses only food requirement of the farmers. However, farmers also need fuelwood for cooking, timber for furniture, and fruits for better returns. These needs can be met by integrating timber trees and fruit crops with cereal crops through a cereal-based multitier cropping system. The Mango + Mahogany + Peach system was found to be suitable for growing cereals on a long-term basis. The filler crop, peach, reached its maximum canopy after 3 years and produced a yield of 45-50 kg/plant. The middle-story crop, mango, yielded 30-35 kg/plant in an 8-yearold system. Net income under the rainfed condition from the 8-year-old system: 1.2 – 1.5 lakh ₹/ha/yr. This technology has been commercialized through NGOs, and four MoUs have been signed.

Table.6.3. Components of multitier systems

Model	Top story	Middle story	Filler crop	Inter crop
I.	Mahogany (45 plants)	Mango (Amrapali) (50 plants)	Sub-tropical peach (120 plants)	Rice
II.	Mahogany (45 plants)	Mango (Amrapali) (50 plants)	Sub-tropical peach (120 plants)	Finger millet

Assured flowering and fruiting in litchi through girdling of primary branch



Fig. 6.40. Fruit appearance in bagged and non-bagged litchi bunches.

Irregular bearing at young stage of the litchi plant is a phenomenon constraint in general and alternate bearing in cultivars of China. Girdling of branches, which involves removing a strip of bark completely encircling them, causes carbohydrates to accumulate, thereby suppressing flushing. Girdling at a width of 4 mm on 50% of primary branches during the first week of September, or after the appearance of the second vegetative flush, resulted in regular flowering and fruiting without affecting the fruit quality in *Litchi* cv. China. The highest flowering percentage (41.66%) and fruit yield (50.30 kg/tree) were achieved with the highest B:C ratio of 2.91 through girdling of primary branches. This technology has been recommended by ATARI Patna for On-Farm Testing (OFT) in Jharkhand and Bihar.

Bagging of litchi bunches for quality fruits

Fruit cracking, sun burning and borer infestation are the major problem in litchi production in all litchi growing regions. The technique of bagging litchi bunches with non-woven PP bag (white and pink) during fruit development stage improve colour and quality, reduced fruit cracking, sunburn and fruit borer infestation. The bagging of litchi fruit bunches provides physical barrier for high intensity light penetration and fruit borer infestation, thereby helps in increasing the humidity and reducing the heat shock/ wave as well as high temperature. The fruit weight (21.82 g), fruit yield (46.78 kg/tree) and B: C ratio (3.26) were found significantly higher when litchi bunches bagged with polypropylene pink on 25 days after fruit set. The sunburn, borer infestation and cracking were significantly lower in all bagging treatments in comparison to control.

Sustainable water management for enhancing productivity of high-density litchi orchard

Typically, litchi orchards often rely on flood irrigation or rainwater for cultivation. Even in high-density plantations where irrigation is crucial, proper water management through drip irrigation is often not implemented, which hampers litchi yield. Under Jharkhand conditions, black polythene mulch combined with drip irrigation at 75% evapotranspiration (ER) per day, from fruit set to just before harvest (March to May). This practice results in better yield and fruit quality, with a benefit-to-cost (B:C) ratio ranging from 1.99 to 3.53.



Fig. 6.41. Litchi production under plastic mulch

Agroforestry models for rehabilitation of coal mine affected areas

In the coal-rich state of Jharkhand, over 180 mines have left vast stretches of land unusable, particularly for agriculture. To transform these barren lands an agri-hortisilvi-pastural system in Phusri, Hazaribagh District. The innovative approach involved planting diverse species like Mahogany (*Swietenia mahogany*), Teak (*Tectona grandis*), and Bakain (*Melia azedarach*), along with selected agroforestry and fruit species. Species like Mahogany and Bakain exhibit resilience, making them ideal for reclaiming mining-affected areas. Notably, Bamboo and Tephrosia candida were introduced for both fodder and nutrient purposes, diversifying the ecosystem. After eight years of plantation, the maximum plant height (10.98 m) and trunk diameter (40.13 cm) was recorded in Bakain



Fig. 6.42. Agroforestry model for coalmine area

compared to other MPTs. The introduction of water conservation measures like Dobha, full moon and half-moon terraces, staggered contour trenching, mulching and zero tillage cultivation practices have led to save more water, labour, time and energy. The rate of erosion measured as peak sediment discharge (concentration) reduced from 232 to 181 g/m^3. The soil became more fertile after introduction of the agroforestry model. The soil available organic carbon has increased from 0.23 to 0.58 % and the soil bulk density has decreased from 2.3 to 1.1 g /cm^3. This technology is being popularized by State Agricultural Management and Extension Training Institute (SAMETI), Govt. of Jharkhand and KVK.

Standardization of NPK requirement of Litchi in eastern plateau and hill region

To ensure high economic productivity and to sustain the available nutrient status in the soil under litchi planation at the desired level, correct doses of manures and fertilizers must be applied. The growth of litchi according to tree age were classified into 4 different phases, viz young non-bearing phase (1-3 years), young bearing phase (3- 10 years), junior adult bearing phase (10-20 years) and senior adult bearing phase(> 20 years). During the junior adult bearing phase, the litchi tree enters in the phase where vegetative growth and fruiting remain relatively balanced. Rational fertilization during this stage is an important operation for switching over to the plant into the senior adult bearing phase with optimum vigour. Based on overall performance in terms of yield and fruit quality, it can be concluded that application of 500 g N, 220 g P and 249 g K/tree/year was found to be the best for junior adult bearing litchi plants growing under sub-humid plateau region of eastern India.

Identification and management of yield-limiting nutrients of fruit orchards

Information about leaf nutrient concentration is very much required for proper fertilizer application in mango and developed the leaf analysis-based diagnosis and recommendation integrated system (DRIS) indices in relation to mango fruit yield in the eastern plateau and hill region. As per DRIS indices, a relative deficiency for magnesium, zinc, and boron corresponding to relative sufficiency for calcium, nitrogen, phosphorus, sulphur, 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. Hence judicious application of N, K, Ca, Mg, S, Zn and B is required in mango orchard grown in acidic soils to get optimum yield under eastern plateau and hill region of India. This technology will reduce time lag between diagnosis and fertilizer recommendation.

Enhancement of soil carbon stock through mango based multitier production system

Cropping systems along with different management practices that ensure higher amounts of crop residue addition to the soil are expected to cause a net build-up of the SOC stock. The research results in eastern plateau and hill region confirmed that the mango orchard registered highest total soil organic carbon (62.5 t/ha) among the different orchards. The mango, guava and litchi orchards caused an enrichment of total soil organic carbon by 17.2, 12.6 and 11%, respectively over the control in a period of 6 year. The mango orchard is considered as the best tree production system for enhancing soil carbon stock.

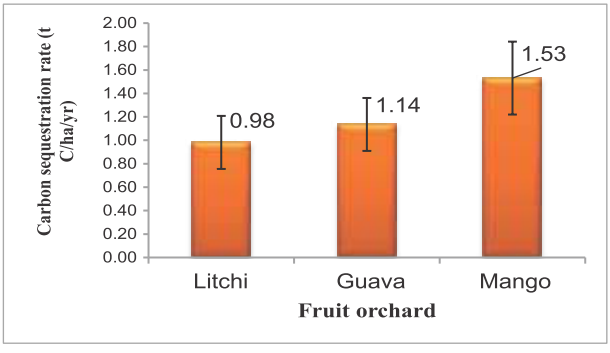

Fig. 6.43. Soil carbon sequestration in different orchards

Carbon stock quantification models for important fruit trees

Currently destructive methods are used to assess C-sequestration potential of trees and mathematical model based assessment can be better alternative. C-sequestration assessment models were developed and validated for mango, litchi and guava. The models use collar dimeter (X) of trunk at 30 cm height as only input. The developed Gompertz model will be suitable for the quantification of standing biomass carbon stock in mango orchards, while the developed Richard's model will be suitable for litchi and guava orchard.Models are applicable for collar diameter range of 0.9 to 18.5 cm in mango, 0.9 to 15 cm in Litchi and 0.84 to 15 cm in guava. The farmer or grower can simply measure the collar diameter of the fruit plant and will get the biomass carbon stock of the entire plant as well as orchard. Thus, the present model will aid in orchard management activities to enhance carbon sequestration while earning significant carbon credits. The developed model can be utilized in the national climate change program and will also be helpful for developing suitable policies for the government to design state plans aimed at minimizing GHG emissions.



Fig. 6.44. Collar diameter measurement for carbon stock

Low-cost non-weighing lysimeter for nutrient leaching loss assessment

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. The weighing type lysimeter is very cost intensive and is costing about 10 lakhs, which can not be afforded by academicians, researchers and persons involved in nutrient management. Thus, the present low-cost non-weighing lysimeter (Rs 10000/unit) with dimension of 4m (L) x 3m (W) x1m (H) is developed for quantification of nutrient leaching loss and soil water balance studies. The N and K-leaching loss varied from 5-22 kg/ha and 4-15 kg/ha, respectively among the cereal, pulses and vegetable crops in EPHR. Organic and INM practices saves N of 5.3-21.5% and 3.5-10% of applied nutrient, respectively from leaching. Organic and INM practices saves K of 5.2-20.7% and 2.5-10% of applied nutrient, respectively from leaching. This technology non-weighing Lysimeter can be popularised in research organization, agricultural university farm and other non-governmental organization engaged in the quantification of leaching loss of nutrients form the soil and its further mitigation strategies.

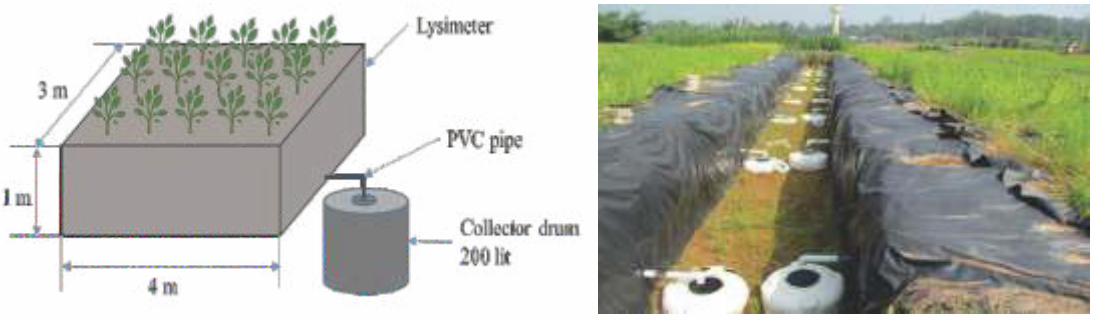

Fig. 6.45. Low-cost non-weighing lysimeter for measurement of nutrient leaching loss

Climate smart agricultural practices for enhancing soil health and food security

The productivity of rice-fallows is largely challenged by deterioration of soil health coupled with limited soil moisture availability during dry season, which precludes the possibility of second and third crop after rice. The CA-based crop management practices in eastern plateau and hill region of India highlighted the importance of including second and third crops in the rice-fallow eco-systems. The adoption of conservational agriculture significantly improved TSOC both in labile and non-labile carbon fractions that led to an increase in carbon retention efficiency (11-13%). Further the CA practice showed a lower carbon footprint, higher carbon sustainability index and carbon efficiency. A cropping system having direct seeded rice (DSR)–mustard–black gram 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.



Rice Mustard Black gram

Fig. 6.46. Direct Seeded Rice (DSR)–mustard–black gram under conservation agriculture

Resource Conservation Technology for Vegetable Cultivation



Fig. 6.47. Raised bed polythene mulched drip fertigation in vegetable

Irrigation inefficiencies and improper planting and fertigation practices have long been major concerns in the eastern region, resulting in excessive water and fertilizer losses, low nutrient use efficiency, and poor water use efficiency. To address these challenges, FSRCHPR developed an innovative technology combining raised beds with polythene mulch and an integrated drip irrigation system. The beds, measuring 80 cm in width and 15 cm in height, were covered with 50-micron polythene mulch, and drip lines were placed beneath the mulch for efficient irrigation and fertigation. This system achieved the highest curd yield of cauliflower at 40.4 t/ha and eggplant at 29.8 t/ha, with a water use efficiency of 12.25 kg/m^3 and economic water productivity of ₹122.61/m^3 for cauliflower. The system also reduced water use by 43.8%,requiring only 80.32 liters of water/kg of cauliflower compared to non-mulched treatments. In addition to water savings, the system improved soil health by enhancing soil organic carbon by 6.3%. This innovative technology addresses the limitations of traditional surface irrigation, offering a sustainable, highly water-efficient, and productive solution for vegetable cultivation in the region.

Planting geometry and fertigation for vegetable crops



Fig. 6.48. Planting geometry and fertigation in vegetable

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. 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/m^3, 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/m^3. 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/m^3 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/m^3. These advancements demonstrate the transformative potential of integrating strategic planting geometry with stage-specific fertigation.

Doba Technology for Water Harvesting



Fig. 6.49. Doba technology for establishment of orchards

Establishing new orchards in the eastern region often faces challenges due to water shortages, particularly after the monsoon withdrawal. Farmers frequently struggle to keep their crops alive during the dry summer months from March to May, often transporting water from long distances. To address this issue, an innovative in situ water harvesting structure known as the Doba was developed. The Doba is a small storage tank, measuring 3.0 x 1.5 x 1.0 m, dug into the ground and lined with 200-micron black polythene. It is specifically designed to collect rainwater directly, without allowing any runoff to enter. Once filled, the tank is covered with a thatch roof made from locally available materials, such as paddy straw or dry grass, supported by a bamboo frame. Each Doba can store approximately 4,500 liters of water, sufficient to provide life-saving irrigation to 10 fruit plants. The use of Doba technology has proven highly effective, ensuring 100% plant survival and promoting healthy growth under water-scarce conditions. A single Doba costs about ₹1,800, and approximately 40 Dobas are required for a one-hectare orchard plantation at a 5 x 5 -meter spacing.

1-Acre model for runoff water harvesting



Fig. 6.50. Polythene lined water harvesting structure

In Jharkhand, where annual rainfall averages 1350 mm, water scarcity is a challenge due to rapid runoff and high seepage from the undulating terrain. Polythene-lined ponds offer an affordable solution, storing up to 1200 cubic meters of rainwater for dry months. A 25 x 20 meter pond with 3m depth, lined with 250-micron LDPE polythene, receives rainwater from a 2-acre catchment area with erosion-resistant trees like custard apple and aonla. The

stored water irrigates a 1-acre area using gravity-fed drip irrigation, eliminating the need for pumps. Around the pond, farmers can grow cucurbits, pulses, rainfed paddy, and multi-tier orchards with crops like litchi and guava. Additionally, the pond supports fish farming and duckery, boosting income and nutrition. With an investment of ₹1.59 lakh, including the pond, irrigation system, and inputs, the system pays off in under six years, enabling sustainable incomes, optimized land use, and year-round water availability.

Solar Irrigation Pump Sizing (SIPS) tool

Solar pumping systems are gaining widespread acceptance in India, supported by the Government of India's initiatives such as farmer-friendly schemes and subsidies under programs like PM-KUSUM. However, a major challenge faced by project implementing agencies was determining the appropriate pump size (hp) for individual farmers, as many farmers sought higher hp pumps to maximize the benefits of subsidies. To address this issue, FSRCHPR, in collaboration with IWMI and GIZ, developed the Solar Irrigation Pump Sizing (SIPS) tool. This user-friendly and innovative tool simplifies the complex task of solar pump sizing by incorporating nationwide datasets on climate, soils, and crops, making it adaptable to any location across India. The SIPS tool is structured into four key modules—crop water requirement, discharge estimation, head loss estimation, and pump selection. These modules work together to ensure scientifically accurate and locationspecific pump designs, empowering farmers, researchers, and technicians to adopt efficient and sustainable solar pumping systems. By promoting precise pump sizing, the SIPS tool supports the Government of India's solarization initiatives, reduces carbon footprints, enhances agricultural productivity, and contributes to better water and energy management in agriculture.



Fig. 6.51. Solar Irrigation Pump Sizing (SIPS) tool

Hybrid Solar light-pheromone insect trap

To provide an eco-friendly, cost-effective, and real-time solution for insect control, Solar Insect Trap was developed. The hybrid solar light-pheromone insect trap is an innovative, eco-friendly solution designed to control agricultural pests effectively without the use of chemicals. By combining light and pheromone-based attraction, it targets a range of pests, including stem borers, fall armyworms, thrips, leaf miners, moths, fruit and shoot borers, and hoppers, making it suitable for vegetable, fruit, and grain crops. Powered by a 30 Wp solar panel and a 12 Ah battery, it operates automatically from dusk to dawn, offering six hours of daily functionality. The trap is portable, ergonomic, and features adjustable height (1.0-1.5 m) to cater to various



Fig. 6.52. Solar light-pheromone insect trap

crop types. With a low operational and maintenance cost, it is an economically viable tool for integrated pest management, requiring only 4-5 traps per hectare for optimal coverage. Equipped with three 3W LED lights and a 10A charge controller, the hybrid insect trap effectively captures day. Solar lightpheromone insect trap and night-flying pests, providing a comprehensive pest control solution while protecting the environment and ensuring healthier crops.

Solar operated paddy thresher

Paddy is a major crop in the operated paddy thresher eastern region, and farmers traditionally rely on labor-intensive threshing methods such as spreading paddy on roads for vehicles to pass over or manually beating the bundles against wooden planks. The solar-operated paddy thresher is an ICAR-certified, ecofriendly innovation designed to revolutionize paddy threshing. Engineered for comfort and safety, it features a portable, ergonomic design with folding solar panels for easy transport and continuous shading for the operator. Operating without a battery, it ensures 6-7 hours of daily functionality, even in remote areas, making threshing accessible anywhere. Equipped with a 975 Wp solar panel and high-efficiency DC motors (500 W for the drum and 250 W for the winnower), it delivers exceptional performance. With drum speeds adjustable between 450-750 RPM, it handles straw moisture content ranging from 18-28%, achieving a remarkable threshing efficiency of 98.4-99.3% and cleaning efficiency of 98.8-99.6%. Capable of processing 5.0-5.5 quintals of paddy daily, it minimizes operating costs to under ₹100 per quintal and requires minimal maintenance. This innovative solution also supports simultaneous threshing and winnowing while preserving straw integrity for alternative uses, promoting resource optimization.



Fig. 6.53. Solar operated paddy thresher

Solar dryer for leafy vegetables

Dried leafy vegetables have larger share in the diet of tribal population in the Eastern India. Leaves, shoots and flowers of vegetables are plucked and sun dried for future use during lean season. To reduce the time, manpower requirement and make it hygienic, a low-cost solar dryer was developed for drying of leafy vegetables. The dryer consists of a cabinet made up of compressed wood and a glass cover with handle. It has a base size of 95 x 100 cm and incline size of 95 x 103.5 cm. A black colour coated perforated aluminium tray was fitted inside the dryer to provide platform for spreading the vegetables. The dryer cover is a glass of 6 mm thickness which avoids entry of dust and other foreign matter. There were two air inlets at base of the dryer and two air outlets at upper backside of the dryer. One thermometer was fitted inside and one outside the dryer to measure the temperature difference between inside and outside. The dryer has a capacity of drying 2.5 kg leafy vegetables per batch. Drying curves (time Vs moisture content) were developed for different underutilized leafy vegetables showed that it takes about

2.0 – 2.5 hrs for drying of different small and large sized leafy vegetables as against 3.75 – 10 hrs in sun drying method.

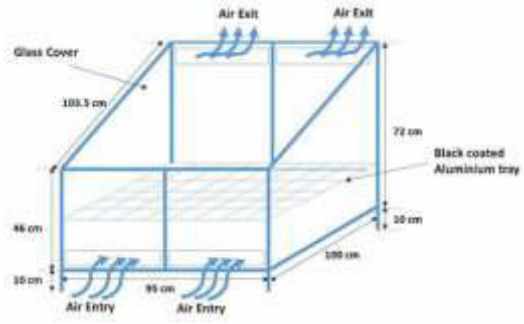

Fig.6.54. Schematic diagram of the solar dryer



Fig.6.55. Drying operation of leafy vegetables using solar dryer

Drying of button mushroom for development of dry instant soup mix



Fig. 6.56. Dry instant mushroom soup mix

Freshly harvested button mushrooms were washed and kept in potassium metabisulphite solution for 15 minute at room temperature for proper sanitization. After proper straining, they were cut uniformly into four pieces. The cut samples of mushrooms were given pre-drying treatment in a microwave oven at power level 800 W for 3.0 min before drying in convective hot air. Drying was accomplished at 60°C air temperature. The dry instant soup mix formulation was mixing of different ingredients such as mushroom powder 20%, tomato powder 20%, wheat fine flour 35%, milk solids 10%, corn starch 10%, onion and garlic powder 1% and dried small pieces of cabbage and carrot 4%. The mix of ingredients was thoroughly blend to achieve a free-flowing mixer.

Development process for jackfruit pulp bar

Ripe bulbs of jackfruit were manually separated and grounded to obtain the homogenized pulp. Sugar syrup of different concentrations was added to the extracted pulp and then dried in a tray dryer till its moisture content reduced to 20-25% (wt). Drying involved two independent variables, viz., drying temperature (60–90°C) and pulp thickness (2-10 mm). The results indicated that the pulp mixture at 300 Brix, drying temperature as 70°C and pulp thickness of 4 mm produced better quality jackfruit bar in terms of color, texture and sensory attributes.



Fig. 6.57. Jackfruit pulp bar

Soy Milk made from vegetable soybean

Soy milk is a plant-based beverage made by blending soaked and cooked mature vegetable soybeans with water and straining the mixture. It is a popular dairy-free milk alternative, rich in protein, essential amino acids, and calcium, often fortified with vitamins like B12 and D. Soy milk is versatile, suitable for drinking, cooking, or using in cereals and smoothies. It is usually packaged in Tetra Pak cartons, plastic bottles, or aseptic containers to ensure freshness and extended shelf life.



Fig. 6.58. Soy milk

Tofu (soybean curd) made from vegetable soybean

Mature soybean tofu, or bean curd, is a soft or firm product made by coagulating soy milk and pressing the curds into solid blocks. It is rich in protein, low in fat, and versatile for use in various cuisines. Tofu absorbs the flavors of marinades and seasonings, making it ideal for savory dishes, stir-fries, soups, and desserts. It is commonly packaged in vacuum-sealed trays filled with water to maintain its freshness.



Fig. 6.59. Soy tofu

Optimized steeping preservation method for immature tender jackfruits

Steeping is the process of preserving vegetables in a solution containing food additives in permissible limits. Steeping solutions were prepared using sodium chloride, acetic acid, ascorbic acid and potassium metabisulphite. A total of twenty steeped jackfruit (JF) samples were kept for a shelf-life study of 90 days at room temperature (25-28°C). Optimization was done using RSM on 90th day of storage; it was observed that the optimum steeping solution comprised of 10% NaCl, 0.83% acetic acid and 0.5% ascorbic acid. The samples kept at optimum treatment were further used for their value addition into snack items (JF pakora), JF pickle and JF curry with a sensory score more than 8.0.



Fig. 6.60. steeping preservation method for immature tender jackfruits

Edible coating for fresh cut jackfruit

Unripe jackfruits were harvested and cut into uniform-shaped pieces. The edible coating experiment was designed with different pre-treatments (Acid Dip: 2% citric acid + 2.5 g/L KMS followed by 1% $CaCl_2$ for 4 min) and different coating agents, viz., guar gum (0.5-1.5%), pectin

(1.33-3.99), starch (2-6%) and their combinations. Coated samples (from 32 treatments) were stored at low temperature (4-8°C) for a shelf study of 15 days. The best coating treatment which comprised guar gum + starch (75:25) (@1% concentration) without pretreatment having PLW, BI, texture, and appearance values of 11.29%, 74.56, 106.34 N and 4, respectively.

Plant protection

Pest management in litchi

Litchi (*Litchi chinensis Sonn*.) is one of the most important subtropical fruit trees in the eastern part of India. Management of insect pests in litchi is difficult due to the high activity of pollinators and pesticide residue in fruits. The centre has standardized management strategies, including the removal of infested twigs in September month and two sprays of miticides at the same time at 10-15 days intervals, effectively checked the mites population in Litchi. Two sprays of insecticides (cypermethrin or spinosad 2.5 sc @ 0.7 ml or flubendiamide 39.35 sc @ 0.8 ml per litre of water) at the colour break stage at the interval of 10 days standardized for litchi seed borer management. Spraying of Dimethoate 30% SC (1.5 ml/L) + Lambda Cyhalothrin 5% E.C (1.0 ml/L) before flower opening and Thiacloprid 21.7% SC (0.5 ml/L) + Lambda Cyhalothrin 5% E.C (1.0 ml/L) after fruit set found toeffective the management of litchi stank bug. Management tactics of litchi pests are widely accepted by the farmers of the region.

Para-pheromone-based fruit flies trap for horticultural crops

Fruit flies are the major insect pest of vegetables and fruit crops in the region. Presently, single-lure para-pheromone based fruit fly traps are available in the market for the management of fruit fly species in fruits and vegetables. Single mixed lure trapping system for management of fruit flies in fruit and vegetable crops developed for the region. This trap can be used by farmers in mango, sapota, guava, citrus, litchi, bottle guard, bitter guard, pumpkin, cucumber, and other cucurbit crops fields as well as in fruit trees intercropped with vegetables. The technology has been commercialized, and traps are produced by M/S Aditya agro crop care, Jharkhand.



Fig. 6.61. Para pheromone fruit fly.

Diamondback moth management in cauliflower through mixed cropping and rotation of insecticide

Diamondback moth (DBM), *Plutella xylostella* is the most important pest of cole crops in the region. The technology for the management of DBM includes crop diversification through intercropping of Onion (*Allium cepa*) and sequential application of screened safer insecticides to reduce the insecticide loads and resistant management of insect pests. The management of DBM includes the onion intercrops between cauliflower rows in a linear pattern and the sequential sprays of insecticides (First spray of neem oil @2.0 ml/L followed by spinosad 2.5% SC @ 0.3ml/L and Flubendiamide 20% WG @ 0.4gm/L of water) at 10 days interval starting from 35 days of transplanting. The recommended strategy for managing DBM in the cauliflower ecosystem in the Bihar and Jharkhand regions is very effective. It was observed that after spraying effective treatments, the DBM population reduction ranges between 70-89% after applying treatments under Jharkhand and Bihar conditions.



Fig. 6.62. Mustard and onion as inter-and border cropping in cauliflower.

Ecofriendly insecticide molecules for the management of thrips in chilli

The injudicious and indiscriminate use of insecticides in chili for managing thrips, *Scirtothrips dorsalis* is a common practice among farmers in the eastern region. The technology of application of Spinosad @70 g a.i./ha, Emamectin benzoate 5 sg @11 g a.i./ha, Imidacloprid 200 sl @40 g a.i./ha and Fipronil 5 SC @30 g a.i./ha were found to be effective against *S. dorsalis* and safer against natural enemies (coccinellids) in chilli crop. These recommended insecticides are used to manage thrips and S. dorsalis, on a rotational basis in the chilli ecosystem in the Bihar and Jharkhand regions.

Mobile apps for mango pests

e-agriculture can be an easy and most effective way for disseminating knowledge and can benefit farmers in remote areas in their local language. In this line, conceptualized and developed two Android mobile apps named "AAM KI SURAKSHA" and "Climate Smart Mango Cultivation" for managing and forewarning mango pests. These mobile apps provide illustrative identification and management practices and forewarning of insects and pests among mango users. Mobile apps provide insect pest forewarning, management, and solutions to mango growers.

Integrated management of bacterial wilt of tomato/brinjal in alfisol

Bacterial wilt (Ralstonia solanacearum) is a serious problem in solanaceaous vegetables grown under alfisol which cause severe losses in yield particularly during the rainy season. The pathogen survives in soil for longer time and it is very difficult to manage it in field. The chemical control of the disease is very costly and not feasible for farmers. Use of resistant Fig. 6.62. Mustard and onion as interand border cropping in cauliflower.varieties and integrated

management offers a better solution to this problem. However, it has been found that some of the resistant variety becomes susceptible after few years due to change in biovars/strains of the pathogen. Keeping this in view the technique for management of bacterial wilt under alfisol has been standardized. The bacterial wilt disease can be effectively managed by adopting any of the following practices like

- o Application of Karanj cake @10 q/ha 15 days earlier to transplanting
- o Use of microbes viz VAM (*Glomus mosseae*), *Trichoderma viride*, *Azotobactor chroococuum*
- o Two years crop rotations with cereals in the vegetable based cropping system
- o Green manuring of *Sesbania* @1.25 kg/m²

Heavy metals scavenging potential of Trichoderma asperellum and Hypocrea nigricans isolated from acid soil of Jharkhand

Trichoderma asperellum (NAIMCC-F-03167) and *Hypocrea nigricans* (NAIMCC-F-03168) were isolated from the acidic soil of the vicinity of Litchi orchard, Ranchi, Jharkhand and were characterized based on morphological, molecular and biochemical features. The strain T. asperellum (88.9% Cd) showed highest scavenging potential followed by H. nigricans (87.2% Cd) while in Pb scavenging potential, H. nigricans (88% Pb) followed highest scavenging potential than *T. asperellum* (81.30% Pb). If both potential bioagents can apply in Cd and Pb affected soil/water will be helpful in scavenging of heavy metals as well as management of phosphorus deficiency and soilborne fungal diseases.

Livestock & Poultry

Feed formulation with agricultural by-products as natural growth promoters

Livestock rearing, specifically pigs and poultry, plays a vital role in the livelihoods of smallholder farmers in Jharkhand, especially within tribal communities. This technology focuses on innovative feed solutions utilizing agricultural by-products such as sundried sweet potato (SSP), spent mahua flowers (SMF), and left-over fermented rice (LFR) as traditional growth promoters for pigs and poultry in Jharkhand. Additionally, the technology delves into harnessing the potential of indigenous flora like *Spilanthes paniculata*, known for its bioactive properties, to enhance livestock productivity. Through the assessment of these alternative feed options and their impact on growth performance, feed efficiency, and economic viability, this technology aims to empower tribal farmers with sustainable feeding practices that optimize productivity while reducing dependency on costly conventional feed ingredients. Table below is illustrates the different traditional growth promoters used in the feed formulations:

Table.6.4. Feed Formulation using agricultural by-products as traditional growth

Sl. No.	Technology	Species (Breed)	Key findings
1.	Sundried Sweet Potato as a Partial Replacement for Maize in Crossbred Pig Feed to Enhance Growth Performance.	Pig (Tamworth and desi cross, T&D)	• SSP inclusion up to 35% significantly enhanced growth performance. • The highest average daily gain (ADG) of 0.57 kg and total body weight gain of 34.0 kg were recorded at 50% SSP inclusion. • SSP was shown to provide digestible carbohydrates and protein, contributing to improved growth outcomes.
2.	Sustainable Poultry Feed Formulations for desi chicken of Jharkhand with LFR	Poultry (Jharkhand native chicken)	• Inclusion of LFR @ 20-40% in desi chicken grower ration demonstrated the highest body weight gain (414.54 g) and the best feed conversion ratio (FCR: 1.56), providing the optimal balance between performance and cost.

Social Sciences

Socioeconomic Status Scale for farmers of Bihar and Jharkhand

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.

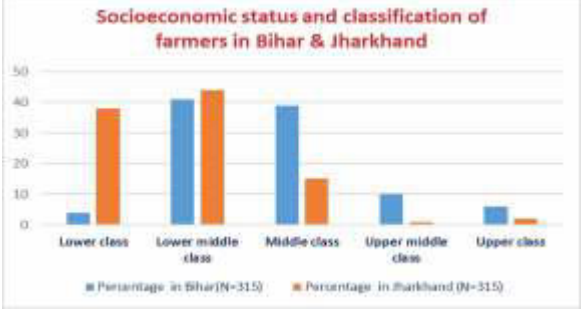

Fig. 6.63. Socio economic status of farmer

The bar chart (Fig. 6.63) illustrates the socioeconomic status and classification of farmers in Bihar and Jharkhand, based on a sample size of 315 farmers from each state. The majority of farmers in both states belong to the lower middle class, with Jharkhand (43%) showing a slightly higher percentage than Bihar (41%). In contrast, middle-class farmers are more prevalent in Bihar (38%) compared to Jharkhand (15%). The proportion of lower-class farmers is minimal in Bihar but significantly higher in Jharkhand (37%). Farmers belonging to the upper middle class and upper class constitute a small fraction in both states, with Bihar having a slightly higher representation in these categories.

Varieties Released from Centre

Fruit crops

Table 6.5 Fruit varieties released from FSRCHPR, Ranchi

Fruit crop	Varieties	Release/Notified for
Jackfruit	Swarna Manohar ***(IVRC 2004)***	Early fruit maturity, suitable for table purpose, average fruit weight: 13.7 kg
	Swarna Poorti ***(IVRC 2004)***	Vegetable purpose, average fruit weight : 4.20 kg, average yield – 120.0 kg/tree, TSS– 18.0^{o}B
Litchi	Swarna Roopa (***IVRC 1996)***	Resistant to fruit cracking, mid late in maturity, contains high pulp (75%), small seed and TSS 19^{0}B.
	Swarna Madhu ***(CVRC 2024)***	High juice recovery (>45%), moderately resistant to seed borer.
Bael	Swarna Vasudha ***(CVRC 2024)***	Suitable for high density planting at 5m x 5m spacing, yield 42-45 kg/plant, TSS >40°B. Low seed content
Mulberry	Swarna Rasrani ***(IVRC 2024)***	Long type fruits with attractive red colour, high yield (35-37 kg/plant) and high TSS (21.64 ^{o}B).

Vegetable crops

Table 6.6. Vegetable varieties released from FSRCHPR, Ranchi

Sl. No.	Crop	Varieties	Major traits
1.	Garden pea	Swarna Amar **(*IVRC*)**	Pod dark green, resistant to powdery mildew disease, average fresh pod yield : 20-25 t/ha
		Swarna Mukti **(*CVRC, 2006*)**	Shelled peas are light green and sweet in taste with very good cooking quality, resistant to powdery mildew disease, average fresh pod yield : 20-25 t/ha
2.	Snow pea	Swarna Tripti ***(CVRC 2008)***	The whole pod is sweet and edible; resistant to powdery mildew; average fresh pod yield : 24-28 t/ha
3.	French bean (Bush type)	Swarna Priya ***(CVRC 2007)***	Dried seeds are bold and maroon in colour, suitable for *Rajma* preparation; average yield: 12-14 t/ha
4.	French bean (Pole type)	Swarna Lata ***(CVRC 2007)***	Pods are fleshy and stringless ith good cooking quality, average yield: 12-14 t/ha
5.	Cowpea (Bush type)	Swarna Mukut ***(CVRC 2006)***	Mature dried seeds are kidney shapes and yellowish, brown. tolerant to cowpea mosaic viral disease and pod borer, average fresh pod yield: 12-15 t/ha
6.	Cowpea (Pole type)	Swarna Sweta (***IVRC 2004)***	Resistant to mosaic viruses and rust and tolerant to pod borer, average fresh pod yield: 25-30 t/ha
7.	Cowpea (Pole type)	Swana Harita ***(CVRC for 12 states 2008)***	Pods round and fleshy having excellent cooking quality; tolerant to mosaic viruses and rust under field condition; average fresh pod yield: 30.0-35.0 t/ha

8.	Cowpea (Pole type)	Swarna Suphala ***(CVRC 2006)***	Resistant to rust and cowpea mosaic viruses under field condition; average fresh pod yield: 21.0-25.0 t/ha
9.	Lablab bean (Pole type)	Swarna Utkrisht ***(CVRC 2006)***	Tolerant to anthracnose, mosaic viruses and pod borer under field condition; average fresh pod yield: 35-40 t/ha
10.	Vegetable soybean	Swarna Vasundhara ***(CVRC 2008)***	fresh green seeds sweet in taste, good cooking quality; average fresh pod yield : 15-20 t/ha
11.	Broad bean	Swarna Safal ***(SVRC, 2016)***	Ready for 1st harvest in 89-94 days after sowing. least infested by leaf eating insects and chocolate spot. fresh pod yield 20-25 t/ha
12.	Lima bean (Pole type)	Swarna Poshan ***(SVRC 2016)***	Cooked unripe seeds are very good in taste. Pod weight 6.0g with 3-4 seeds/pod, fresh pod yield: 12-15 t/ha
13.	Aromatic vegetable soybean	Swarna Sugandha ***(IVRC 2024)***	Edible shelled green beans are bold, sweet and emit fragrance similar to basmati rice during boiling/ cooking. Average fresh pod yield: 13-13.5 t/ha.
14.	Photo-insensitive/ Off-season Lablab bean	Swarna Rituvar (***IVRC 2011)***	Tolerant to anthracnose and pod borer under field condition, photo-insensitive and suitable for off-season (rainy season) cultivation, average fresh pod yield: 12- 15 t/ha
15.	Photo-insensitive/ Off-season Lablab bean	Swarna Nidhi ***(IVRC 2024)***	Tender green pods are having very good cooking quality and consumer preference. rich source of protein, Calcium, Phosphorus, Potassium, Magnesium and Sulphur, tolerant to anthracnose under field condition.
16.	Leaf amaranth	Swarna Raktim ***(SVRC 2015)***	Red colored; multi-cut variety; yield of greens in 4 cuttings 15-20 t/ha
17.	Leaf amaranth	Swarna Suparna ***(IVRC 2024)***	Green colored; multi-cut varietyyield of greens in 4 cuttings 20-25 t/ha
18.	Brinjal	Swarna Mani ***(CVRC, 004)***	Shiny purple round fruits, Moderately wilt resistant
19.	Brinjal	Swarna Pratibha ***(CVRC 2004)***	Shiny purple oblong fruits, Wilt resistant
20.	Brinjal hybrid	Swarna Shakti (***IVRC 2004)***	Light purple oblong fruits, Resistant to Phomopsis blight, Moderately resistant to bacterial wilt
21.	Brinjal	Swarna Shyamli ***(CVRC 2006)***	Fruits round, green colour with white stripes, Resistant to bacterial wilt
22.	Brinjal	Swarna Shree ***(CVRC 2006)***	Fruits creamy white in colour, round to oval, Moderately resistant to bacterial wilt
23.	Brinjal	Swarna Shobha ***(CVRC 2006)***	Fruits round, milky white with purple tinge. Tolerant to bacterial wilt
24.	Brinjal	Swarna Abhilamb ***(CVRC 2007)***	Long fruits, attractive purple colour
25.	Tomato	Swarna Lalima ***(CVRC 2006)***	Deep red, round fruits, Resistant to bacterial wilt
26.	Tomato	Swarna Naveen ***(CVRC 2006)***	Oblong, deep red fruits, Resistant to bacterial wilt
27.	Brinjal hybrid	Swarna Ajay ***(CVRC 2006)***	Oblong fruits, attractive purple colour, resistant to bacterial wilt & phomopsis blight
28.	Brinjal hybrid	Swarna Neelima ***(CVRC 2008)***	Fruits round, attractive purple black colour

29.	Brinjal hybrid	Swarna Mohit ***(CVRC 2012)***	Oblong fruits, light purple colour, resistant to phomopsis blight, Moderately resistant to bacterial wilt
30.	Tomato hybrid	Swarna Samriddhi ***(IVRC 2004)***	Round red fruits in clusters, resistant to bacterial wilt & early blight
31.	Tomato hybrid	Swarna Baibhav ***(CVRC, 2004)***	Deep red round fruits, high pulp proportion, suitable for long distance transportation & processing
32.	Tomato hybrid	Swarna Sampada ***(CVRC 2006)***	Round red fruits, firm, resistant to bacterial wilt & early blight
33.	Tomato hybrid	Swarna Vijaya ***(CVRC 2008)***	Round red fruits, resistant to bacterial wilt & early blight
34.	Tomato hybrid	Swarna Deepti ***(IVRC 2011)***	Deep red round fruits in clusters, resistant to bacterial wilt and early blight disease, suitable processing
35.	Brinjal variety	HABR-21 (***CVRC 2013)***	Fruits attractive with black colour and calyx dark purple
36.	Tomato hybrid	Swarna Anmol (***SVRC 2015)***	Indeterminate, round, red fruits with light green shoulder, borne in clusters, Resistant to bacterial wilt
37.	Tomato variety	Swarna Kanchan ***(SVRC 2015)***	Oblong, red fruits with less seed, more pulp, borne in clusters, suitable for processing, resistant to bacterial wilt
38.	Tomato variety	Swarna Ratan ***(SVRC 2015)***	Cherry type very small fruits (15-20g), round, red, borne in clusters, resistant to bacterial wilt
39.	Tomato variety	Swarna Prakash ***(CVRC 2024)***	Attractive round and slightly flattened fruits, Resistant to bacterial wilt
40.	Chilli variety	Swarna Praphulya ***(SVRC 2015)***	Fruits pendulous, dark green and dark red when ripe, Resistant to bacterial wilt
41.	Chilli variety	Swarna Tejaswi ***(SVRC 2015)***	Less pungent dark red ripe fruit suitable for pickle.
42.	Chilli variety	Swarna Arohi ***(CVRC 2024)***	Dark green upright fruits, good source of vitamin A & C, highly pungent, Resistant to bacterial wilt
43.	Chilli variety	Swarna Apurva ***(CVRC 2024)***	Green pendulous fruits, good source of vitamin A & C, highly pungent, Resistant to bacterial wilt
44.	Capsicum variety	Swarna Atulya ***(SVRC 2015)***	Fruits almost round, green and yellow coloured at maturity
45.	Cucumber variety	Swarna Poorna ***(CVRC 2004)***	Light green fruits with no placental hollowness, Tolerant to powdery mildew
46.	Cucumber variety	Swarna Sheetal ***(CVRC Gazette No. 1422, 2006)***	Greenish white fruits with no placental hollowness, tolerant to powdery mildew
47.	Cucumber variety	Swarna Ageti ***(CVRC 2006)***	Green fruits with no placental hollowness, tolerant to powdery mildew
48.	Pointed gourd variety	Swarna Rekha ***(CVRC 2006)***	Fruits elongated, striped green, contain soft seed
49.	Pointed gourd variety	Swarna Alaukik ***(CVRC 2006)***	Fruits elongated, light greenish, suitable for table and sweet preparation
50.	Pointed gourd variety	Swarna Suruchi ***(IVRC 2011)***	Fruits oval having blunt end on both sides, light greenish, suitable for table and sweet preparation
51.	Ridge gourd variety	Swarna Manjari ***(CVRC 2006)***	Fruits elongated, highly ridged, pulp soft and contain less fibre, tolerant to powdery mildew

52.	Ridge gourd variety	Swarna Uphar ***(CVRC 2006)***	Fruits elongated, long ridged at edible stage, pulp soft and contain less fibre
53.	Ridge gourd variety	Swarna Sawani *(satputia)* ***(SVRC, 2015)***	Fruits (35-45g) borne in clusters with 6-8 fruits per cluster.
54.	Sponge gourd variety	Swarna Prabha ***(CVRC 2006)***	Pulp soft and contain less fibre, tolerant to powdery, downy mildew & resistant to leaf minor under
55.	Bottle gourd variety	Swarna Sneha ***(SVRC, 2015)***	Fruits long, light green and fruit weight 900-1000g
56.	Bitter gourd variety	Swarna Yamini ***(SVRC, 2015)***	Fruits dark green with deep tubercles, tolerant to powdery mildew and downy mildew.
57.	Pumpkin variety	Swarna Amrit ***(CVRC 2009)***	Fruits round and dark green, average fruit weight 2.5-3.0 kg

Planting materials produced

Fruit and agroforestry saplings

- A total of 10-12 lakh planting material of fruits and agroforestry plants produced
- More than 3.0 lakh farmers benefited through quality planting materials, trainings, exposure visits, demonstrations. The technologies were also scaled up at farmers field through NABARD Wadi program, National Horticulture Mission, Birsa Bagwani Yojana of MGNREGA, NGOs (PRADAN, BAIF, TRIF, etc.).



Fig. 6.64. Planting materials production for fruits and agroforestry species

Mushroom spawn

- A total of 889.2 q of mushroom spawn was produced and distributed among farmers of Jharkhand and adjacent states after the inception of the project.

Intellectual Property

Trade mark SWARNA filed

The trademark SWARNA was filed under TM Application No. 2833351 on 28th October 2014 with the Trademark Registrar, Kolkata. It was accepted for registration under the provisions of Section 20(1) of the Trade Marks Act, 1999. A counterstatement for opposition was filed at the IPO, Kolkata, on 10th November 2018, followed by the filing of evidence in support of the application at the IPO, Kolkata, on 13th June 2019.



Fig. 6.65. Trademark Swarna

Patents filed

The center has filed two patents with the Indian Patent Office, showcasing its commitment to innovation and sustainable solutions. The first patent is for a Hybrid Solar Light-Pheromone Insect Trap, designed to effectively manage insect populations using environmentally friendly technology. The second patent pertains to a Solar Operated Hold-On Type Paddy Thresher, aimed at enhancing agricultural efficiency through solar-powered mechanization. These advancements reflect the center's dedication to addressing key challenges in agriculture and environmental sustainability.

Machine	Application No.	Date of filing
Hybrid Solar Light-Pheromone Insect Trap	202311034975	18/05/2023
Solar Operated Hold-On Type Paddy Thresher	202311038252	03/06/2023

Teaching, Extension and Capacity Building

Teaching activities

The scientists of FSRCHPR are serving as esteemed faculty members across prominent institutions such as BAU, ICAR-IARI Jharkhand, ICAR-IARI New Delhi, and Jharkhand Rai University. They have significantly contributed to academia by guiding numerous Master's and PhD students, while also teaching a diverse range of undergraduate and postgraduate courses. The number of students who completed their degree programmes from the centre are 31 (M.Sc. & Ph. D.), highlighting their dedication to nurturing future scholars and advancing educational excellence. Scientists are also involved in teaching nearly 30 UG and PG courses in all the hubs.

Entrepreneurship Development

The Agri Business Incubation (ABI) centre of ICAR-Research Complex for Eastern Region, Patna was initiated during 2000 and has two operational units located at Patna and Ranchi. Major focus of the ABI centre is to support operations on business projects as a measure of enhancing the foundation for new technology-based industries. The modalities are finalized through mutual discussions and Memorandum of Agreement (MoA) is signed accordingly. The ABI centre provides mentoring on technology backstopping and capacity building of incubatee on the aspects of capital raising, entrepreneurial setup, inventory and human resource management, collaborations, production, packages, marketing and market led extension of the products. Till now 17 entrepreneurs have registered till now as incubates in different fields pertaining to agricultural activities including crops, nursery management, seed production, medicinal & aromatic plants, livestock, fisheries and mushroom based projects. Industry Meet is organized to provide a common platform for various stakeholders and showcase their technologies. About 18 MOUs signed with various NGOs, company, entrepreneurs on various aspects of seed production of vegetable crops, mother block development of planting materials, commercialization of vegetable crops.

Technology dissemination

Varieties/hybrids on farmers' fields

For rapid spread of the varieties, a total of 340 kg seeds of the varieties were produced at the centre through the seed multiplication programme during 2006-2024. Apart from this, for ensuring self-sufficiency in seeds to the farmers, more than 1500 numbers of farmers have been provided training on seed production technique including production of hybrid seeds of tomato and brinjal. Frontline demonstrations of the varieties in 325 farmers' fields through the institute's program, along with providing technical support for the cultivation of these varieties in 600 additional farmers' fields in Jharkhand, Odisha, and Chhattisgarh, have been carried out by establishing linkages with PRADAN, OUAT, Ramakrishna Mission, AVRDC, Steel Authority of India Limited, IFFCO, NABARD, and the Art of Living. Apart from generating income ranging between ₹ 70,000/- to ₹ 1,20,000/- per acre, cultivation of these varieties/hybrids has resulted in creation of additional employment i.e., 340 man-days per acre and significant increase in the consumption of vegetables in the farm families. A higher benefit cost ratio of the improved varieties/hybrids (2.95 in tomato and 3.79 in brinjal) were recorded



Fig. 6.66. Promotion of bacterial wilt resistant varieties/hybrids of brinjal and tomato

over that of indigenous varieties. The developed bacterial wilt resistant varieties/hybrids in brinjal are the most popular among the tribal farmers spreading to more than 80 ha area as estimated according to sale of seed from the centre. Similarly, in the case of tomato, the bacterial wilt-resistant tomato hybrid Swarna Sampada is cultivated in more than 3,000 hectares, generating a cumulative value of ₹ 54.14 crores during the period from 2002 to 2024.

Transfer of technology under Farmer FIRST

The Farmer FIRST Project facilitated transfer of technology to evaluate the effectiveness of various technological interventions in enhancing the profitability of peri-urban agricultural systems. Among the tested technologies, the rainy-season cultivation of solanaceous vegetables gained widespread acceptance among farmers due to its higher yield potential and the ease of marketing perishable produce in nearby urban and suburban markets, even during adverse weather conditions. The provision of fencing under the project emerged as a significant enabler, allowing farmers to utilize vast tracts of rice fallow land for the successful cultivation of crops such as wheat. Findings from experimentation highlighted several promising



Fig. 6.67. Oyster mushroom

technological options, including the cultivation of wheat, chickpea, and other rabi and summer vegetables in rice fallow areas, effective management of ecto- and endoparasites in livestock, and supplementation of area-specific mineral mixtures to improve animal health. Additionally, the introduction of oyster mushroom cultivation provided an alternative source of income, further diversifying the agricultural production system.Under crop based module, drought tolerant variety of paddy- Swarn Shreya was adopted by 250 households. Under horticulture-based module, wilt resistant grafted tomato, grafted brinjal, fruit plants, etc were adopted by 195 households. Under Rice fallow management in NRM module, rabi (wheat, lentil, gram, etc) and summer crops (bottle gourd, cucumber, etc.) were grown by 30 households in more than 12 ha of land after harvesting of paddy. Under livestock based module, feeding mineral mixture to the animals, vaccination and deworming of animals were adopted by 230 households. The socio-economic impact confirms that most of the households shifted from kuchcha to pucca house. In case of marginal farmers, the net income per hectare increased from ₹34,000/- to ₹1,78,000/-. The per hectare net income of small farmers has increased from ₹58,000/- to ₹1,05,000/-. Enterprises like mushroom, piggery, high value crops etc. contributed in income enhancement of farmers.



Fig. 6.68. RAC team visiting farmers First Village

Success story of women mushroom growers

Mrs. Sukramani Kharkhusa, wife of late Suresh Kharkhusa, resident of Plandu village of Namkum block of Ranchi district, is a landless hardworking woman. She is the only earning member in her family of six. Before she became as a beneficiary of the Farmer FIRST Program (FFP), she used to work as a maid in others' homes and earned only ₹ 6,000/- a month. However, due to financial constraints in the family, her children left their studies. She had taken a loan of ₹ 50,000/- from a women self-help group for arranging the basic needs of the family members.The Farmer FIRST Program team visited their home during 2019 and interacted with family members. They came to know about the interventions being implemented under the program and showed interest in mushroom cultivation. She attended a training on "cultivation of mushroom". She started mushroom cultivation in the month of September, 2019. ICAR-RCER, FSRCHPR, Ranchi provided them with mushroom spawn, PPP



Fig. 6.69. Success story of women mushroom growers

bags, Formalin and Bavistin under FFP. She was able to sell 145 kg of fresh mushrooms at the rate of ₹ 150/- per kg in local haats (Rampur market, Namkum market, etc.) within two months. She uses spent mushroom bags for vermicomposting. She is now earning about ₹ 0.85 lakh from mushroom and another ₹ 50, 000 from associated activities. She returned the loan to the women self-help group from the profit earned in the business. Then, her children went to private school for further studies. She is a role model for other women mushroom growers. Her success story was telecasted in local news channel "Jharkhand Ki Buniyaad".

Capacity building

The Centre is actively involved in capacity-building programmes on cultivation of seasonal and off-season vegetables, seed production of hybrid and open pollinated varieties in vegetables, production of quality planting material, fruit-based multi-tier cropping systems, management of insect pest and diseases, mushroom cultivation, micro-irrigation, water harvesting and multiple-use, processing of fruits and vegetables etc. The Centre has a strong outreach programme for effectively transferring the technologies developed at the institute to the farmers' fields under different projects, viz. Farmer FIRST Project, DBT Biotech KISAN Hub project, Tribal Sub-plan and Scheduled Caste Sub-plan projects. The technology transfer programme of the Centre includes frontline demonstrations, technological backstopping to different stakeholders of the region, on-farm trials, training programmes, field visits of farmers, supply of seed and planting material, and participatory research.

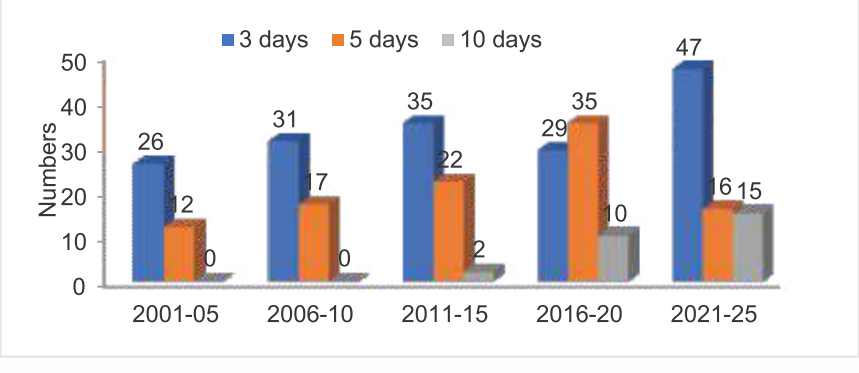

Fig. 6.70. Capacity building programmes organized

Foreign Deputation and Training

a) Dr. Santosh Mali, Senior Scientists, SWCE, FSRCHPR, Ranchi undergone four foreign visits and training programme as detailed below.

1. Visit to the from May 10, 2024, to November 29, 2024. Dr. Mali explored advanced methodologies for applying multispectral and thermal drone imagery to assess water stress in winter wheat
2. Visited the International Water Management Institute (IWMI) in Nepal on June 27–28, 2023, to participate in the "IPSR Innovation Scaling Workshop on Solar Irrigation Pump (SIP) Sizing Tool for Nepal."
3. Participated in a 10-day capacity-building program at the International Water Management Institute (IWMI), Sri Lanka, from November 15 to 25, 2023.
4. Visited the International Water Management Institute (IWMI), Nepal, from April 24 to 26, 2024. The visit marked a significant milestone in the ICAR-IWMI collaborative project by facilitating the introduction and promotion of the Beta version of the solar pump sizing tool developed for Nepal.



Fig. 6.71. Dr. S. S. Mali in digital lab of University of Southern Queensland, Australia.

b) Dr. P Bhavana, Senior Scientist (Plant Breeding) attended the International Course on "Plant Variety Protection" at Centre for Development Innovation, Wageningen University and Research during 19-30 June 2017 under Nuffic Fellowship 2017.



Fig. 6.72. Dr. P. Bhavna at Centre for Development Innovation, Wageningen University, Netherland

Awards, Honours and Peer Recognitions

Fakhruddin Ali Ahmed Award

Dr. Bikash Das, Dr. B. P. Bhatt, Dr. A. K. Singh, and Dr. R. S. Pan received the Fakhruddin Ali Ahmed Award for Outstanding Research in Tribal Farming Systems (collaborative) in 2013, awarded by the Indian Council of Agricultural Research, New Delhi



Fig. 6.73. Fakhruddin Ali Ahmed Award

Regional Official Language Award (Hindi)

ICAR-RCER, Farming System Research Centre for Hill and Plateau Region, Ranchi has received the Regional Official Language Award for the year 2020-21 and 2022-23 in the category of Central Government Offices of Region "A" located in the Eastern Region of the country for excellent implementation of Official Language Policies of the Government of India in its office.

Publications

The scientists at the Centre have published more than 317 high-quality papers in peer-reviewed national and international journals, as well as 10 books and 60 book chapters, from 2001 to 2025.

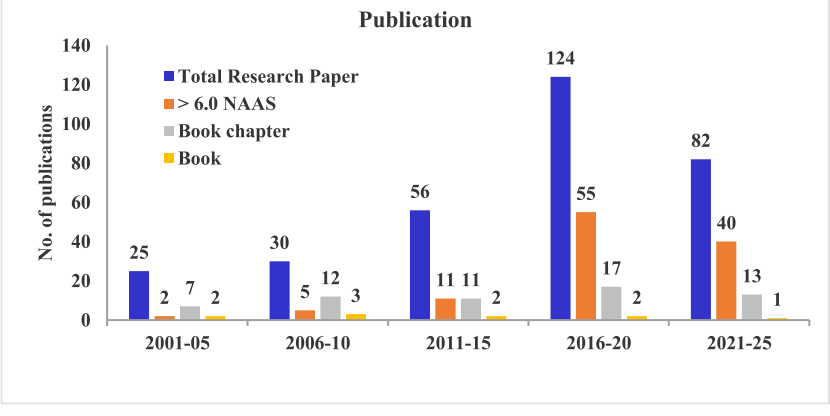

Fig. 6.74. Year-wise research publications

Future Research Thrusts

The Farming System Research Center for Hill and Plateau Region (FSRCHPR), Ranchi is dedicated to developing sustainable and climate-resilient agricultural practices tailored to the unique agro-climatic conditions of the region. The center focuses on optimizing resource use, enhancing productivity, and integrating modern technologies with traditional knowledge to support long-term farm sustainability and profitability.

Key Research Thrust Areas:

- Implement climate-smart agriculture, integrate natural and organic farming systems, and reduce carbon footprints to enhance system productivity and resilience.
- Optimize soil-water-plant interactions through advanced fertigation, predictive irrigation scheduling using AI, and renewable energy-driven irrigation solutions.
- Develop forewarning, forecasting, and long-term spatio-temporal prediction models for adaptive pest and disease management in horticultural crops.
- Improve fruit and vegetable varieties through genetic enhancement and evaluation, while identifying superior traits in Jharkhandi cattle, goats, ducks, and Chotanagpuri buffalo for better productivity and adaptation.
- Develop and standardize integrated farming system models to enhance productivity, sustainability, and income diversification in both irrigated and rainfed farming conditions.

Research and Innovation for Empowering Makhana Farmers

I S Singh, Manoj Kumar, B R Jana, S M Raut, V K Padala
Research Center for Makhana, Darbhanga, Bihar
(Presently : National Research Center on Makhana)

Background

The National Research Centre for Makhana, Darbhanga (Bihar) under Indian Council of Agricultural Research was sanctioned by the Dept. of Agricultural Research and Education, Govt. of India, as a new scheme during the IXth Five Year Plan period for Conservation, Research & Development of the makhana crop. The NRC for Makhana came into existence on National Science Day i.e. 28th February 2002 with setting up of a camp office at the Central Potato Research Station, Patna. It was shifted in 2004 to the building of the European Guest House, Lalit Narayan Mithila University Campus, Darbhanga. In the Xth plan period the Centre was merged with ICAR Research Complex for Eastern Region, Patna w.e.f 1st April 2005, since then the Centre worked as a research Centre of ICAR RCER, Patna till 14/05/2023.Thereafter, it restored the status of NRC for Makhana, Darbhanga on 15/05/2023 and functioning under administrative control of the Agricultural Engineering Division, ICAR. Under the control of ICAR RCER, Patna, the Centre has achieved significant milestone interms of developing some important technologies such as:

✓ Released first ever variety of makhana: "Swarna Vaidehi" on 15/11/2013.

✓ Developed makhana based cropping systems

✓ Developed Makhana Popping Machine on 03/12/2013.

✓ Standardized makhana cultivation in cropping system mode.

✓ Developed makhana based Integrated Farming System Models for Pond & Field ecosystems.

Additionally, the centre expanded its research mandate to include aquatic crops such as water chestnut, sweet flag, alocasia, and lotus, to enhance the productivity, sustainability, and resilience of these crops, which are of significant regional importance, especially in areas with abundant water bodies and wetlands. During the 18 years, the centre was under the leadership of various heads as given in Table 7.1

Table 7.1. Heads of the Research Centre for Makhana

Name	Designation	Tenure	
		From	To
Dr. Janardan Jee	OSD	28/02/2002	02/04/2008
Dr. V K Gupta	Head	03/04/2008	06/11/2014
Dr. Rajvir Sharma	Head	07/11/2014	15/09/2018
Dr. I S Singh	In-Charge Head	16/09/2018	11/01/2023
Dr. Manoj Kumar	In-Charge Head	12/01/2023	14/05/2023

State wise Area and Production of Makhana

The area under Makhana cultivation has increased by 171% in last 9 years from 13,000 ha in FY 2012-13 to 35,224 ha in FY 2021-22 and the total makhana pop production has been increased by 152% in last 9 years from 9360 t in FY 2012-13 to 23,656 t in FY 2021-22. The livelihood of around 80,000 fishermen families of nine districts (Darbhanga, Madhubani, Saharsa, Supaul, Madhepura, Purnea, Katihar, Kishanganj and Sitamarhi) of north Bihar are directly or indirectly dependent on cultivation and processing of makhana.

Table 7.2 State wise approximate production details of Makhana

Sl. No.	Name of States	Area (ha)	Production (t)	Production (t/ha)
01.	Bihar	35,224	56,329	1.6
02.	West Bengal	1,000	1,500	1.5
03.	Manipur	2,000	2,400	1.2
04.	Chhattisgarh	50	80	1.6
05.	Uttar Pradesh	60	60	1.0
06.	Odisha	Cultivation discontinued (<10 ha).	-	-
07.	Jammu & Kashmir	Data not available	-	-
08.	Kerala	Being cultivated but current data not available	-	-
09.	Assam	Being cultivated but current data not available	-	-
10.	Madhya Pradesh	Cultivation discontinued	-	-
	Total	38,334	60,369	1.57

Research Contributions

Varietal development and improvement

An aquatic crop of the Nymphaeaceae family, makhana (Euryale ferox) is a distinctive, nutrient-dense dry fruit that is primarily cultivated in stagnant perennial water bodies. The creation of Swarna Vaidehi" makhana variety was an attempt in this regard. With average production of 2.83 t/ha, Swarna Vaidehi is 60% more productive than the local check variety. This variety's seeds are bold, spheroidal, and deep black in color (Fig. 7.1). There are 65–110 seeds per fruit, and the popped result (white in off white crispy) is larger than that of typical cultivars. This type has a high potential yield and is resistant to common insect pest and diseases. To meet the demand from farmers, more than 1000 kg of this variety's seed are produced annually. Table 7.3 shows the nutritional profile of makhana. All the necessary amino acids are abundant in it as well.



Fig. 7.1. Swarna Vaidehi: Field View



Fig. 7.2. Swarna Vaidehi: Fruit



Fig. 7.3. Swarna Vaidehi: Seeds

Table. 7.3. Nutritional quality of Swarna Vaidehi vs. local variety

Parameters	Swarna Vaidehi	Local Variety
Moisture (% by wt)	10.4	11.1
Total ash (% by wt)	0.4	0.4
Fat (% by wt)	0.5	0.2
Protein (% by wt) (N × 6.25)	8.7	8.6
Crude fiber (% by wt)	0.2	0.3
Carbohydrates (% by wt)	79.8	79.4
Calorific value (K cal/100 g)	358	354
Amylose (%)	18.2	18.5
Phosphorus (mg/100 g)	53.2	79.1
Potassium (mg/100 g)	42.0	56.0
Iron (mg/100 g)	1.4	1.9
Calcium (mg/100 g)	18.5	13.0
Magnesium (mg/100 g)	13.9	11.9
Sodium (mg/100 g)	71.0	65.2
Copper (mg/100 g)	0.5	0.4
Manganese (mg/100 g)	1.3	1.3
Zinc (mg/100 g)	1.1	0.7

The Makhana variety Swarna Vaidehi is suitable for cultivation in perennial water bodies, waterlogged, marshy areas and even to the areas where assured irrigation is possible in cropping system mode. Before the development of this variety makhana was cultivated only in 15,000 ha area. However, after the development of improved variety, it is being cultivated in approximately 35,224 ha area with a total productivity of 5,688 t/yr. The varietal development has opened up the scope of Makhana cultivation in more than 6.0 lakh ha area in North Bihar

alone. It has the potential for adoption in 1.0 million ha area in other Eastern states. Around 1.25 lakh families are directly engaged in makhana cultivation and processing.

- The Green Spineless (Swarna Harit) germplasm of water chestnut achieved the highest yield of 12.00 t/ha, followed by the Red Spineless variety with a yield of 9.50 t/ha.
- A new promising strain of makhana, named Superior Selection-1, was identified, with a maturity period of just 3.92 months and a yield potential of 4.9 t/ha.
- The Tumkur-1 variety of sweet flag (Acorus calamus) collected from Karnataka was found to be the highest yielder, producing 8.1 t/ha of rhizomes.
- The Alocasia (Alocasia montana) germplasm (ICAR-RCER-RC-7) demonstrated superior yield potential, reaching 22.9 t/ha, compared to other varieties.

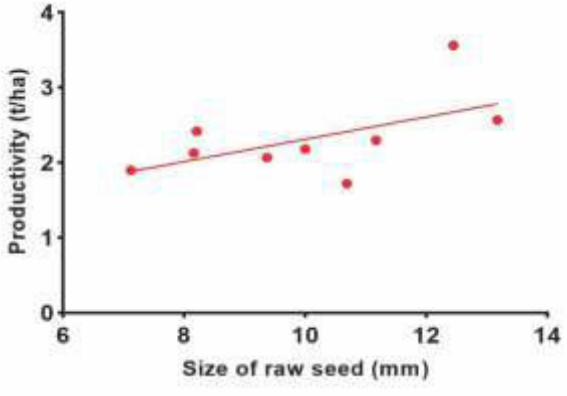

Fig.7.4. Relation between size of seed and productivity of Makhana

Ponds system of cultivation

Makhana is traditionally cultivated in natural ponds where leftover seeds from the previous crop serve as planting material. In new water bodies, 20 t/ha of FYM is added, followed by two to three wet ploughings. The pond is filled with 45 cm of water, and seeds are broadcast at 80 kg/ha in December, with sapling transplantation in March. Pond cultivation, however, has low productivity due to the labor-intensive process of collecting seeds and health risks for farmers. Moreover, the full-year cultivation cycle prevents growing other crops.





Fig.7.5. Makhana+ Fish culture under pond condition at RCM, Darbhanga

Pond water properties: The pond water exhibited a pH range of 8.2 to 8.6, with alkalinity varying from 13.5 to 31.0 mg/L and hardness between 7.2 to 26.0 mg/L. Calcium (Ca) levels ranged from 1.65 to 7.31 mg/L, while magnesium (Mg) concentrations were between 0.52 and 2.25 mg/L. DO was found between 2.41 and 9.26 mg/L. These chemical properties suggested that the underground irrigation water is highly suitable for cultivating carp fish species such as Rohu (Labeo rohita), Catla (Catla catla), Mrigal (Cirrhinus mrigala), and common carp (Cyprinus carpio), along with water chestnut, a high-value aquatic crop.

Pond soil: The soil properties of water chestnut-fish ponds were found to be favourable for cultivation, with a pH of 7.25, electrical conductivity (EC) of 0.30 dS/m, organic carbon content of 0.52%, and adequate levels of nutrients like nitrogen (265 kg/ha), phosphorus (33 kg/ha), and potassium (440 kg/ha). Micronutrient levels were also sufficient, with iron (51 mg/kg), manganese (25 mg/kg), copper (2.35 mg/kg), and zinc (0.48 mg/kg) present, though zinc was slightly below optimal levels. The integration of water chestnut and fish helped maintain neutral soil pH and optimum nutrient levels, making the soil well-suited for both water chestnut cultivation and fish farming.

Field system of makhana cultivation

The Research Centre for Makhana, Darbhanga, has standardized Makhana cultivation in agricultural fields with 30-60 cm of water depth. This method is easy to manage and allows for the cultivation of cereals and fodder crops on the same land within the same year, increasing crop intensity by 200-300% (Fig. 7.6).



Fig. 7.6. Makhana growing under field condition at research farm of RCM, Darbhanga

Effect of makhana cultivation on fertility status of soil

Makhana plants contain 0.31% N, 0.48% P, 0.40% K, 2200 mg/kg Fe, 1000 mg/kg Mn, 8.0 mg/kg Cu, and 105 mg/kg Zn. The seeds have 1.67% N, 0.40% P, 0.12% K, 960 mg/kg Fe, 40 mg/kg Mn, 12.0 mg/kg Cu, and 125 mg/kg Zn. Makhana contributes 7.0 t/ha/year of biomass to the soil, enhancing soil health with 34.35 kg/ha of N, 56.04 kg/ha of P, 53.07 kg/ha of K, 27.26 kg/ha of Fe, and 12.31 kg/ha of Mn annually.

Cultivation techniques of water chestnut

Water chestnut is traditionally grown in organic-rich ponds with 0.45 m of water, planting rootlets 3 meters apart. If transplanting isn't possible, seeds are broadcast at 69 kg/ha. Transplanting occurs in June-July, and harvesting is done with a wooden boat. It can also be cultivated in fields with 0.30-0.45 m water depth, allowing for both water chestnuts and fodder crops in one year, boosting crop intensity by 200-300%. Nutrients vary by plant part, with leaves

rich in carbon, phosphorus, potassium, and zinc, while fruits concentrate nitrogen, roots absorb iron, manganese, and copper. Water chestnut helps reduce pollution and recycle heavy metals. It is economically valuable, with growers earning ₹ 2,68,800/ha from thornless varieties. The fruit is sold fresh or boiled, and dried kernels are sold as nuts (₹250/kg) or ground into flour (₹300/kg). It's also used in tea, wine making, and as a festival food.



Fig. 7.7. Thornless red colour fruit bearing water chestnut



Fig. 7.8. Red colour thornless fruit of water chestnut

Makhana cultivation in cropping system mode

Makhana is typically cultivated in perennial water bodies, but its productivity tends to be low. Additionally, collecting seeds from the bottom of the pond is a labor-intensive process, requiring extra effort. As a result, the possibility of cultivating Makhana in agricultural fields with shallow water depths was explored to improve productivity and reduce labor.

In the field system, in addition to Makhana, various other crops including cereals and forages can be grown successfully. While 4-5 months are sufficient for Makhana cultivation, other crops could be cultivated during rest of the months. In general, Makhana is transplanted in the second week of April and harvested by the second week of August. Thereafter, short duration varieties of rice are cultivated in the same field. After harvesting of rice (November), wheat is sown by mid of December and harvested by the second week of April and the field is prepared for the subsequent crop of Makhana.





Fig.7.9. Water chestnut and Barseem cultivation in Makhana growing fields



Fig. 7.10. Rice and wheat in makhana-based cropping system

Hence, cultivation of three crops per year is possible in field method of cultivation. In general, the Makhana based different cropping system include: Makhana-Water chestnut; Makhana-Barseem; Makhana-Rice; and Makhana-Rice-Wheat

Crop calendar for makhana-based cropping systems

(i) Makhana (March-July) – Rice (July – Nov.)

(ii) Makhana (March-July) – Rice (July – Nov.) –Wheat (Nov to March)

(iii) Makhana (April-Aug.) – Wheat (Nov. – March)

(iv) Makhana (March – July) – Water chestnut (July – November)

(v) Makhana (April – Aug.) – Berseem (Nov. – April)

Table 7.4 Economics of makhana-based cropping system:

Cropping system	Economics (₹/ha)
Makhana, followed by water chestnut	88,790
Makhana, followed by Barseem	98,465
Makhana, followed by rice and wheat	₹ 1,22,570

Sequential double cropping systems of Makhana (*Euryale ferox Salisb.*) cultivation in agricultural fields of north Bihar, India.

(i) 1st Crop: 2nd February to 30th June (Yield potential: 3.04 t/ha)

(ii) 2nd Crop: 2nd July to 30th October (Yield potential: 2.23 t/ha)

The technology is suitable for waterlogged and marshy areas and even to the areas where assured irrigation is possible.

Integration of sweet flag and vegetable alocasia with makhana

Eight Sweet Flag (*Acorus calamus*) germplasm collected from Jharkhand, Bihar and Karnataka were evaluated at RCM, Darbhanga. It was found that Tumkur-1 collected from Karnataka was indicated as superior in terms of yield (8.1 t/ha) and recorded about almost double income as compared to local cultivars Araria-1. Seven Alocasia (*Alocasia montana*) germplasm were collected from ICAR-RCER, RC, Ranchi. Collection 7 (ICAR-RCER-RC-7) was found superior in comparison to others in terms of yield (22.9 t/ha.) potential. The germplasm

Alocasia-18 and Ranchi-3 were also found superior in terms of low co-oxalate content 67.8 mg/100 g and 13.5 mg/100 g, respectively. The protein content of these germplasm were 4.05 and 3.58%, respectively.



Fig. 7.11. Superior germplasm of sweet flag and Alocasia

Physico-chemical properties of soil and mineral composition of plants as affected by Fox nut-based cropping systems

Fox nut (*Euryale ferox*) is an aquatic crop typically grown in non-saline wetland areas. To boost productivity in these lowlands, crop diversification is crucial. Over three years (2012-2016), eight fox nut-based crop rotations were tested. The fox nut-water chestnut-berseem rotation proved most effective in improving soil quality, increasing organic carbon, nitrogen, phosphorus, and potassium compared to the fox nut-fox nut system. It also showed higher levels of DTPA extractable iron (Fe) and manganese (Mn). Additionally, the fox nut-rice-berseem system had the highest copper and zinc concentrations. Overall, the fox nut-water chestnut-berseem system significantly improved soil fertility in aquatic ecosystems.

Nutrient Management in Lotus

Lotus thrives in wetland ecosystems, especially in the ponds of north Bihar. It is cultivated in water depths of 1.20-1.80 m or 30-45 cm shallow fields, using leftover seeds from previous crops. Transplanting occurs in February-March, and harvesting is done with a wooden boat. The best soil is clayey or silty clay loam, which retains water. Lotus prefers neutral to slightly alkaline water and requires continuous irrigation. Organic-rich soil provides essential nutrients like N, P, S, and B, influencing plant growth and nutrient availability. The highest yield (0.8 t/ha) was achieved with a 120:60:60 treatment. Nutrient accumulation pattern in different parts of lotus is shown below:

N: leaf (3.16%) > petiole (2.63%) > seed (2.58%) > seed coat (1.98%) > fruit sheath (1.22%)

P: seed (0.62%) > petiole (0.53%) > leaf (0.51%) > seed coat (0.49%) > fruit sheath (0.28%)

K: petiole (3.28%) > leaf (2.02%) > fruit sheath (1.59%) > seed coat (1.05%) > seed (1.01%)

Ca: fruit sheath (1.31%) > leaf (1.26%) > petiole (1.13%) > seed coat (0.80%) > seed (0.65%)

Mg: leaf (0.83%) > fruit sheath (0.81%) > seed coat (0.64%) > petiole (0.37%) > seed (0.34%)

S: petiole (0.91%) > leaf (0.32%) > seed coat (0.28%) > fruit sheath (0.26%) > seed (0.25%)

Fe: leaf (2232 mg/kg) > petiole (2066 mg/kg) > seed coat (817 mg/kg) > fruit sheath (507 mg/kg) > seed (302 mg/kg)

Mn: leaf (916 mg/kg) > fruit sheath (787 mg/kg) > seed coat (528 mg/kg) > petiole(484 mg/kg) > seed (187 mg/kg)

Cu: seed coat (29.26 mg/kg) > fruit sheath (25.60 mg/kg) > leaf (23.20 mg/kg) > seed (22.63 mg/kg) > petiole (16.20 mg/kg)

Zn: seed coat (105.86 mg/kg) > petiole (88.7 mg/kg) > fruit sheath (71.43 mg/kg) > seed (69.70 mg/kg) > leaf (61.96 mg/kg)

Post-Harvest Handling of Makhana

The resource-poor fisherman communities carry out its processing and the following steps are involved in the processing of fox nut.

Sun Drying: Fresh seeds are dried for 2-3 hrs in bright solar light to reduce the moisture content to an extent of 25% (w.b.). From a processing point of view, the optimum level of sun drying of the seeds is a significant element. The appropriate drying of seeds is judged by the experienced member of the processor's family. The dried seeds are pounded with a wooden hammer, and the simple separation of kernel fragments demonstrates that the seeds have been well-dried.



Fig. 7.12. Sun drying of Makhana



Fig. 7.13. Grading of Makhana

Grading: For seed screening, seven to fourteen wooden framed sieves of varying sizes are used, with the largest pore size being 14 mm and the smallest being 4 mm. Seed grading is necessary for uniform heating and popping. All graded seeds are stored individually.

Pre-heating: Sun-dried seeds are heated in an earthen pitcher or cast iron pan by placing them over the fire and stirring them continuously. Firewood and seed coat of fox nut is used as a source of energy and the time taken in heating is solely determined by the experience of the farmers engaged in this profession.

Tempering: The storage of pre-heated seeds for duration of 48-72 hrs at the ambient condition is known as the tempering of the seeds. It is done purposefully to loosen the kernels within hard seed coat and helping the equilibrization of the moisture within the seeds (Vermaet al., 2010).

Roasting and popping: In a cast iron pan, 200–250 g of preheated and tempered seeds are roasted in a single layer over a fire at 300°C surface temperature while being constantly stirred for two minutes. A wooden hammer is used to fracture the roasted seeds in a matter of seconds after 8–10 of them are swiftly taken out of the pan and placed on a hard wooden surface. The kernels of the seeds burst out in the expanded shape of fox nuts as soon as the hard shell breaks. 38–40 kg of popped nuts are produced from 100 kg of seed on an average.



Fig. 7.14. Makhana Seed Decorticator and Popping Machine

Polishing and Packaging: Rubbing in bamboo baskets removes the thin red membrane that is still attached to the ruptured fox nut. This process, which is done right after popping before it absorbs moisture, gives fox nuts extra whiteness and sheen. The crop is put in gunny sacks lined with polythene and is less perishable. 7.5–8.0 kg of popped nuts could be kept at room temperature in a single gunny bag.



Fig. 7.15. Makhana pop processed from Makhana Popping Machine

GI Tag to Makhana

The NRC on Makhana and Bihar Agricultural University has emerged as the two major research centres of Makhana. On August 16, 2022, Makhana received Geographical Indication (GI) recognition from The Gazette of India under the name Mithila Makhana. This announcement was made in the Ministry of Agriculture and Farmers Welfare Notification (F.N. 30941) dated July 20, 2022. Furthermore, the GI tag Mithila Makhana (No. 896, Certificate No.

421) was granted to Mithilanchal Makhana Utpadak Sangh, Purnea, by the Government of India through the Registrar of Geographical Indications in Chennai. This recognition highlights the distinct quality and traditional cultivation methods of Makhana from the Mithila region in Bihar.

Technology Developed

Development of Popping Machine

The popping machine was developed by CIPHET, Ludhiana in collaboration with ICAR RCER, Research Centre for Makhana, Darbhanga on 03/12/2013. The popping efficiency of the machine is 95% with an output of 25 kg raw seed per hour.



Fig. 7.16. Popping Machine

Relationship between size of seed and size of makhana pop

The study on Makhana seed sizes revealed the following key findings

- **Seed Size and Weight:** Makhana seeds were categorized into various size ranges, from <8 mm to 14-16 mm. The largest seed measured 14.23 mm and weighed 1.36 g, while the smallest seed measured 7.34 mm and weighed 0.24 g.
- **Pop Size and Seed Size:** While larger seeds resulted in larger Makhana pops, the relationship between seed size and pop size was not linear. Specifically, the size of the pop from three consecutive seed sizes was almost identical. This indicates that the increase in seed size does not necessarily translate to a proportionate increase in the size of the pop.
- Larger Makhana seeds tend to have better yields, but the size of the pop does not increase linearly with seed size. The pop size remains relatively consistent across different seed grades, despite variations in the seed's original size.

Table 7.5 Effect of size of seed on productivity of makhana

Sl. No.	Size of raw seed (mm)	Productivity (t/ha)
01	13.18	2.57
02	12.45	3.56
03	11.17	2.30
04	10.69	1.72
05	10.00	2.18
06	9.37	2.07
07	8.21	2.42
08	8.16	2.13
09	7.12	1.90

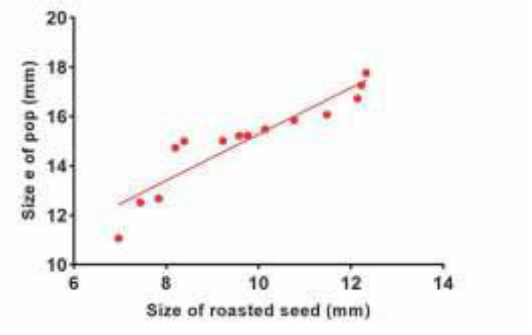

Fig. 7.17. Relation between size of roasted seed and size of makhana pop



Fig. 7.18. Experimental plots of Makhana

IFS model by integration of fish and Singhara with makhana

Makhana (Euryale ferox) and water chestnut (Trapa natans) are widely cultivated in North Bihar, providing a nutritious food with high carbohydrates, protein, and minerals. Traditionally grown as a mono-crop, Makhana was integrated with fish and Singhara to improve water productivity and income. The integrated system involved pond cleaning, gap filling, and fish seed introduction in two stages (March-April and September), with fish harvested twice a year and Singhara grown in October-November. Results from 50 ha showed yields of 0.18-0.4 t/ha for fish, 1.06-2.06 t/ha for Makhana, and 3.08-8.8 t/ha for Singhara. The system generated a net profit

of ₹20,015/ha for Makhana, ₹11,806/ha for fish, and ₹13,445/ha for Singhara, with a benefit-cost ratio of 1.94, higher than the 1.63 from the traditional Makhana-only system.

Table 7.6 Economics of Integrated system of makhana cultivation

Parameter	Traditional System	Integrated System		
	Makhana only	Makhana	Fish	Singhara
Productivity (t/ha)	1.40	1.33	0.27	3.7
Cost (₹/ha)	32693	31, 058	11, 323	13, 445
Net Income (₹/ha)	20614	20, 015	11, 806	20, 614
Labour employed (Man-days/ha)	247	240	24	83
Benefit cost ratio	1.63			1.94

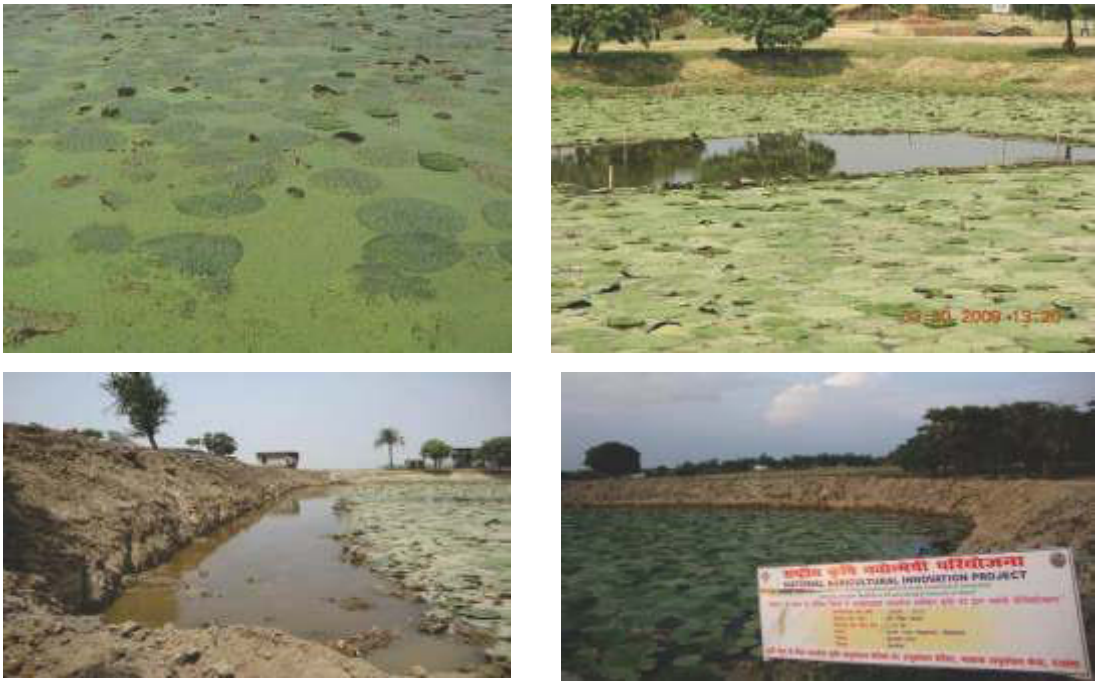

Fig. 7.19. View of renovated Makhana pond and Makhana cum fish with water chestnut farming

Integration of fish and horticultural components with Makhana ponds

Traditionally, Makhana is grown as a sole crop in deeper perennial water bodies, where agronomic management is challenging, leading to low yields (1.0–1.2 t/ha). Additionally, these deep-water bodies prevent the cultivation of other crops. To optimize land and water use, a new system was developed where 20% of the Makhana pond area was converted into a raised platform (1.5 m high) for horticultural crops, while the remaining 80% was kept as a pond for Makhana and fish cultivation. In this system, Makhana was transplanted in March-April at 1.25 x 1.25-meter spacing, with 10% of the water area left as a refuse zone. The raised platform was

used to grow fruit plants (e.g., mango, guava, papaya) and seasonal vegetables, providing yearround income. The system resulted in an average yield of 1.2 t/ha for Makhana and 0.31 t/ha for fish. The total gross return from the system, including horticultural crops, was ₹1,19,246/ha, with a net return of ₹50,439/ha.

Table 7.7 Comparative economics of different pond based Makhana farming

Component combinations	Total area (ha)	Total production of differen components (t)				Average productivity (t/ha)				Gross return /ha (₹)	Net return /ha (₹)
		Makhana	Fish	Water chestnut	Horti-Comp. (banana /papaya)	Makhana	Fish	Water chestnut	Horti. Comp. (banana /papaya)		
Makhana+ Fish	20.743	26.39	5.93	--	---	1.27	0.29	---	----	95,700	37,660
Makhana+ Fish+ Horticulture	2.181 (M+F 1.74) (Hort. 0.436)	2.08	0.53	--	6.87 (banana) 12.6 (papaya)	1.19	0.31	---	31.5 (banana) 58.0 (papaya)	1,19,246	50,439
Makhana+ Water Chestnut	0.635	0.84	---	7.1	----	1.32	---	11.2	----	1,06,035	41,745
Makhana	7.362	9.74	----	----	----	1.32	----	----	----	72,765	25,725

Field-based systems of Makhana Cultivation

The new Makhana cultivation system, implemented from 2012-2014, involves growing Makhana in shallow water (1 ft) on clay soil with a normal pH. In addition to Makhana, other crops like Makhana+Fish, Makhana-Rice, Makhana-Water Chestnut, and Makhana alone are cultivated to boost income. Makhana seedlings are raised in a nursery and transplanted in February or April. Ten percent of the field is reserved for Makhana, and fish fingerlings (Rohu, Catla, Common Carp, Mrigal) are stocked at 5000/ha in a 40:20:20:20 ratio. Fish are harvested in November-December, while Makhana is harvested in JulyAugust. After Makhana, rice or water chestnut can be planted.

Table 7.8 Comparative economics of different fields based Makhana farming

Component combinations	Total area (ha)	Total production (q)				Net return (₹/ha)	B C Ratio
		Makhana	Fish	Water chestnut	Rice		
Makhana+ Fish	8.40	240.24	37.80	-	-	1,21,520	1.75
Makhana- Rice	3.00	90.72	-	-	123.60	1,16,322	1.74
Makhana- Water Chestnut	1.20	35.54	-	252	-	1,56,436	1.79
Makhana	1.00	31.56	-	-	-	88,368	1.67



Fig. 7.20. Field based makhana cultivation



Fig. 7.21. Fish production in makhana fields



Fig. 7.22. Harvesting of fish from makhana field



Fig. 7.23. A view of water chestnut in makhana field

Future Research Thrust

- Emphasis on post-harvest processing and value addition
- Mechanization of makhana harvesting and cultural activities
- Nutraceuticals and food value of makhana to establish it as a super food