Annual Report 2022

भाकृअनुप
ICAR

ICAR Research Complex for Eastern Region
ICAR Parisar, P.O.: Bihar Veterinary College
Patna- 800 014 (Bihar)

Annual Report

2022

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International year of millets

Preface

It gives me immense pleasure to bring out the 22nd Annual Report of ICAR Research Complex for Eastern Region, Patna for the year 2022, focusing the significant research achievements and activities of the institute. The institute undertakes multi-disciplinary and multi-commodity research to enhance the productivity of agricultural production systems through efficient management of available natural resources, and demonstration as well as dissemination of developed technologies in diverse agro-ecological zones of the eastern region.

For achieving the goal of food and nutritional security along with enhancement of farmers' income especially of small holders and landless farmers, the institute has developed several viable technologies. Health services and agro-advisories are also regularly provided to the farmers of the region to cope-up with the prevailing situation. Presently institute is focusing on management of rice-fallows, development of stress tolerant varieties, popularization of resource conservation technologies, natural farming, integrated farming systems, crop diversification, water productivity enhancement, solar energy application in agriculture, fruit and vegetable production, characterization of indigenous poultry and livestock resources etc. For adaptation to the changing climate situations, a high yielding, multiple stress (drought, disease/insect pest) tolerant rice variety Swarna Purvi Dhan 3 (IET 28329) has been released and notified by Govt. of India. Simultaneously a large number of rice genotypes have been evaluated under dual stress (submergence & drought) condition. Five rice genotypes have been promoted from IVT to AVT - 1 trial under AICRP programme and one rice genotype from AVT 1-aerobic to AVT 2. Under pulses, one entry of chickpea was promoted to AVT-2 under AICRP on Chickpea and one entry of lentil from IVT to AVT-1 under AICRP on MULLaRP. In vegetables, eighteen genotypes of brinjal and five genotypes of tomato have been screened for bacterial wilt resistance under hill and plateau region. Focus has been also drawn on application of different mixture of weedicides for effective management of weed in rice-wheat-greengram system. Studies on agricultural production under natural and organic farming, nutri-garden and nutri-cereal production have been undertaken by the institute. A solar irrigation pumps sizing tool developed by the Institute for selection of right size of pump by farmers adopted under the PM-KUSUM scheme of the Government of India.

Further 14.72 t of breeder seed, 0.25 t of nucleus seed and 13.21 t of truthfully labeled seed of Institute rice varieties have been produced. In case of pulses, 44.5 t of quality seeds of recently released varieties of mungbean, pigeonpea, chickpea and lentil were produced. Besides, 1.3 t of vegetable seeds, 3 t of mushroom spawn and 1.18 lakh planting materials were also produced during 2022. During the period, 5 Farmer Producer Organization (FPO) have been formed, 4 MoUs have been signed and 5 entrepreneurs have been registered as Incubatees.

The institute has also been providing technological support to the farmers, extension workers and state officials through its extensive extension network. A total of 174 training programmes, 27 Front Line Demonstrations, 14 On - Farm trials have been conducted for the farmers and the state government officials. During the period under report, the institute published 118 research papers in the journal of national and international repute, 09 books, 32 book chapters, 2 training manual, 13 extension folders, 10 bulletins and 62 popular articles.

Year 2023 has been declared as the International Year of Millets. The ICAR-RCER conducted several programmes and activities to promote, enhance as well as popularize millets among the farmers. As agriculture is the priority sector under G 20 summit, the institute shall also participate different programme and follow guidelines so as to contribute significantly towards achieving goal of the G 20 summit.

I acknowledge the consistent support, keen interest and guidance received from Dr. H. Pathak, Secretary, DARE and Director- General, ICAR towards planning and implementing various research and extension activities of the institute. The encouragement, valuable guidance and support rendered by Dr. S. K. Chaudhari, DDG (NRM), and Dr. S. Bhaskar (ADG, AAF & CC) are duly acknowledged. All Heads of the Divisions/Research Centre/KVK deserve appreciation for submitting their research findings in time and adequate shape. I also sincerely acknowledge the support received from Universities, Research Organizations, Line Departments, NGOs, Participating farmers, etc., from the eastern region for implementing various programmes of the institute. The support from Administration & Finance section is duly acknowledged. I also express my appreciation to the editorial team and other staff members of the Institute for compiling and bringing out this valuable report in time.

Anup Das
Director

Content

Coverage of ICAR-RCER Technologies and outreach activities in eastern India

Legend:
- Rice-fallow Management Programme
- High yielding Climate Resilient Rice varieties
- High yielding Fruits and Vegetable varieties
- Outreach/Capacity building activities
- Flood and its impact assessment activities

States labeled: Assam, West Bengal, Bihar, Jharkhand, Orissa, Chhattisgarh, Uttar Pradesh

Coverage of ICAR-RCER technologies and outreach activities in eastern India

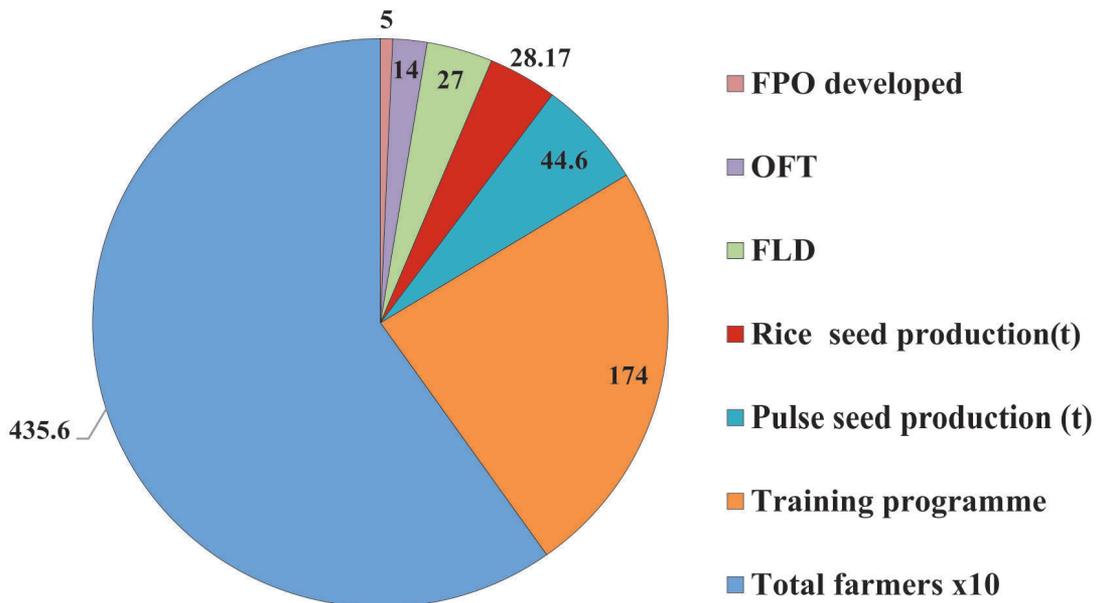| Activities	Bihar	Jharkhand	Odisha
High yielding climate resilient Rice varieties	Swarna Shreya, S. Shakti Dhan, S. Samriddhi Dhan, S. Sukha Dhan, S. Unnat Dhan and S. Purvi Dhan 3	S. Shreya, S. Shakti Dhan, S. Samriddhi Dhan, S. Sukha Dhan, S. Unnat Dhan and S. Purvi Dhan 3	S. Shreya, S. Shakti Dhan, S. Samriddhi Dhan and S. Unnat Dhan
High yielding Fruits and vegetable varieties	S. Madhu (Litchi), S. Rekha, S Alaukik, S Suruchi (Pointed gourd), S Sampada, S Baibhav, S Lalima (Tomato), S. Vasundhara (V. Soyabean)	S. Madhu (Litchi), S. Rekha, S Alaukik, S Suruchi (Pointed gourd), S Sampada, S Baibhav, S Lalima (Tomato), S. Vasundhara (V. Soyabean)	S. Rekha, S Alaukik, S Suruchi (Pointed gourd), S Sampada, S Baibhav, S Lalima (Tomato), S. Vasundhara (V. Soyabean)
Rice fallow Management Program	25 acre, Mustard , Chick Pea (BG 3043), Lentil (IPL-220)	52 acre, Rice, Mustard, Linseed, Safflower, Chick Pea, Lentil, Bottle gourd	-
Outreach / capacity building activities	HYV Pulse seed Pigeonpea (IPA 203) Chickpea (BG 3043) Lentil (IPL220) Mungbean (IPM 02-3), SCSP program on IFS Model, Flood-prone area assessment and impact activities	HYV Pulse seed Pigeonpea (IPA 203), Nutri-garden (tomato, brinjal, chilli, f bean, v. soyabean etc.), SCSP program on IFS Model	SCSP program on IFS Model

Activities	Chhattisgarh	Eastern UP	Assam	West Bengal
High yielding climate resilient Rice varieties	S. Shreya, and S. Shakti Dhan	S. Shreya, S. Shakti Dhan, S. Samriddhi Dhan S. Unnat Dhan and S. Purvi Dhan 3	S. Shreya, S. Shakti Dhan and S. Samriddhi	S. Shreya, S. Shakti Dhan, S. Samriddhi Dhan and S. Unnat Dhan
High yielding Fruits and vegetable varieties	S. Madhu (Litchi), S. Rekha, S Alaukik, S Suruchi (Pointed gourd)	S. Rekha, S Alaukik, S Suruchi (Pointed gourd), S. Tripti (Snow Pea)	Arecanut and Assam lemon plantation	S. Madhu (Litchi), S. Rekha , S Alaukik , S Suruchi (Pointed gourd), S Sampada, S Baibhav, S Lalima (Tomato), S. Vasundhara (V. Soyabean)
Rice fallow Management Program	5 acre, Rice, Mustard,Linseed, Safflower, Chick Pea, Lentil, Bottle gourd	-	-	-
Outreach / capacity building activities	Nutri-garden (tomato, brinjal, chilli, f bean, v. soyabean etc.), 25 Knapsack Sprayers, SCSP program on IFS Model	HYV Pulse seed Pigeonpea (IPA 203) Chickpea (BG 3043) Mungbean (IPM 02-3), SCSP program on IFS Model	Flood-prone area assessment and impact activities, SCSP program on IFS Model	SCSP program on IFS Model

Publications of ICAR RCER, Patna

Legend:
- Research Paper — 118
- Popular article — 62
- Book Chapter — 32
- Paper/ poster/ presentation — 24
- Extension / technical bulletins & folder — 23
- E publication — 10
- Award & recognition — 19
- Books — 9
- Training manual — 2
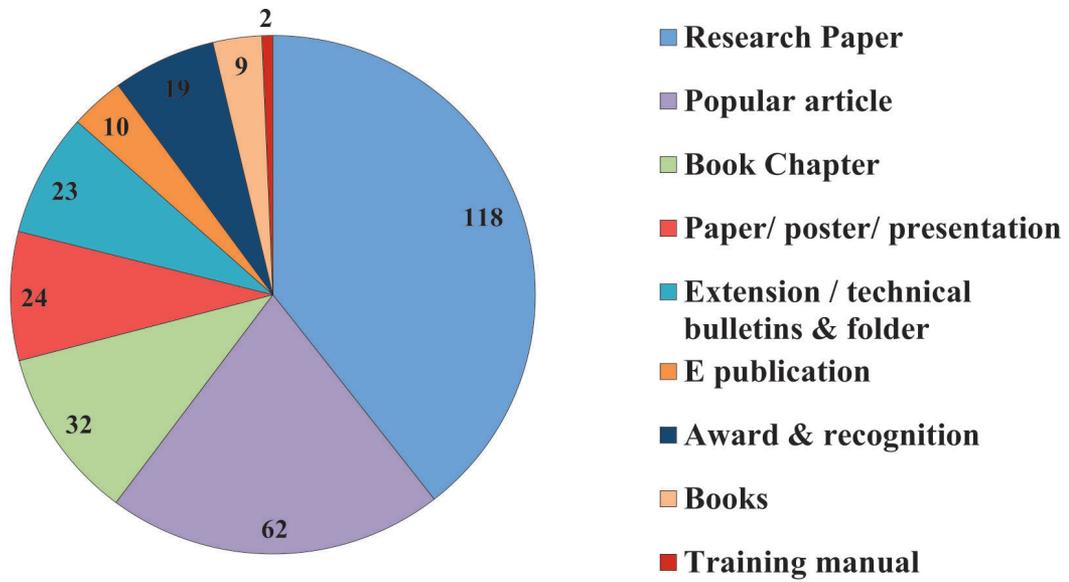
Capacity building programme organised

Legend:
- FPO developed — 5
- OFT — 14
- FLD — 27
- Rice seed production(t) — 28.17
- Pulse seed production (t) — 44.6
- Training programme — 174
- Total farmers x10 — 435.6

Executive Summary

During the period under report, the Institute has undertaken multi-disciplinary and multi-commodity research and capacity building activities. The salient achievements are summarized below:

Natural Resource Management:

- During the period under report, the annual rainfall of Patna was 883.7 mm, which was 21.6% less than the long-term average rainfall (1127.3 mm). Maximum rainfall was received in the month of August and the mean monthly maximum and minimum temperature varied from 38.2 °C in April to 19.8 °C in January and from 27.5 °C in June to 10.8 °C in January, respectively. April was the hottest and January was the coldest month of the year in Patna as well as Ranchi. At the Ranchi center, the annual rainfall was 1074 mm which was about 23% less than the long-term average from the normal rainfall (1398 mm).

- A high yielding (5.0-5.5 t/ha), early duration (115-120 days), semi-dwarf, multiple stress (drought, disease/insect pest) tolerant rice variety Swarna Purvi Dhan 3 (IET 28329) has been released and notified by Govt. of India for cultivation under irrigated transplanted conditions of Bihar, UP, Chhattisgarh, Haryana, Rajasthan and Maharashtra.

- Nine rice genotypes (IR 102777-18-64-1-2-6, IR 96321-315-323-B-3-1-3, etc.) have been identified for multiple stress (submergence & drought) tolerance with productivity range of 1.66 - 2.10 t/ha. Another nine rice genotypes, along with Swarna Shreya and Swarna Shakti Dhan have been found promising with high resources remobilization efficiency (35.03 -43.24%) of assimilates as compared to check varieties IR64 (25.8%) and Sahbhagi Dhan (32.41%) under drought condition. In respect to multi-stages drought tolerance eleven rice genotypes have been found promising with a yield range of 1.27-1.77 t/ha as compared to Sahbhagi Dhan (0.93 t/ha).

- Five promising rice genotypes (RCPR 92, 93, 94, 95 and 96) have been nominated to AICRP for multi-locational testing/evaluation during *Kharif* 2022. Moreover, another five rice genotypes *viz.* RCPR 79, 80, 81, 82 & 84 have been promoted from IVT to AVT 1 trial after first year testing during *Kharif* 2021 under AICRP programme whereas RCPR 70 has been promoted from AVT 1-aerobic to AVT 2-aerobic trial after second year of testing.

- In chickpea, one entry 'DBGC 3' was promoted to AVT-2 under AICRP on Chickpea for timely sown condition while in lentil, one entry 'DBGL 105' (DPL 15 × ILL 864) was promoted from IVT to AVT-1 under AICRP on MULLaRP for evaluation during 2021-22.

- Out of the fifty two yard-long bean genotypes screened for yellow mosaic disease, eight genotypes showed resistance reaction and eleven showed moderate resistance.

- Phytoplasma causing phyllody in chickpea and lentil was characterized and the 16S rRNA gene sequences from the symptomatic plants were deposited in GenBank. Blast analysis revealed that sequence was related with Candidatus Phytoplasma asteris related strain (16SrI-B).

- In Mustard crop, irrigation through drip and sprinkler system increased grain yield, biomass yield, test weight and number of seeds/pod by 18.67, 22.88, 10.65 and 25.0%, respectively over no irrigation system.

- Wheat genotypes DBW 187, HD 2967, HD 2093 and RAJ 3765 were found promising for late sown (24th December) under heat stress condition while under combined stress (heat + drought) wheat grain yield reduced by 44.21% as compared to that from normal sown condition (26th November).

- In one acre Integrated Farming System model, cowpea- cauliflower - onion cropping system along with poultry + mushroom + goatry fetched the highest net income of Rs. 1,09,528/annum (Rs. 300/day, B: C: 2.1) with an initial investment cost of Rs.1,59,970/- whereas in two acre IFS model crop + dairy + fishery/duck integration fetched a net return of Rs. 1,69,620/annum (Rs. 465/day, B: C: 1:9) with an initial investment of Rs.2,05,500.

- In Patna, field study on Natural farming in Rice-wheat-mungbean was initiated in *Kharif* 2022

to study the efficacy of natural farming. A rice productivity of 4.77, 5.21, 5.68 and 6.58 t/ha was achieved by practicing natural farming, organic farming, conventional and integrated nutrient management, respectively in the first year.

- Rice-cauliflower-spinach-greengram has been identified as more productive (39.38 t/ha) and remunerative cropping system (Benefit cost ratio: 2.63) as compared to existing Rice-wheat-greengram system (12.91 t/ha, 1.09) for middle Indo-Gangetic Plains. Application of 50% recommended dose of nitrogen + two foliar spray of nano urea @ 4 ml/liter was found more beneficial for *rabi* vegetables than cereals.

- Evaluation of Nano-DAP revealed that the highest wheat grain yield (4.8 t/ha) was achieved with 75% recommended dose of fertilizer + one foliar spray of nano DAP @ 4 ml/liter i.e., followed by 50% RDF + two foliar spray of nano DAP @ 4 ml/liter (4.7 t/ha). The study indicated that the nano DAP could save up to 25-50% of conventional DAP dose without affecting grain yield.

- In weed dynamics study, according to Jaccard's index, no weed species was found similar between Lemon-turmeric and Okra-cauliflower-onion system while highest similarity was observed between Rice-maize and Rice-lentil-moong cropping system.

- In Rice-wheat-greengram cropping system, application of pyrazosulfuron-ethyl as pre-emergence followed by cyhalofop-butyl + penoxulam at 25 days after sowing in rice, clodinafop-propargyl + metsulfuron-methyl at 30 DAS in wheat and pendimethalin as pre-em. fb imazethapyr (100g/ha) at 15 DAS in greengram led to efficient weed control.

- Under the climate change impact studies, it was found that uncertainties in rainfall and temperature projections were within reasonable limits. Further, it indicated an increasing trend in both minimum and maximum temperatures under the future (2030 and 2050) climate related to the baseline period at almost all stations in Patna, Samastipur and Sabour.

- LISS III and LANDSAT images of the year 2000, 2011 and 2018 have been collected, georeferenced, classified, accuracy assessed, map generated and change in the area of rice, wheat and maize in last 18 years has been identified, which shows an increase in the area of rice, wheat and maize from the year 2000 to 2018.

- Flood mapping study showed that in Assam about 23470 km^2 area is flood-prone which is 29.9% of the geographical area of Assam. Zoning of the flood hazard area as per its flood vulnerability revealed that about 1154 km^2 area of Assam comes under very high risk, 2432 km^2 under high risk, 4589 km^2 under moderate risk, 4975 km^2 under low risk and 10650 km^2 under very low risk zone.

- In the study of solar based irrigation command area, 1HP-0.9 kWp, 1HP-1.2 kWp, 2HP-1.8 kWp and 3HP-3.0 kWp solar groundwater pumping system was quantified for few promising vegetables and fruits crop under the prevailing solar radiation condition of 6.4 -3.6 kWh/m^2/day and groundwater depth regime of ≤10 m, bgl in Eastern region of India.

- Water balance components in paddy were assessed by employing drum culture technique. Percolation beyond root zone of the crop and water losses through evapotranspiration were 220.2 mm and 439.5 mm, respectively under conventional puddled condition which was about 25.78 and 51.45% of total water applied and rest amount of water (22.77 per cent) stored within root zone of the crop.

- The irrigation water price for lentil, tomato, pumpkin, mustard, tuberose, chilli, pointed gourd, Aman rice and Boro rice was assessed in Sahebbari village under Nadia district in West Bengal, which was 89.66, 88.43, 74.20, 64.0, 43.42, 27.26, 15.28, 13.33 and 12.26 Rs/m^3, respectively when irrigation was applied through ground water. The existing water productivity value of this area was also estimated as 7.921 Rs/m^3.

- In Nalanda, Bihar, detailed studies of several morphological parameters at the scale of watersheds have been conducted using remote sensing and amp; GIS, and overall analysis revealed that about 56.3% area comes under very high priority, 30.5% as high, 4.2% as medium whereas 2.22 to 6.78% area come under very low to low priority for execution of water harvesting planning.

- A prototype of manual cole crop harvester was designed and developed based on data of cauliflower stem diameter and its maximum canopy cover length. The average canopy cover was recorded as 54±4.23 cm and average stem diameter as 32.02±3.1 cm.

- The existing octagonal maize sheller has modified, increasing its output capacity by 30 per cent.

Fruits, Vegetables and Agroforestry:

- Plant Variety Registration certificate for commericialization of bottle gourd variety Swarna Sneha (REG/2019/134) and Bitter gourd variety Swarna Yamini (REG/2019/130) has been received from PPV&FRA, New Delhi.

- In wilt screening study of vegetables, among 18 genotypes of brinjal collected from NBPGR and local sources, nine genotypes showed resistance to bacterial wilt under artificial wilt sick conditions. The tomato genotypes RCDT-1116, RCDT -1128-1 were found resistant to wilt under hill and plateau region.

- The jackfruit genotype ICAR-RCER JS-4/2 was identified as the best suitable genotype for vegetable purpose.

- The multitier cropping systems, Mango + Mahogany + Peach + Rice and Mango + Mahogany + Peach + Ragi, recorded highest system productivity of 13.4 and 13.6 t/ha, respectively.

- Two years study on natural farming revealed that adoption of natural farming practices resulted in significantly higher seed yield (0.610 t/ha), straw yield (2.07 t/ha), biological yield (2.56 t/ha), harvest index (25.0%) and rice equivalent yield (1.76 t/ha) of chickpea while conventional farming performed better in case of mustard.

- By adopting organic and integrated nutrient management practices, the nitrogen-leaching loss in brinjal could be minimized by 16 and 8.6 kg/ha, along with saving of K-fertilizer to the magnitude of 10.3 and 5.6 kg/ha, respectively.

- Adoption of organic and integrated nutrient management practices in maize reduced the N-leaching loss by 7.0 and 3.5 kg/ha, while K-leaching loss by 5.53 and 3.1 kg/ha, respectively.

- Among the small seeded litchi seedlings, selection ICAR RCER LS 16/4 was identified with lowest seed weight (0.67 g), fruit weight (14.86 g), fruit length (34.4 mm), fruit diameter (29.4 mm), pulp (77.68 %) and TSS (17.50 °B).

- Differentially Expressed Genes (DEGs) associated with the cell wall and polysaccharide metabolism, phenolics and flavonoids biosynthesis, plant hormone biosynthesis and signalling, nutrient transport, and MAPK signalling were significantly down regulated in fruit cracking in bael.

- Jackfruit pulp mixture at 30°Brix, drying temperature as 70 °C and pulp thickness of 4 mm produced better quality of jackfruit bar in terms of colour, texture and sensory attributes.

- Analysis of litchi insect pollinators showed that optimum ecological ranges for Apis species required 30 to 32 °C temperature, 48 to 52% relative humidity and 2 to 8 m/s wind velocity while non-Apis species pollinators required 28 to 30 °C temperature,

- The spray of insecticides profenophos 50 EC (1.5 ml/L) + thiacloprid 21.7 SC (0.5 ml/l) and imidacloprid 17.8 SL (0.3 ml/l) were found effective against Tessratoma javanica.

- Based on plant growth performance, market value and availability of planting material, four medicinal plants *viz.*, Giloe, Shatavari, Hadjor, and Sarpagandha were identified for plantation under Teak+Karanj and Mahogony+Karanj agroforestry systems under rainfed condition.

- In Maize-frenchbean cropping system, application of Vermicompost at the rate of 7 t/ha and Phosphorous Solubilizing Bacteria at the rate of 7 kg/ha were found more efficient for P solubilization in soil.

- Enrichment of guava basin with biomass mulching at the rate of 3 kg dry biomass/m^2 resulted in the maximum plant height and trunk diameter and increased total organic carbon in the crop root zone.

- A solar irrigation pumps sizing tool has been developed for selection of right size of pump based on cropping patterns and water sources. The tool has been adopted in the PM-KUSUM scheme of the Government of India.

- A socio-economic status scale has been developed for classifying the farmers of Bihar and Jharkhand. Correlation and reliability coefficients of the developed scale were 0.96 and 0.97, respectively indicating that the scale is highly reliable.

Livestock and Fisheries:

- The phenotypic and morphological characteristics of Tirhut goats and Champaran pigs were identified from Zone I of Bihar. Champaran pig was showing high fecundity *viz*.12 to 18 piglets per parturition. Maithali goats vary in white, brown and black coats and are taller but slimmer in size with drooping ears.

- The performance of Murrah buffaloes under Network project has been consistently better, with total herd strength of 105 units. The average lactation milk yield was 2486.33±48.45 kg, ranging from 1678 to 2786 kg.

- The study on effect of photoperiod, the percentage of fecundity and fertility was significantly higher in the

females submitted to the male effect using photo-stimulated bucks irrespective of age groups. The effect was observed associated with higher serum level of progesterone in the exposed female goats.

- Supplement of feed diet with 15% of spent mahua flowers to piglets in Jharkhand resulted in higher drymatter consumption (179.22±0.89g), body weight (45.95±1.25) and body measurements

- Characterization of indigenous chickens in five districts of Jharkhand recorded dominance (82%) of native chickens compared to Naked Neck (5%) and Aseel (13%).

- The mean level of arsenic in the water samples from Bhojpur and Saran districts was higher than the maximum permissible limit of 10 μgm/liter. The impact of bioaccumulation of arsenic was also reflected in the hair and blood of the animals.

- *Theleria orientalis* circulating in the cattle population was subtyped as chitosi using MPSP gene amplification. Six numbers of GenBank accession (NCBI) were obtained.

- Genetic polymorphism in targeted regions of PLAG1, STAT3, β-LG and NGF genes in Black Bengal goats was studied. Five nucleotide changes were observed in this breed. PCR-RFLP analysis showed SNPs at a few loci of these genes.

- A total of 98 *E. coli* isolates were confirmed by uspA gene PCR and were further characterized for presence of shiga toxin gene by Vtcom, VT1, VT2 and eae genes. High percentage of samples were found positive for Shiga toxin which is having zoonotic potential.

- Antimicrobial drug resistance in *E. coli* and *Staphylococcus aureus* isolated from animal origin was assessed. The resistance of Penicillin and fluoroquinolones (>60%) in *E coli*. was the highest. *S. aureus* isolates were found to be resistant to ampicillin, enrofloxacin, polymixin-B and penicillin-G.

- Under Integrated fish -cum- prawn polyculture system, prawn attained an average weight of 49.66 g, while Catla, Rohu, and prawn combinedly produced 1580, 1160, and 638 kg ha after culture.

- The fingerlings of *L. gonius* attained 8.95 g after three months, juveniles 31.51 g after four months, and adults 270.49 g after a year. The successful breeding trial was also carried out at the institution's portable hatchery unit, and species exhibited 71.5% fertilisation and 74.5% hatching.

- In a Biofloc system, the growth performance of minor carp, *C. reba*, at moderate to high stocking densities are more productive and economically lucrative than low stocking densities.

- Kasaraiya Dhar Maun recorded a total of 42 aquatic species from 15 finfish, prawn, and mollusc families. Water quality parameters were also analysed and found to be within the normal range

- A total of 11 indigenous fish species from the Ganga in Bihar, were studied for morphometric characteristics, length-weight relationships (LWRs), and condition factors (K).

- In a feeding trial on Cyprinus carpio, 30% Azolla powder supplement fish fed produced the highest weight, and the Feed Conversion Ration(FCR) was lowest with 10% azolla powder.

Outreach and Miscellaneous activities

- During *Kharif* 2022, Breeder seed (14.72 t), nucleus seed (0.25 t) and truthfully labelled seed (13.21 t) of rice varieties Swarna Shreya, Swarna Shakti Dhan, Swarna Samriddhi Dhan, Swarna Unnat Dhan, Swarna Sukha Dhan & Swarna Purvi Dhan 3 have been produced.

- During the reported period a total of 44.5 t of quality seeds (breeder, foundation, certified & truthfully labelled) of recently released varieties of mungbean (Virat, Shikha, IPM 2-3 & IPM 2-14), pigeonpea (IPA 203 & IPA 206), chickpea (Pusa 3043, GNG 2299 & RVG 202) and lentil (IPL 220, PL 8 & IPL 316) were produced.

- During the period, 5 numbers of Farmer Producer Organization (FPO) have been formed to facilitate the agriculture produce 4 numbers of MoUs have been signed and 5 entrepreneurs have been registered as Incubatees.

- During the period under report, the Institute published 118 nos. of research papers in journals of national and international repute, 32 book chapters, 09 books, 02 training manual, 62 popular articles, 10 extension/technical bulletins, 13 extension folder and 10 e-publication.

- Further, total of 174 training programmes, 27 Front Line Demonstration and 14 On-Farm Trials have been conducted for different stakeholders. A total of 4356 farmers were trained in different emerging topics of NRM.

2 Introduction

The Eastern region of India encompasses the plains of Assam, Bihar, Chhattisgarh, Eastern Uttar Pradesh, Jharkhand, Odisha and West Bengal. It represents 21.85% of the country's geographical area and is home to 33.62% of the human and 31% animal population. Despite having abundant natural resource such as fertile soils, water resources and ample solar radiation, the farmers in the Eastern region face low productivity and per capita income due to various challenges like unpredictable climate variations, population growth, land degradation, small and fragmented land holdings, inadequate access to quality seed and planting materials, large areas under rice-fallows, deficient extension mechanism and poor marketing infrastructure. However, the region has potential for Second Green Revolution, which could be realized through integrated management of land, water, crops, nutrient, biomass, horticultural, livestock, fishery and human resources. Although the Eastern region is endowed with natural resources, it has not yet fully realized its potential in terms of improving agricultural productivity, poverty alleviation and enhancing livelihoods.

On February 22nd, 2001, the ICAR Research Complex for Eastern Region (ICAR-RCER) was established in Patna to address a wide range of issues related to the management of land and water resources, crop and horticulture management, agroforestry, aquatic crops, fishery, livestock and poultry, agro-processing, and socio-economic aspects. The aim of the institute is to improve research capabilities and provide support for enhancing agricultural productivity and sustainability in a comprehensive manner. The institute is located geographically at a latitude of 25^{0}35'30"N, a longitude of 85^{0}05'03"E, and an altitude of 52 meters above mean sea level.

The mandates of the institute are:

- Strategic and adaptive research for efficient integrated management of natural resources to enhance the productivity of agricultural production systems in the eastern region.

- Transform low productivity-high potential eastern region into high productivity region for food, nutritional and livelihood security.

- Utilization of seasonally waterlogged and perennial water bodies for multiple uses of water.

- Promote network and consortia research in the eastern region.

The modalities to achieve the mandate are:

- To facilitate and promote coordination and dissemination of appropriate agricultural technologies through network/consortia approach involving ICAR Institutes, State Agricultural Universities, and other agencies for generating location-specific agricultural production technologies through sustainable use of natural resources.

- To provide scientific leadership and act as a center for vocational and advanced training to promote agricultural production technologies.

- To act as a repository of available information and its dissemination on all aspects of agricultural production systems.

- To collaborate with relevant national and international agencies in liaison with state and central government departments for technology dissemination.

- To provide need-based consultancy and advisory support for promoting agriculture, horticulture and livestock in the region.

- Socio-economic evaluation and impact assessment of agricultural technologies.

The complex has four divisions besides two research centres and two KVKs. The organizational setup of the complex is given in Fig. 2.1.

Finance

A summary of budget allocation and expenditure during the financial year 2022-23 of the complex is presented below (Table 2.1).

Table 2.1 Financial allocation and expenditure during the year 2022-23 (Rs. in Lakhs)

Head of accounts	BE allocation		Actual expenditure	
	Inst Grant	SCSP	Inst Grant	SCSP
Establishment charges	2856.51	0.00	2856.15	0.00
TA	22.94	1.02	22.90	1.02
HRD	0.90	0.00	0.87	0.00
Capital	50.00	22.34	50.00	22.31
Other charges	383.25	82.36	683.08	82.36
Total	3613.30	105.72	3613.00	105.69

Table 2.2 Staff position as on 31st December, 2022

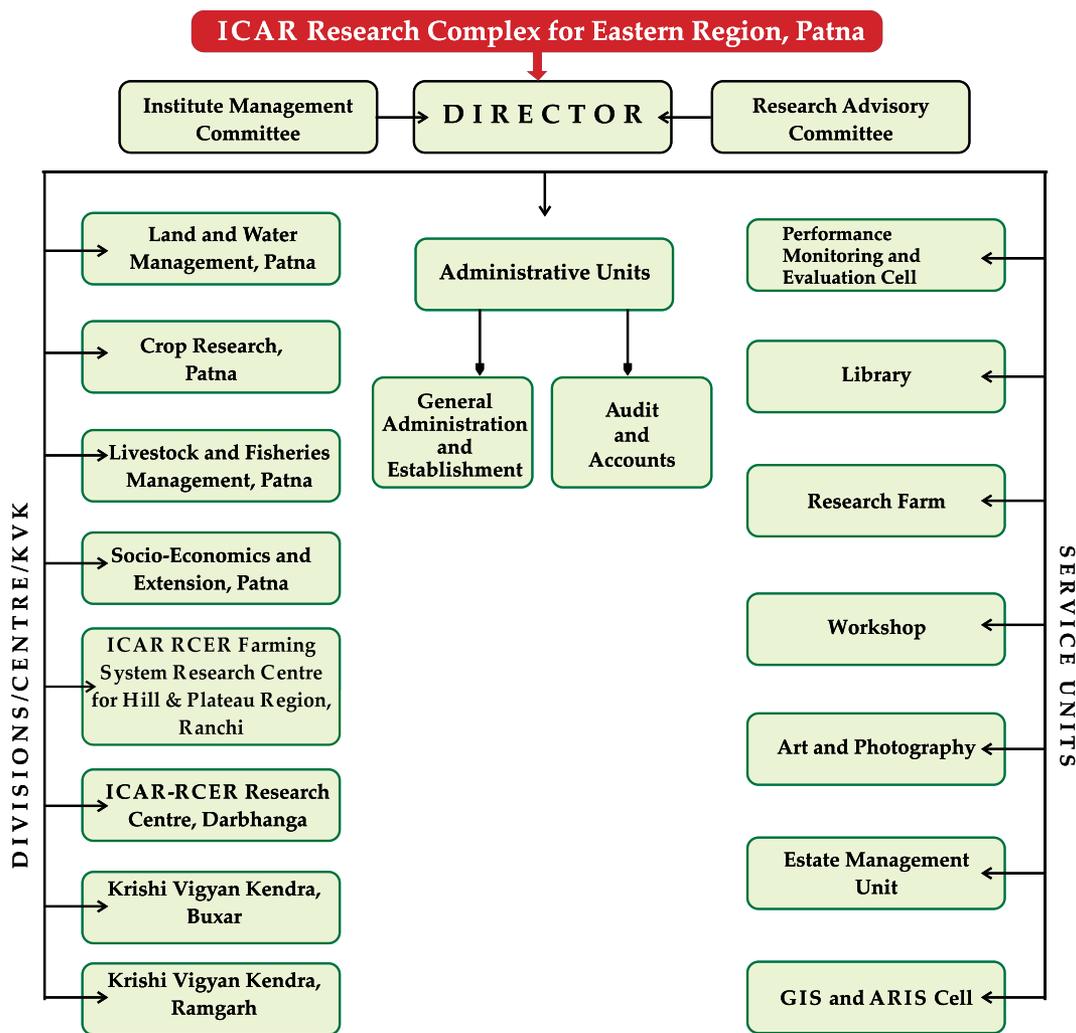| Category	Position	
	Sanctioned	Filled
Scientific*	91	70
Technical	61	39
Administrative	47	23
Skilled Supporting Staff	63	28

*including Director

Fig. 2.1 Organogram of ICAR Research Complex for Eastern Region, Patna

3 Weather

The Climate at ICAR RCER Patna

The agrometeorological observatory was established at ICAR RCER Patna in June 2012. Both manual, as well as automatic data recording system, is available in the observatory. Weather parameters *viz.* air temperature, humidity, rainfall, sunshine hours, and pan evaporation were recorded regularly twice a day at the Observatory. The Long Period Average (LPA) annual total rainfall of Patna is 1127.3 mm. The year 2022 was a deficient rainfall (21.6% deficit) based on the total amount of rainfall received. The total annual precipitation accumulated in 2022 was 883.7 mm which was distributed over 50 meteorological rainy days.

The monsoon rainfall (714.8 mm) was well below the normal (951.9 mm). It was highest in August (235.7 mm) and lowest in September (135.6 mm). The mean monthly maximum temperature varied from 38.2°C in April to 19.8 °C in January. April remained the warmest month for the year 2022. Similarly, the mean monthly minimum temperature varied from 27.5°C in June to 10.8°C in January. Mean monthly relative humidity was lowest in April (59 %) and highest in September (77.7 %).

The highest average daily sunshine hours were recorded in March (7.1 hrs/day) whereas the minimum was in January (1.2 hrs/day). Total open pan evaporation was 1405.8 mm, which was recorded minimum in January (41.3 mm) and maximum in July (163.3 mm). The mean wind speed reached its maximum during May (10 km/hr). A summary of the monthly meteorological data for the year 2022 is presented in Table 3.1. The monthly variation of temperature and rainfall is presented in Fig. 3.1.
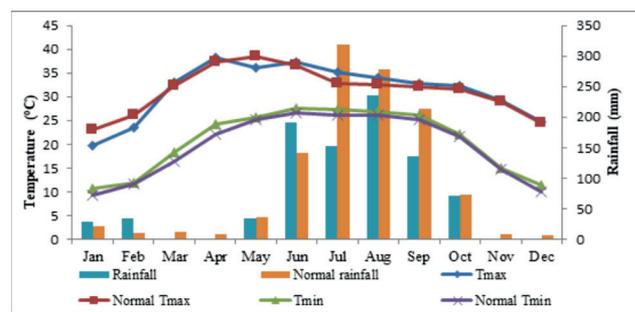
Fig. 3.1 Monthly variation of temperature and rainfall during 2022

Table 3.1 Mean monthly weather parameters for the year 2022

Month	Temperature (ºC)				Avg. RH (%)	Avg. Sunshine (hrs/day)	Total rainfall (mm)		Rainy days	Pan. Evaporation (mm)	Mean Wind Speed (km/h)
	Max	Normal	Min	Normal			Observed	Normal			
January	19.78	23	10.79	9.3	77.5	1.2	28.6	20.4	2	41.3	3.27
February	23.60	26.1	11.81	11.6	67.0	5.8	34.8	11.1	1	73.3	4.72
March	33.01	32.4	18.22	16.4	60.8	7.1	0.0	11.4	0	93.5	3.91
April	38.21	37.4	24.16	22.1	59.0	4.9	0.0	9.0	0	115.1	7.53
May	36.12	38.4	25.62	25.1	63.9	4.8	34.6	35.6	3	145.8	10.00
June	37.30	36.7	27.51	26.7	64.0	2.8	191.6	141.1	5	149.3	8.90
July	35.12	32.9	27.36	26.1	70.8	6.0	151.9	319.2	12	163.3	8.95
August	33.99	32.5	26.85	26.1	76.3	4.5	235.7	279	8	155.9	7.98
September	32.87	32.2	26.14	25.3	77.7	3.0	135.6	212.6	15	141.9	5.15
October	32.29	31.7	22.21	21.6	71.5	6.5	70.9	72.3	4	146.4	2.88
November	29.15	28.9	15.01	14.8	62.3	4.2	0.0	8.2	0	123.4	1.71
*December	24.6	24.6	11.4	10.1	76.3	3.20	0.0	7.4	0	56.6	-
Annual	31.3	31.4	20.6	19.6	68.9	4.5	883.7	1127.3	50	1405.8	5.9

*Data collected from IMD, Patna Centre

The warmest and coldest days in the entire year were obtained based on daily mean temperature data, and it was found that 17th of April was the hottest day of the year (42°C) while the 20th of January was the coldest day (6.6°C). The maximum amount of rainfall in a day (Most rainy day) was recorded on 29th June (121.1 mm), the highest wind speed was on 15th August (18.72 km/h) and the highest relative humidity was on 5th January (86%) while the least humidity was reported on 18th April (36%). Maximum bright sunshine hours of 10 hrs 16 min were recorded on 16th August 2022.

Climate at FSRCHPR Ranchi

At Farming System Research Center for Hill & Plateau Region (FSRCHPR), Ranchi, the mean monthly maximum temperature ranged from 22.6°C in January to 39.1°C in April while the mean monthly minimum temperature varied from 9.0°C in December to 25.4 °C in June, depicting December as the coldest month of the year 2022 (Fig. 3.2). The lowest temperature of 4 °C was recorded on 29th December while the highest temperature of 40°C was recorded on 14th May. The maximum diurnal variation of 17.3°C was recorded for the month of April while it was lowest (5.6°C) during August.
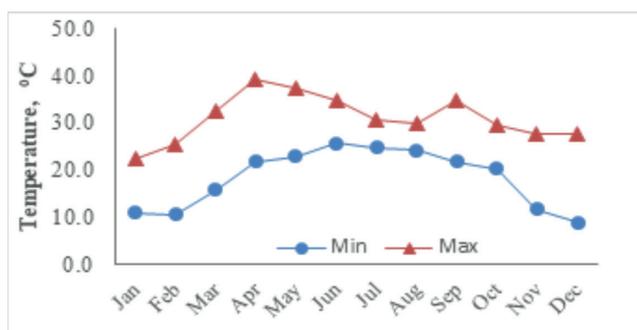

Fig. 3.2 Variations in average monthly minimum and maximum air temperature

The annual rainfall for the reporting year was 1074 mm which was about 23% deficit over the normal rainfall (1398 mm) at the Ranchi center (Fig. 3.3). Rainfall received during the four monsoon months (929 mm) was 19.4% lower than the normal monsoon rainfall. The month of August received the highest rainfall of 378.4 mm, which was 18.6% higher over the normal monthly rainfall of August. The monthly rainfall receipts during June, July, and September were 24.5, 51.6, and 19.3%

lower than the normal rainfall of the respective month.

The year 2022 had 78 rainy days, out of which 60 rainy days occurred during the monsoon season. The months of July and August had 18 and 20 rainy days, respectively (Fig. 3.3). Mean monthly weather parameters at FSRCHPR, Ranchi for the year 2022 are presented in Table 3.2.
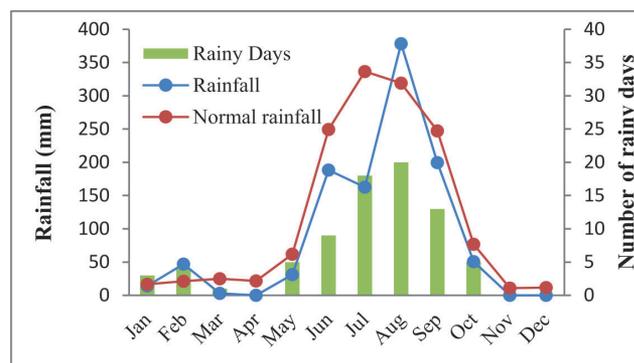
Fig. 3.3 Comparison of monthly normal rainfall with monthly rainfall of 2022

Table 3.2. Mean monthly weather parameters at FSRCHPR, Ranchi for 2022

Month	Average Temperature (°C),		Rainfall- 2022 (mm)	Normal rainfall (mm)	Rainy Days
	Min	Max			
Jan	10.9	22.6	14.2	16.7	3
Feb	10.7	25.3	46.8	21.2	4
Mar	15.8	32.3	2.8	25	1
Apr	21.8	39.1	0.0	21.8	0
May	22.9	37.4	31.0	62	5
Jun	25.7	34.9	188.3	249	9
Jul	24.7	30.5	162.8	337	18
Aug	24.3	29.9	378.4	319	20
Sep	21.8	34.7	199.5	247	13
Oct	20.4	29.3	50.8	77	5
Nov	11.7	27.5	0.0	10.8	0
Dec	9.0	27.7	0.0	11.6	0
Annual	**18.3**	**30.9**	**1074.6**	**1397.8**	**78**

4 Climate Change

Climate Resilient Agriculture Programme (CRAP)

The Climate Resilient Agriculture Programme was launched to introduce strategies to combat major climatic threats in farmers' fields in Bihar. The programme is funded by the Government of Bihar. ICAR-RCER Patna is one of the four implementing agencies along with Bihar Agricultural University (BAU), Sabour; Dr. Rajendra Prasad Central Agricultural University (RPCAU), Pusa and Borlaug Institute of South Asia (BISA), Pusa. Ten villages have been selected, 5 each in Gaya and Buxar district of Bihar for demonstration of climate resilient technology. Crop specific climate smart agricultural technologies are being demonstrated on farmers' field for development of climate resilient and futuristic cropping systems (crop-cycle) modules. Long-term trials are being laid at KVK, Buxar & Gaya farm for better understanding of climate change, adaptation and mitigation measures.

Fig. 4.1 Districts under CRAP project

In 2022, farmers were given demonstration on climate smart agricultural techniques across a total of 2,902 acres of land throughout different crop seasons. The target areas for the summer, *Kharif*, and *rabi* seasons were all met or exceeded, with coverage of 100%, 97.14%, and 100%, respectively (Table 4.1). A total of 2,161 beneficiaries, including 1,105 farmers from Gaya and 1,056 farmers from Buxar district, benefited from the programme.

Fig. 4.2 Direct seeded rice (Arize 6444 Gold) at farmers' field (Manpur, Gaya).

Table 4.1   Area coverage and beneficiaries under CRA Programme during the year 2022-23.

Seasons	Area covered (acres)			No of beneficiaries		
	Gaya	Buxar	Total	Gaya	Buxar	Total
Summer - 2022	250	250	500	242	261	503
Kharif - 2022	581	575	1156	294	307	601
rabi - 2022-23	623	626	1249	569	488	1057
Total	**1454**	**1448**	**2902**	**1105**	**1056**	**2161**

Demonstration of Climate Resilient Technologies during *rabi* 2021-22

During *rabi* season, zero tillage (ZT) technology was demonstrated in wheat, chickpea, lentil and mustard crop at Gaya & Buxar and encouraging results were found in terms of increase in grain yield over local check. The grain yield of wheat, chickpea, lentil and mustard under demonstration were 12.41, 3.77, 5.88 and 3.84% higher over local practices at farmer's field in Buxar district. In case of Gaya, increase in grain yields were 8.25, 4.3, 3.9 and 2.58% higher in wheat, chickpea, lentil and mustard crop, respectively. The performance of the farmers in Buxar was better than in Gaya districts.

Table 4.2 Yield and economics of *rabi* crops at Buxar, Bihar (2021-22)

Crop	Technology	Grain Yield (t/ha)		Straw Yield (t/ha)		Net Return (INR/ha)		B:C ratio	
		Demo	Local check	Demo	Local check	Demo	Local check	Demo	Local check
Wheat	Zero tillage	5.07	4.51	7.42	7.02	80612	64588	3.1	2.12
Chickpea	Zero tillage	1.65	1.59	2.83	2.70	63801	54442	2.65	1.80
Lentil	Zero tillage	1.44	1.36	2.50	2.37	60670	47965	2.96	1.67
Mustard	Zero tillage	1.11	1.07	3.36	3.24	43727	37183	3.36	2.12

The crop production profitability under zero tillage was analyzed. The highest net return was reported in zero tillage wheat, i.e., Rs 80612/ha in Buxar and Rs 73548/ha in Gaya, which were 24.8 and 19.14% higher over traditional broadcasting method. This was due to the reduction in cost of cultivation and use of high yielding varieties under CRA programme. In the case of chickpea, lentil and mustard, the net return was 17.2%, 26.5% and 17.6% higher in Buxar district. In Gaya, the net return in chickpea, lentil and mustard were observed as 17.6, 25.5 and 14.4 % higher than local check. Similarly, a higher Benefit-Cost ratio was observed in demonstration plots over the local check for all the crops in both the districts.

Table 4.3 Yield and economics of *rabi* crops at Gaya (2021-22)

Crop	Technology	Grain Yield (t/ha)		Straw Yield (t/ha)		Net Return (INR/ha)		B:C ratio	
		Demo	Local check	Demo	Local check	Demo	Local check	Demo	Local check
Wheat	Zero tillage	4.72	4.36	7.40	7.39	74548	61728	2.83	2.02
Chickpea	Zero tillage	1.70	1.63	2.96	2.72	66488	56545	2.67	1.87
Lentil	Zero tillage	1.33	1.28	2.56	2.33	54595	43505	2.66	1.52
Mustard	Zero tillage	1.19	1.16	3.17	3.14	47729	41708	3.67	2.38

Evaluation of Zero Tillage in Green Gram

As part of the CRA program, farmers in 10 villages received high-quality Mungbean seeds (variety Samrat) covering a total area of 500 acres in the Buxar and Gaya districts. Instead of the traditional method of broadcasting, farmers used a seed drill to sow the seeds. This sowing with improved method had increased the grain yield by 17.40 and 12.78% in Buxar and Gaya districts respectively (Table 4.2 & 4.3). Net return was also increased by 24.12% and 22.50% in Buxar and Gaya, respectively over traditional practice. Farmers were ready to take up more area under mungbean in upcoming summer season. Laser land levelers were used to level the farmers' fields, and a total of 300 acres of land (200 acres in Buxar and 100 acres in Gaya) were leveled under this project to effectively implement the CRA program (Table 4.4).

Table 4.4 Yield and economics of CRA interventions at farmers' field (Summer, 2022)

Crop	District	Grain yield (q/ha)		Straw yield (q/ha)		Net Return (INR)		B : C Ratio	
		Demo	Local check	Demo	Local check	Demo	Local check	Demo	Local check
Mung (Samrat)	Buxar	8.10	6.90	10.21	9.52	39287	31652	3.05	2.75
	Gaya	8.91	7.90	21.80	21.7	46244	37748	3.63	3.00

Demonstration of Climate Smart interventions during *Kharif*-2022

During *Kharif* 2022, technology related to direct seeded rice, raised bed planting of maize and bajra were demonstrated in both the districts. Ragi crop was demonstrated in Gaya district only. Varieties of rice demonstrated in Gaya were Arize 6444 Gold, Swarna Shreya, Swarna Samriddhi and Rajendra Sweta. For maize, DKC 7074 hybrid was used for raised bed planting while ragi variety RAU 8 was used.
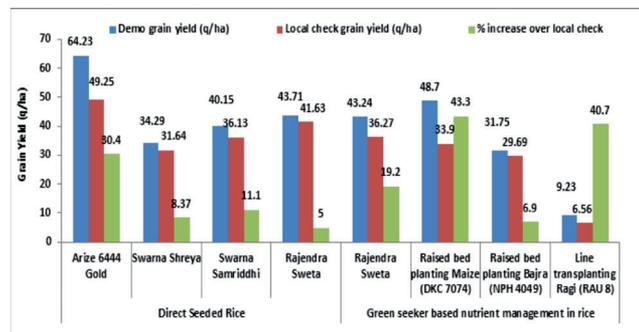

Fig. 4.3 Comparative yield advantage of different CRA interventions at farmers field, Gaya (*Kharif* 2022)

From the recorded data, it was clear that grain yield of all *Kharif* crops were found higher in demonstration plots over traditional practices in both districts (Fig 4.3 & 4.4). Among the rice varieties, Arize-6444 Gold recorded the highest grain yield (i.e. 64.23 and 66.14 q/ha at Gaya and Buxar) under direct seeded method. Compared to the local check, the yield was higher by 30.41% in Gaya and 15.06% in Buxar. As *Kharif* season 2022 was negatively affected by rainfall scarcity and monsoon was delayed by a month, farmers in Buxar demonstrated the use of a short duration rice variety (110 days) CO-51. Despite the delay in monsoon, CO-51 yield 54.23 q/ha, which was even higher than the yield of a medium duration rice variety Rajendra Sweta (47.09 q/ha).
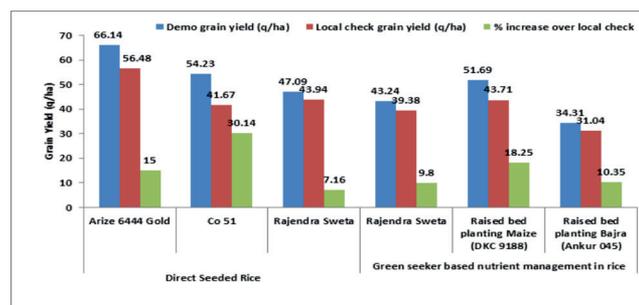

Fig. 4.4 Comparative yield advantage of different CRA interventions at farmers field, Buxar (*Kharif* 2022)

The raised bed method of planting in maize (DKC-7074, 9188) had shown significant yield boost, which was 43.3 and 18.3% higher than traditional method. Some of the farmers also had grown vegetables and pigeonpea between the maize rows for their own consumption. Raised bed bajra grown in both districts under this programme got huge popularity by providing good yield with low irrigation. The grain productivity of bajra was 31.75 q/ha (Var. NPH 4915) in Gaya and 34.31q/ha (Var. Ankur 045) in Buxar district. Ragi (Var. RAU-8) seeds were distributed to farmers of Gaya district for drought affected areas, which yielded 9.23 q/ha.

An economic analysis was carried out for these field trials. The cost of cultivation under direct seeded rice was lower than local transplanting method, which increased the net profit in direct seeded rice. Moreover, direct seeding saved time and labour by avoiding the need for plowing and puddling the field. This helped in timely sowing, which had a positive impact on yield. The net income differs greatly within rice varieties in both the locations. Arize-6444-Gold rice variety performed better than the local check in terms of net return. In Gaya district, the net return was 42% higher, while in Buxar district, it was 39.5% higher. The other demonstrated rice varieties also showed higher net return compared to local practices.

Among all the interventions in *Kharif,* raised bed maize was evaluated as better option from the economic profitability point of view as this technology fetched 58% and 39% higher net income as compared to traditional maize cultivation practices in Gaya and Buxar respectively.

Progress of Climate Resilient Interventions during *rabi*-2022-23

In *rabi* season, this program covered a total of 1249 acres with various interventions like zero tillage wheat, lentil, chickpea and mustard, maize potato intercropping system and raised bed potato planting (Fig. 4.5 & 4.6). Among the *rabi* interventions, zero tillage wheat covered the largest share.

Table 4.5 *Rabi* 2022-23 area coverage under CRA Programme.

Buxar			Gaya		
Crop and varieties	**Interventions**	**Area coverage (acre)**	**Crop and varieties**	**Interventions**	**Area coverage (acre)**
Wheat (HD-2967, DBW-187)	Zero Tillage	390	Wheat (HD 2967, DBW-187, Swarna Shreshtha, HD 2733)	Zero Tillage	415
	Raised Bed	10		Raised Bed	25
	Total	400		Green seeker based nutrient management	75
Lentil (IPL-220)	Zero Tillage	100	Lentil (IPL-220)	Zero Tillage	25
Chickpea (GNG-2299, Pusa-3043)	Zero Tillage	70	Chickpea		
(Pusa -3043)	Zero Tillage	40			
Mustard (PM 30)	Zero Tillage	50	Mustard (NRCYS)	Zero Tillage	30
Maize +Potato (DXC 4244+ Kufri Mohan)	Intercropping	3	Maize + Potato		
(DKC-9165 +Kufri Khyati))	Intercropping	10			
Potato (Kufri Mohan)	Raised bed planting	3	Potato (Kufri Khyati)	Raised bed planting	3
Total		**626**	**Total**		**623**

Fig. 4.5 Zero Tillage Mustard at Harkishanpur, Buxar

Fig. 4.6 Zero Tillage Chickpea at Manpur, Gaya

Capacity Building and other activities

A total of 96 capacity building programmes were conducted, which included 13 field days, 37 farmers training, 33 exposure visits and 13 other programs. Total beneficiaries of these HRD programmes were 3471 including 19% farm women. Exposure visits of farmers were conducted to learn new farming practices from farms located in other districts and States under the. Biochar production units were established in KVK Buxar and Gaya, where 56 q of biochar was produced from harvested rice straw (Fig. 4.7).

Fig. 4.7 Exposure visit and Biochar Unit under CRA Programme at Buxar

Climate Change Impact studies through Crop Simulation Models in Bihar

In developing nations with an agricultural economy, climate change and the accompanying uncertainties have substantial direct and indirect consequences on agricultural output and food security. Analysis of long-term climate data can pinpoint climate risks and predict new ones to help with suitable adaptation and mitigation strategies. The study uses weather data from three stations across the state of Bihar, India. Historical (1980–2009) daily rainfall, maximum temperature, and minimum temperature data for the three stations were obtained from the Indian Meteorology Department (IMD).
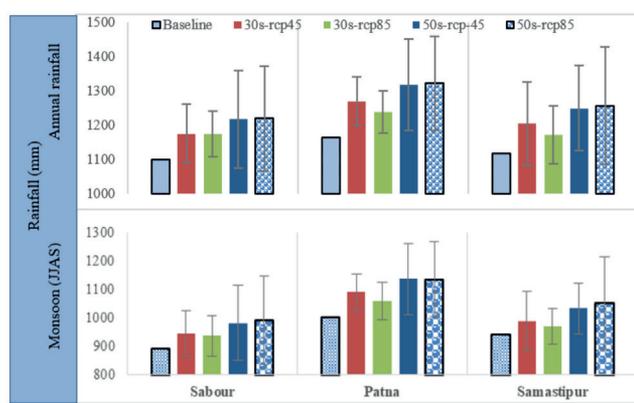

Fig. 4.8 Baseline and projected rainfall (2030 and 2050 with two RCPs) at three locations in Bihar (Vertical bars indicate standard deviation of selected general circulation models)

The primary goal is to identify climate hazards and/or opportunities in the state of Bihar for the short-term (2030) and medium-term (2050) periods, using baseline weather data. The General Circulation Models (GCMs) employed by the Intergovernmental Panel on Climate Change (IPCC) were used to downscale future weather data for 2030 and 2050. Global climate models (GCMs), which are climate models that project into the future, are the most advanced tools now available for simulating the response of the global climate system to rising greenhouse gas concentrations. The GCMs were selected based on the availability of data for the two (4.5 and 8.5) representative concentration pathways (RCPs) used in this study.
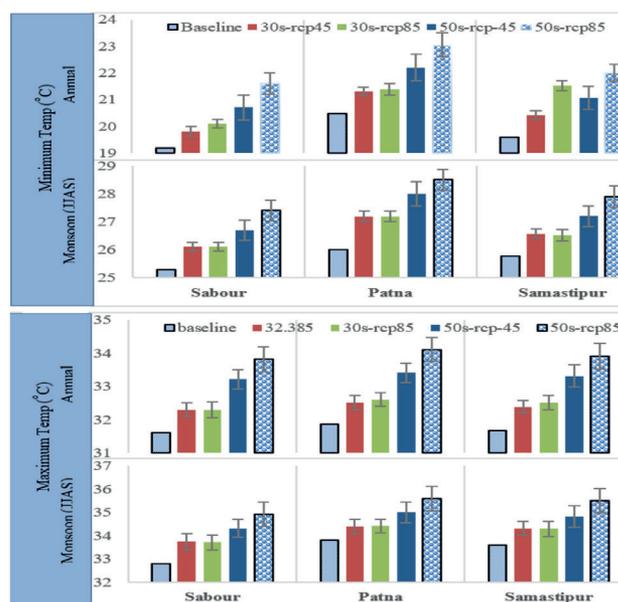
Fig. 4.9 Baseline and projected (2030 and 2050) mean temperature (minimum and maximum) at three locations in Bihar

During the baseline periods, the mean annual rainfall ranges from 1092 (Sabour) to 1165 mm (Patna) among the stations and has a mean value of 1130 mm. The emission scenarios evaluated for 2030 and 2050 do not significantly differ from one another, even though most stations tend to see more rainfall under RCP 4.5 than under RCP 8.5 in 2030 (Fig. 4.8). Past and future monthly Tmin remain in the range of 10-19 °C from December to March, and around 25–30 °C in the monsoon season. In the baseline period, the average annual Tmax ranges from 31.4 (Sabour) to 31.9 °C (Patna) among stations and has a mean value of 31.7 °C (Fig. 4.9). Under the future climate, the mean annual Tmax is expected to increase across Bihar by 0.68–0.79 °C in 2030 and 1.59–2.21°C in 2050 depending on the emission scenario (Fig. 4.9). Increased temperatures over the chosen sites will have detrimental effects on crops by altering crop phenology, physiology, and plant-water relations, although increasing rainfall levels normally offer opportunities. The research aids in the creation of site-specific adaptation and mitigation strategies that reduce the adverse consequences of climate change while increasing potential.

5 Cereals

RICE

Evaluation and Identification of Rice Genotypes for Tolerance to Drought in Reproductive stage

Sixty rice genotypes comprised of advanced breeding lines and check varieties were evaluated under reproductive stage drought stress and non-stress (irrigated) conditions during *Kharif* 2022. Fifty-five days old seedlings were subject to drought by withholding irrigation and withdrawing water from the stressed field and thereafter crop was left rainfed upto maturity. Grain yield varied from 3.30 to 7.16 t/ha and 2.99 to 5.77 t/ha under non-stress and drought stress conditions, respectively. Irrespective of genotypes, drought stress at the reproductive stage caused significant reduction in plant height (9.7%), tillers (9.3%), panicle length (8.6 %), grain yield (20.2%), and biological yield (13.6%); however, the responses varied among genotypes. Rice genotypes, IR18R1188 (5.77 t/ha), IR 95781-15-1-1-4 (5.64 t/ha), IR93330:15-B-16-11-18-1RGA-2RGA-1-B-B (5.35 t/ha), IR 107891-B-B-111-2-1 (5.32 t/ha), IR 108198-23-1-1-B (5.25 t/ha), IR 107891-B-B-1284-2-1 (5.17 t/ha), IR 97044-6-2-1-2 (5.12 t/ha), IR18R1179 (5.06 t/ha), IR14L586 (5.04 t/ha), IR 107891-B-B-1019-1-1 (4.98 t/ha), IR18R1123 (4.93 t/ha), IR15F1886 (4.75 t/ha) and IR15A2407 (4.69 t/ha) showed better drought tolerance at reproductive stage compared to check varieties Sahbhagi Dhan (4.08 t/ha) and IR64 (2.99 t/ha).

Evaluation of Rice Genotypes for Tolerance to Multiple Stresses

Twenty-four rice genotypes were evaluated under control (non-stress), drought, submergence and combined stress (submergence + drought) conditions during *Kharif* 2022. The crop was kept submerged under 1.0 to 1.25 m water depth for 16 days and thereafter water was drained out from the plot. Under drought stress experiments, crops faced stress at the reproductive stage. Under combined stress crops faced 16 days of submergence at the vegetative stage and later drought at the reproductive stage. Average grain yield of 7.50, 3.11, 2.36, and 1.40 t/ha were recorded under non-stress, drought, submergence, and combine stress conditions, respectively. The study revealed that irrespective of genotypes, there was a significant reduction in grain yield of rice under drought (58.5%), submergence (68.49%), and combined stress (81.33%) conditions as compared to control. Among rice genotypes, IR 102777-18-64-1-2-6 (2.10 t/ha), IR 96321-315-323-B-3-1-3 (1.89 t/ha), IR 96321-315-294-B-1-1-1 (1.86 t/ha), IR 102796-14-77-2-1-2 (1.80 t/ha), IR 96321-558-563-B-2-1-1 (1.75 t/ha), IR 94391-131-152-3-B-3-1-1 (1.73 t/ha), IR 96321-558-209-B-6-1-1 (1.70 t/ha), IR 96322-34-223-B-1-1-1 (1.66 t/ha) and IR 96321-558-257-B-5-1-2 (1.66 t/ha) have been found promising for multiple stress (submergence + drought) tolerance as compared to check variety Swarna Sub 1 (1.02 t/ha).

Resource Remobilization during Grain Filling under Drought

Thirty-six rice genotypes comprised of twenty-five advanced breeding lines & eleven high-yielding varieties commonly grown in south and eastern India were evaluated under reproductive stage drought (15 days) and non-stress conditions during *Kharif* season, 2022 with an aim to identify drought tolerant genotypes having high mobilization efficiency and harvest index. The finding showed that irrespective of genotypes, drought stress (reproductive stage) caused a significant reduction in grain yield (17.7%), biological yield (18.9%), plant height (12.7%), total grains per panicle (5.3%), spikelet fertility (6.2%) and test weight (9.8%) however, the responses varied among genotype. Under drought conditions, the highest grain yield was recorded in DRR 47 (5.94 t/ha, 48.1%), followed by DRR Dhan 44 (5.81 t/ha, 52.1%), DRR Dhan 52 (5.74 t/ha, 45.6 %), IR 134116-5-B RGA-B RGA-B RGA-32 (5.49 t/ha, 47.1%), IR 134117-2-B-RGA-B-RGA-B-RGA-30 (5.48 t/ha, 46.4%), Swarna Shreya (5.46 t/ha, 49.9%), IR 134118-4-B-RGA-B-RGA-B-RGA-17 (5.38 t/ha, 47.7%) DRR Dhan 42 (5.36 t/ha, 45.3%) and Swarna Shakti Dhan (5.22 t/ha, 50.3%). They showed better harvest index as well as drought tolerance at the reproductive stage as compared to check

varieties IR64 (4.049 t/ha, 41.4%), and Sahbhagi Dhan (5.22 t/ha, 43.8%). Further, resources remobilization efficiency (%) of assimilates was recorded highest in rice genotype Swarna Shreya (43.24%) followed by IR 134117-2-B-RGA-B-RGA-B-RGA-30 (38.76%), IR134119-2-B-RGA-B-RGA-1 (38.14%), IR134118-3-B-RGA-B-RGA-B-RGA-30 (37.98%), DRR Dhan 54 (37.57%), IR 134116-5-B RGA-B RGA-B RGA-32 (36.53%), DRR Dhan 44 (36.01%), IR 134119-5-B-RGA-B-RGA-B-RGA-32 (35.95%), IR 134118-4-B-RGA-B-RGA-B-RGA-17 (35.53%) and Swarna Shakti Dhan (35.03%) as compared to check varieties IR64 (25.82%) and Sahbhagi Dhan (32.41%) under drought condition.

Evaluation of Rice Genotypes for Submergence Tolerance

Twenty-four rice genotypes along with Swarna Sub 1, IR 64 Sub1 and Sambha Mahsuri Sub 1 as tolerant and Swarna as susceptible checks were evaluated for submergence tolerance during *Kharif* 2022. After 11 days of transplanting, the crop was completely submerged with 1.0 to 1.25 m water depth for 21 days and thereafter water was drained out of the field but due to natural rainfall, the crop was again submerged for next 7 days. The maximum survival percentage was recorded in IR 102796-14-77-2-1-2 (21.9%), followed by IR 102777-18-64-1-2-6 (10.4%), IR 96321-315-294-B-1-1-1 (9.44%) and 96321-558-563-B-2-1-1 (8.33%) compared to Swarna Sub 1 (1.6%). Rice genotypes IR 102796-14-77-2-1-2 (1.10 t/ha), IR 102777-18-64-1-2-6 (0.844 t/ha), 96321-315-294-B-1-1-1 (0.455 t/ha) and IR 96321-558-563-B-2-1-1 (0.417 t/ha) performed better as compared to Swarna Sub 1 (0.090 t/ha) and Sambha Mahsuri Sub 1 (0.113 t/ha). Further, higher spikelet fertility was recorded in 102796-14-77-2-1-2 (86.8%) followed by IR 102777-18-64-1-2-6 (78.0%) and 96321-315-294-B-1-1-1 (73.8%) compared to check variety Swarna Sub 1 (59.3%).

Evaluation and Identification of Rice Genotypes for Multi-stages Drought Tolerance

Thirty-two rice genotypes were evaluated under multi-stage drought (MSD), reproductive stage drought (RSD), vegetative stage drought (VSD), seedling stage drought (SSD) and non-stress conditions during *Kharif* 2022. In MSD experimental field, water was provided only once on the day immediately after sowing so that the seeds can properly germinate. In RSD, VSD and SSD experimental field, drought stress was imposed at respective stages by withholding irrigation. Grain yield of different genotypes varied from 0.44 to 1.77 t/ha, 1.19 to 2.80 t/ha, 2.15 to 4.51 t/ha, 2.48 to 5.00 t/ha and 3.90 to 5.95 under MSD, RSD, SSD, VSD and non-stress conditions, respectively. Results of study revealed that irrespective of genotypes, there was a significant reduction in mean grain yield under MSD (76.5%), RSD (58.2%), SSD (31.2%), VSD (22.1%) stress compare to non-stress condition. Among rice genotypes IR83929-B-B-291-2-1-1-2 (1.77 t/ha), Swarna Shreya (1.45 t/ha), IR108199-24-32-1-1-B (1.38 t/ha), IR 84899-B-184-16-1-1-1 (1.37 t/ha), IR 95786-9-2-1-2 (1.35 t/ha), IR 97069-1-1-1-1 2 (1.34 t/ha), IR83929-B-B-291-3-1-1 (1.33 t/ha), IR 106312-50-1-1-1 (1.32 t/ha), IR84899-B-182-3-1-1-2 (1.28 t/ha), IR 84899-B-185-8-1-1-1 (1.28 t/ha), IR 14 L 362, (1.28 t/ha) and IR 95817-5-1-1-2 (1.27 t/ha) were identified promising for multi-stages drought tolerance as compared to Sahbhagi Dhan (0.94 t/ha).

Response of Drought Tolerant Rice Cultivars to Iron and Zinc

A field experiment was conducted during *Kharif* 2022 in ICAR-RCER, Patna under the ICAR Window 3 Project (ICAR-IRRI collaborative project) to study the response of Nano-N and Nano-Zinc on drought resistance rice variety Swarna Shreya. Nano-N, Nano-Zinc, and ferrous sulphate were sprayed at the panicle initiation stage. Treatment with 75% N of RDF + 1% $FeSO_4$ + Nano Zn + Nano-N produced the highest yield of 4.46 t/ha. Among the different treatments, combined foliar application of nano-Zn and nano-N (T8) at 75% N, recorded a higher number of filled grain /panicle (147), total grain/panicle (154), plant height (44.86 cm) and panicle length (20.53 cm).

Release and Notification of Rice Variety Swarna Purvi Dhan 3

A high-yielding multiple stresses tolerant rice variety Swarna Purvi Dhan 3 (IET 28329) has been developed by ICAR RCER, Patna. It has been released and notified by Central Sub-Committee on Crop Standards, Notification and Release of Varieties for Agricultural Crops, Govt. of India (vide notification number S.O. 4065 (E) dated 31st August 2022) for cultivation under irrigated transplanted condition in the states of Haryana, Rajasthan, Bihar, Uttar Pradesh, Chhattisgarh, and Maharashtra. Swarna Purvi

Dhan 3 is an early duration (115-120 days), semi-dwarf, high yielding (5.0-5.5 t/ha), multiple stresses (drought, disease/insect pest) tolerant, lodging resistant with desirable cooking quality traits and having long slender grain type. Quality-wise, IET 28329 showed desirable quality parameters like high hulling (80.1%), milling (71.05%), HRR (64.7%), desirable amylose content, ASV, a soft GC, and long slender grain type. In addition, Swarna Purvi Dhan 3 (Fig. 5.1) showed moderately resistant to Bacterial leaf blight (BLB), leaf blast, neck blast, sheath blight, brown spot, false smut, sheath rot, and glume discoloration diseases & stem borer, leaf folder, BPH and Gall Midge insect pests under natural conditions.

Fig. 5.1 Swarna Purvi Dhan 3

Frontline Demonstrations (FLDs) of Rice Varieties

Frontline Demonstrations (FLDs) of rice varieties Swarna Shakti Dhan, Swarna Shreya, Swarna Samriddhi Dhan, Swarna Sukha Dhan, and Swarna Unnat Dhan were conducted by ICAR RCER, Patna during *Kharif* 2022 at 85 beneficiary farmers' (including 12 women farmers) fields covering an area of 36.1 hectares in four districts (Buxar, Darbhanga, East Champaran, and Gaya) of Bihar and Ramgarh district of Jharkhand. At the farmer's field, rice varieties Swarna Shreya, Swarna Shakti Dhan, Swarna Samriddhi Dhan, Swarna Sukha Dhan and Swarna Unnat Dhan recorded an average grain yield of 4.07, 4.29, 4.73, 3.75 and 4.37 t/ha, respectively and they showed 27.19, 32.11, 29.59, 9.71 and 44.1 % yield advantage over respective local check varieties.

Organization of Field Days under FLDs Programme

Field days were organized by ICAR RCER, Patna at Rasalpur in Gaya district, Jale in Darbhanga, Chiraya in East Champaran, and Chotki Basauli in Buxar of Bihar on 19th October, 26th October, 4th November, and 5th November 2022, respectively with an objective to demonstrate the performance of climate resilient rice varieties Swarna Shreya, Swarna Shakti Dhan, Swarna Samriddhi Dhan, and Swarna Unnat Dhan at farmer's field grown under frontline demonstration (FLDs) program. Besides, field day was also organized at Kumri villages, Ramgarh (Jharkhand) on 9th November 2022.

Breeder Seed Production of Rice Varieties

Breeder seeds of rice varieties Swarna Shreya (4.59 t), Swarna Shakti Dhan (2.96 t), Swarna Samriddhi Dhan (6.18 t), Swarna Unnat Dhan (0.30 t), Swarna Sukha Dhan (0.15 t) and Swarna Purvi Dhan 3 (0.52 t) were produced by ICAR RCER Patna during *Kharif* 2022. The representatives of National Seed Corporation (NSC), Patna, Bihar State Seed and Organic Certification Agency (BSSOCA), Patna and scientific staff of ICAR RCER, Patna participated in monitoring of breeder seed production of these rice varieties. Besides, nucleus seeds (0.25 t) of above-mentioned rice varieties ere also produced during *Kharif* 2022. In addition, truthfully labelled (TL) seeds of rice varieties Swarna Shreya (4.88 t), Swarna Shakti Dhan (1.42 t), Swarna Samriddhi Dhan (5.87 t), Swarna Unnat Dhan (0.20 t), Swarna Sukha Dhan (0.85 t) and Swarna Purvi Dhan 3 (0.40 t) were also produced during *Kharif* 2022.

Evaluation of Traditional Short Grain Aromatic Rice Germplasm of Eastern India

Twenty seven traditional aromatic short grain rice germplasm were also evaluated for agro-morphological characters during *Kharif* 2022 along with two improved aromatic rice varieties Pusa Basmati 1176 and CR Dhan 909. Significant variation was observed for all the characters under study (Table 5.1) indicating that there is scope for further improvement in these characters. The traditional aromatic short grain rice varieties are very tall in height (1.52-2.03 m) and hence prone to lodging. Crop duration is also longer (~160 days). Despite poor grain yield farmers grow these varieties for their excellent grain quality and aroma. Although the CR Dhan 909 is the highest yielding check (5.27 t/ha), among traditional varieties the grain yield of Shyamjeera-1 (4.78 t/ha), Gopalbhog (4.35 t/ha) and Satlakha Basmati (4.24 t/ha) are the top three varieties giving at par grain yield than the improved check variety.

Table 5.1 Range of different characters in traditional short grain aromatic rice germplasm of Eastern India

Character	Lowest value	Highest value	Mean value	CR Dhan 909 (HY check)
Days to 50% flowering (day)	117 (Marchdhan)	139 (Katarni)	128	113
Plant height (cm)	152 (Katarni)	203 (Bhatsimer Local)	174	135
Panicle length (cm)	25.0 (Lalbasmati)	32.8 (Marchdhan)	28.4	26.9
Panicle bearing tillers/hill	10.3 (Karia Kamod-2)	15.6 (Satlakha Basmati)	12.2	12.7
Fertile grain/ panicle	77 (Lalbasmati)	242 (Keteki Joha)	148	169
Spikelet fertility %	62 (Katarni)	93 (Chandanchur)	82	90
1000- grain weight (g)	10.4 (Tulsiphul-2)	25.5 (Black rice-1)	16.1	25.2
Harvest index (%)	5.9 (Kalanamak)	42.6 (Gopalbhog)	26.3	40.0
Grain yield (t/ha)	0.69 (Kalanamak)	4.78 (Shyamjeera-1)	2.97	5.27

Evaluation of Traditional Rice Landraces in Flood-plains of Eastern India

Eighty traditional lowland rice germplasm collections from eastern India along with three improved lowland varieties Mahsuri, Rajshree, Rajendra Mahsuri and Varshadhan were evaluated during *Kharif* 2022 for agro-morphological characters. The traditional lowland rice is called agahnidhan in vernacular and they possess varying degree of reliance to adverse climatic conditions prevailing during the *Kharif* season in which they are grown. The range of variations for different characters is presented in Table 5.2.

Table 5.2 Range of different characters traditional rice landraces of eastern India

Character	Lowest value	Highest value	Mean value	Rajendra Mahsuri
(HY check)				
Days to 50% flowering (day)	128 (Palia)	144 (Padumani)	135	127
Plant height (cm)	148 (Balidhan)	243 (Badal)	176	126
Panicle length (cm)	22.6 (Phul Jaswa)	31.0 (Bodbi)	27.2	26.0
Panicle bearing tillers/hill	10.6 (Bodbi)	14.0 Badal	12.1	12.4
Fertile grain/ panicle	70 (Badal)	263 (Hanuman Joha)	135	203
Spikelet fertility %	52 (Badal)	95 (Balidhan)	84	85
1000- grain weight (g)	10.5 (Kunkuni Joha-1)	33.2 (Jaldubi)	23.1	21.1
Harvest index (%)	3.5 Dhepa bao	45.7 (Balidhan)	28.0	46.9
Grain yield (t/ha)	0.56 t/ha (Dalmora Bao)	5.46 (Tilbora-1)	3.63	6.2

The highest grain yield (6.25 t/ha) was obtained from Rajendra Mahsuri which is an improved variety for rainfed lowland with semi-tall plant statue (126 cm). Among the traditional varieties under evaluation, Tilbora-1(5.46 t/ha), Balam (5.12 t/ha), Jaldubi (5.10 t/ha) and Panjhali (4.78 t/ha) produced high grain despite having very tall plant stature (>175 cm). Reduction of plant height to semi-tall stature in these genotypes may provide climate resilient varieties for the rainfed lowland rice ecosystem.

Germaplasm Utilization through Mutagenesis

Three traditional short grain aromatic rice varieties *viz.* Kalajoha, Katarni and Shyamjeera were treated with Gamma ray irradiation and ethyl methane sulphonate to induce mutagenesis. These varieties are popularly grown by the farmers for their excellent grain quality and aroma. Due to tall plant stature (1.5-2 m) and consequent crop lodging causes poor grain yield in these varieties. The objective of mutagenic treatment of these genotypes was to induce variation for plant height and crop duration for selection of desired plants with shorter plant height and early maturity. M1 generation was raised and it was observed that variation for plant stature and maturity duration was induced in both EMS & Gamma-ray treatments.

Screening of Rice Genotypes for Submergence Tolerance

Five elite rice genotypes along with eight tolerant checks and one susceptible check (Swarna) were screened for submergence tolerance during *Kharif* 2022. Thirty days old seedlings were transplanted on 16.7.2022 and the crop was fully submerged from 02.08.2022 to 23.08.2022 (21 days). Thereafter, the water was drained out. The crop

got partial submergence for one week due to rainfall and side seepage from adjoining fish pond. Almost all the plants in submergence tolerant varieties died. Among the test genotypes IR10L 182 (12.6%), IR11F 195 (9.0%) and IR09L 342 (6.0%) could show better survivability.

Evaluation of Elite Rice Genotypes for Flood-prone Ecosystem (IIRSTN-FP, 2022)

Forty elite rice genotypes (IIRSTN-FP, 2022) suitable for flood-prone including IR64sub1 and Swarna sub1 as tolerant check and Swarna as susceptible check were evaluated for agro-morphological characters under direct sown condition during *Kharif* 2022. Performance of top ten promising genotypes is presented in Table 5.3. The genotype ING316 (6.56 t/ha) was found most promising with phenotypic acceptability score 1. There are several other genotypes with higher grain yield and phenotypic acceptability score 3. Lower score of phenotypic acceptability indicates better suitability of the genotype for the given location (Table 5.3) The promising genotypes are required to be further evaluated for submergence tolerance.

Table 5.3 Performance of promising rice genotypes for flood prone ecosystem (IIRSTN-FP, 2022)

Genotype	Phenotypic acceptability	Days to 50% flowering	Plant height (cm)	Effective tillers/hill	Panicle length (cm)	Harvest index (%)	Grain yield (t/ha)
ING290	3	79	106	11.6	26.0	48.8	6.75
ING319	3	80	98	12.5	23.1	49.6	6.75
ING316	1	80	126	11.6	28.2	47.1	6.56
ING306	3	80	108	12.2	26.5	47.4	6.35
ING299	3	75	110	12.3	26.7	47.5	6.15
ING288	3	80	109	12.0	24.4	46.2	5.76
ING289	3	83	107	13.5	24.1	45.7	5.76
ING296	3	79	118	11.2	27.1	47.4	5.76
ING298	3	74	113	10.5	28.1	49.3	5.76
ING293	3	82	113	10.7	26.7	45.9	5.56
Swarna sub1	3	103	102.2	12.2	23.1	28.3	4.66

Evaluation of Elite Rice Genotypes for Irrigated Ecosystem (IIRON, 2022)

Thirty elite rice genotypes suitable for irrigated ecosystem along with nine checks were evaluated for grain yield and other characters under direct seeding during *Kharif* 2022.

Performance of ten promising test genotypes along with the late duration check (Swarna) and mid-early duration check (Naveen) is presented in Table 5.4 ING013, ING030, ING002 and ING027 exhibited phenotypic acceptability score 1.

Table 5.4 Performance of promising rice genotypes for irrigated ecosystem (IIRON, 2022)

Genotype	Phenotypic acceptability	Days to 50% flowering	Plant height (cm)	Effective tillers/hill	Panicle length (cm)	Harvest index (%)	Grain yield (t/ha)
ING013	1	84	113.8	12	26.1	47.4	6.17
ING030	1	79	106.5	12	25.0	48.1	5.85
ING002	1	80	116.5	12	26.7	47.2	5.76
ING027	1	89	117.7	12	25.1	44.0	5.60
ING012	3	80	114.1	13	26.4	49.2	6.61
ING011	3	77	115.4	13	26.7	47.6	6.34
ING003	3	87	119.8	11	25.2	47.8	6.15
IRRI 180	3	86	111.9	12	27.4	46.3	5.84
ING004	3	79	116.4	12	25.5	47.9	5.78
ING006	3	78	115.7	12	26.3	43.5	5.76
Naveen	3	82	131.9	12.5	27.8	48.4	6.65
Swarna	3	102	100.8	12.5	23.1	45.0	6.07

Evaluation of Rice Genotypes for Boro Condition

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 the present case, nursery seeding was done on 22nd January and transplanting was done on 3rd March in 2022 to escape cold injury to seedlings during winter months. Naveen is the highest-yielding check variety with a grain yield of 6.70 t/ha whereas, CR Dhan 204 (7.07 t/ha) and CR Dhan 203 (6.83 t/ha) are the two top-yielding varieties with early maturity (107 days to flowering) (Table 5.5).

Table 5.5 Performance of rice genotypes under late boro condition

Genotype	Phenotypic acceptability	Days to 50% flowering	Plant height (cm)	Effective tillers/hill	Panicle length (cm)	Harvest index (%)	Grain yield (t/ha)
CR Dhan 101	114	123	28.3	206	73.2	18.5	6.67
CR Dhan 102	110	108	26.7	181	57.4	23.7	6.59
CR Dhan 203	107	106	27.3	157	83.4	21.4	6.83
CR Dhan 204	107	123	28.5	190	85.2	21.9	7.07
IRF195	114	116	24.5	200	80.4	23.2	6.59
Swarn Shreya	111	122	27.3	224	84.4	20.9	6.39
Sahabhagidhan	108	104	24.9	151	58.1	21.7	6.15
IR64 drt1	112	109	29.5	153	65.1	27.5	6.74
Naveen	116	126	29.0	178	53.1	17.5	6.70
IR64	113	101	26.7	204	74.8	26.0	5.63
CR Dhan 601	121	91	27.3	174	71.8	19.0	6.22
Chandrama	123	103	25.0	192	74.3	19.0	6.15
CD (0.05)	3.6	4.4	0.7	13.6	3.2	0.6	NS
SEM	1.2	1.5	0.2	4.6	1.1	0.2	0.3

Evaluation of Nano DAP Fertilizer on the Performance and Yield of Rice and Wheat Crops

A field experiment with wheat variety "DBW 187 (Karan Vandana)" was carried out during *rabi* 2021-2022 to evaluate the efficacy of nano DAP fertilizer on crop growth and grain yield (Fig. 5.2). There were ten treatments *viz.*

T1:0 % P (No Basal DAP); 100 % N & K, T2: 100 % NPK (University Recommendation); 100% Basal DAP, T3: 75 % Basal DAP; 100% N & K, T4: 50% Basal DAP ; 100% N & K, T5:T3 + ST with Nano DAP @ 5 ml/kg Seed + FS with Nano DAP @ 2 ml/ liter of water at 20-25 DAT, T6:T3 + ST with Nano DAP @ 5 ml/kg Seed + FS with Nano DAP @ 4 ml/ liter of water at 20-25 DAT, T7:T4 + ST with Nano DAP @ 5 ml/kg Seed + FS with Nano DAP @ 2 ml/ liter of water at 20-25 DAT, T8:T4 + ST with Nano DAP @ 5 ml/kg Seed + FS with Nano DAP @ 4 ml/ liter of water at 20-25 DAT, T9:T4 + ST with Nano DAP @ 5 ml/kg Seed + First FS with Nano DAP @ 2 ml/ liter of water at 20-25 DAT and Second Spray- 45 days after seed germination/transplanting, T10: T4 + ST with Nano DAP @ 5 ml/kg Seed + First FS with Nano DAP @ 4 ml/ liter of water at 20-25 DAT and Second Spray- 45 days after seed germination/transplanting. Plant height varied from 92.2cm to 102cm among all the treatments. The highest value was observed in T2 and the lowest in T1. It was perceived from Table 5.6 that spike length varied from 9.9 cm to 10.8 cm among all the treatments. No. of spikelets/spike was noted from 19 to 20.6 in all the treatments under study. It is apparent from the data that grains/spike was noted from 47 to 55 in all the treatments. Significantly greater values of grains spike-1 were noted in T8 and T10 compared to T2. A significant increase in test weight was observed in T5 compared to the university practice (T2). Grain and straw yield were found higher in P applied treatments. However, 50%

RDF treatment (T9 and T10) maintained the grain/straw yield equivalent to T2 (100% RDF). The highest grain yield was achieved with 75% RDF + one foliar spray of nano DAP @ 4 ml/liter (T6) i.e., 4.8 t/ha followed by 50% RDF + two foliar spray of nano DAP @ 4 ml/liter (T10) i.e., 4.7 t/ha.

Fig. 5.2. Field view of Nano-DAP experiments

Table 5.6 Yield and yield parameters of wheat as influenced by Nano-DAP fertilizer application

Treatments	Plant height	No. of Spikelets / Spike	Spike length	No. of grains/ Spike	Test weight (g)	Biological yield (t/ha)	Grain Yield (t/ha)	Straw yield (t/ha)
T1	92.14	19.00	9.93	47.12	39.50	11.47	3.84	7.62
T2	102.00	20.20	10.82	50.05	41.20	13.12	4.62	8.50
T3	99.26	20.00	10.44	49.09	40.30	12.17	4.14	8.03
T4	92.15	19.60	10.04	47.74	40.05	12.23	4.09	8.14
T5	94.50	19.30	10.12	53.13	42.85	13.06	4.34	8.72
T6	94.10	20.60	10.80	54.65	37.85	13.87	4.81	9.06
T7	100.13	20.20	10.40	50.30	40.75	10.54	3.84	6.70
T8	94.08	20.10	10.78	55.08	39.25	11.92	4.13	7.79
T9	96.30	19.60	10.46	53.94	40.60	13.14	4.45	8.69
T10	95.24	20.50	10.83	54.87	39.95	13.67	4.70	8.97
C.D. (0.05)	NS	0.771	0.25	4.58	NS	1.7	0.601	NS

Rice Straw Recycling for Developing the Soilless Growing Media

The present study aims at formulating a suitable strategy to obtain hydroponic media/microgreen mat through the chemical treatment of rice straw. We performed the winter season vegetable germination test on vermiculite and blotting paper along with our prepared media.

Cabbage, radish, spinach, cauliflower, and wheat microgreens were successfully grown on it. No such microbial growth was observed in rice straw media during the study period,which makes this media to be reused multiple times as microgreen mat or hydroponic substrate easily (Fig. 5.3).
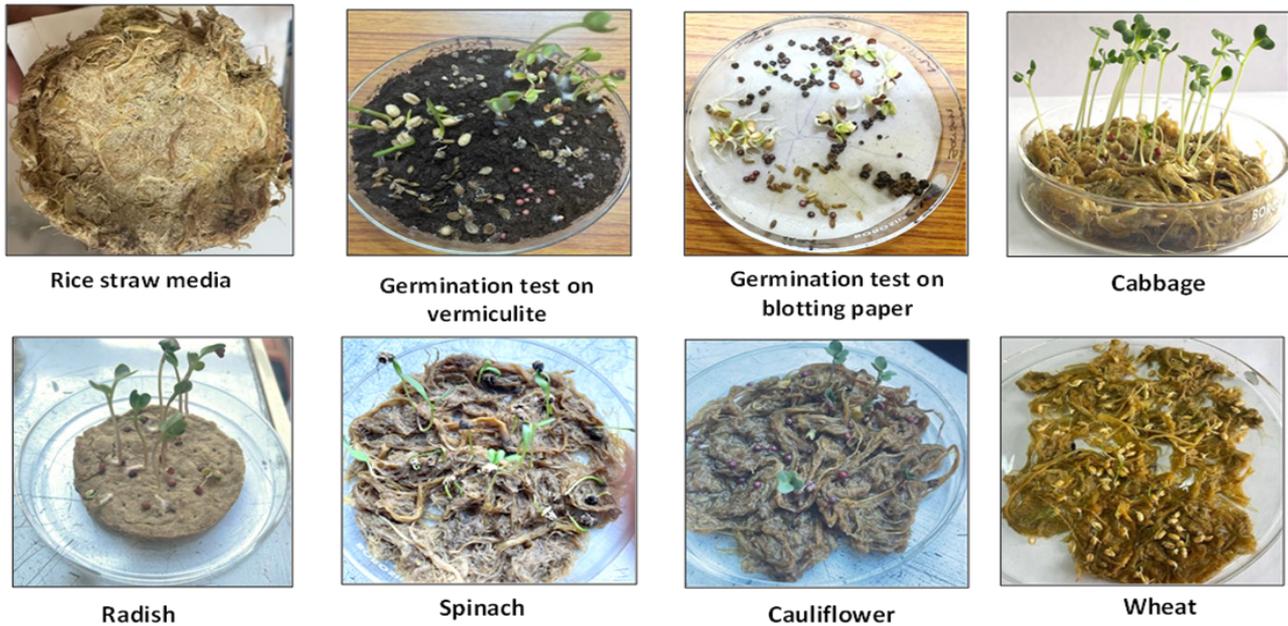

Rice straw media | Germination test on vermiculite | Germination test on blotting paper | Cabbage

Radish | Spinach | Cauliflower | Wheat

Fig. 5.3 Rice straw media

WHEAT

Effect of Drought and Heat Stress on Wheat: Changes in Plant Physiological Traits and Yield Attributes

Thirteen wheat genotypes were evaluated during *rabi* season of 2021-22 at the experimental farm of ICAR RCER, Patna under timely (26 Nov 2021) and late sown conditions (24 Dec 2021) in order to study the effect of water deficit and heat stress on physiological traits and yield attributes. Treatments were (a) Irrigated condition: Control, (b) Vegetative stage drought: VSD and (c) Reproductive stage drought: RSD; under timely and late sown conditions. Maximum & minimum temperature was 40.3 and 6.6 °C during the crop growth period. Total rainfall during the crop growing period was 150.1 mm. Optimum temperature for wheat anthesis to grain filling ranges from 12 to 22°C. The maximum temperature range at anthesis for late sown crop was 23.6-37.9°C (15 Feb-25 March) indicating late sown crops faced heat stress conditions as shown in Fig. 5.4.
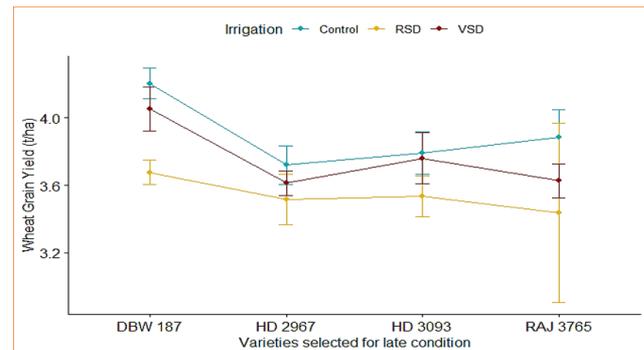

Fig. 5.4. Wheat crop under heat stress condition.

In terms of yield and yield attributes, the grain yield (kg/ha) significantly declined by 34.4% from timely sown (control) to late sown (Table 5.7). Similarly, physiological traits like relative water content (RWC) and Chlorophyll content showed decreasing trend from control to RSD under timely to late sown conditions. The maximum reduction in RWC (27.9%) and Chl (15.2%), were observed under combined stress (terminal drought and heat) from timely sown control conditions. Biochemical traits like TBARS content (indicating lipid peroxidation

in N mol/g) (74.9%) and Proline level (indicating water deficit stress) were higher in both stress conditions, indicating the negative effect of stresses on wheat genotypes. Overall, the negative effect of combined stress was more pronounced as compared to individual stress. The top four promising genotypes which showed yield of more than 3.5 t/ha even under heat and drought stress were DBW 187, HD 2957, HD 3093 and Raj 3765.

Table 5.7   Effect of water deficit and heat stress on yield and yield attributes of wheat genotypes grown under different experimental conditions

Parameters	TIMELY			LATE			% reduction from TS-C to LS-C	% reduction from TS-C to LS -VSD	% reduction from TS - C to LS - RSD
	Control	VSD	RSD	Control	VSD	RSD			
Grain yield (t/ha)	5.35[a]	4.96[b]	4.63[c]	3.51[a]	3.19[b]	2.98[b]	34.37	40.40	44.21
Biological yield (t/ha)	15.66[a]	15.05[b]	14.53[b]	10.97[a]	10.06[b]	9.39[b]	29.91	35.75	39.98
Number of tillers/m^2	676[a]	546[c]	582[b]	457[a]	381[c]	434[b]	5.01	6.39	5.71
TGW (g)	40.1[a]	38.4[ab]	36.9[b]	33.9[a]	32.5[b]	31.8[b]	15.46	18.97	20.70
Plant height (cm)	94.15[a]	92.38[ab]	89.33[b]	88.74[a]	84.97[b]	82.97[b]	32.34	43.66	35.80
Panicle length (cm)	9.88[a]	9.62[a]	9.02[b]	9.52[a]	9.17[b]	8.87[c]	4.98	9.33	12.64
No. of grains/per panicle	57[a]	51[b]	49[b]	57[a]	53[a]	49[b]	5.75	9.75	12.17
Harvest index	34.25[a]	33.04[ab]	31.89[b]	32.53[a]	32.29[a]	32.06[a]	3.61	7.24	10.28

Studies on Weed and Seed Bank Dynamics in different Cropping Systems in the middle Indo Gangetic plains (MGIP)

Weed flora and seed dynamics study was carried out in *Kharif* and *rabi* season of 2021-22 for 12 cropping systems. It was observed that Jowar-chickpea–fallow (11 species) and Rice-CF-spinach-moong (13 species) cropping systems had most diverse weed species during *Kharif* and Rice-mustard-mungbean/rice-lentil-mungbean (46.5/42.8/m²) had recorded higher weed infestations in terms weed count per unit area at 10-20 cm soil depth whereas, horticulture based production systems were heavily infested at 0-10 cm of soil depth (25.2/34.4/m²) than that of other cropping systems. Further, frequency, dominance and abundance of weed species occurred *viz. Cyperus rotundus* (100.0, 5.40, 5.40), *Eleusine indica* (100, 3.60, 3.60), *Trichodesmus indicum* (100, 5.20, 5.20), *Leptochloa chinensis* (100, 4.40, 4.40), *Alternanthera paronychioides* (100, 4.0, 4.0), *Cynodon dactylon* (100, 6.0, 6.0), *Brachiaria reptans* (100, 5.0, 5.0) in rice- wheat, rice-maize, rice-mustard-moong, rice-lentil-moong, lemon-turmeric, okra-cauliflower-onion, rice- cauliflower-spinach-moong and jowar-chickpea-fallow cropping systems during *Kharif* season. To interpret the trends of species turnover (species uniqueness) in different weed-crop associations Jaccard's index (β-diversity) was also calculated and 100% β-diversity was recorded between cropping systems Lemon-Turmeric and Okra-Cauliflower-Onion, indicating no species similarities between these two cropping systems and highest species similarity was observed between Rice-Maize and Rice-Lentil-Moong system (Table 5.8).

Table 5.8 Jaccard's index (β-diversity in %) between different cropping systems

	T2	T3	T4	T5	T6	T7	T8	T9	
T1	42.86	53.85	57.14	69.23	83.33	57.14	83.33	62.50	66.67
T2		33.33	12.50	60.00	71.43	50.00	57.14	44.44	50.00
T3			33.33	57.14	69.23	46.67	84.62	52.94	47.37
T4				60.00	71.43	50.00	42.86	44.44	50.00
T5					38.46	46.67	69.23	52.94	47.37
T6						71.43	100.00	75.00	55.56
T7							71.43	55.56	40.00
T8								37.50	55.56
T9									27.27

Insect Pest and Diseases

Management of False Smut by Modifications in Sowing Dates

Five rice genotypes *viz*., IR11F195, IR09L 342, Moudhamini, Swarna Shreya and Swarna Samridhi, and five sowing dates i.e., 21 May 2022, 5 June 2022, 20 June 2022, 5 July 2022, and 20 July 2022 with three replications was carried out at the experimental field of ICAR RCER, Patna to evaluate the severity of false smut. Disease severity for different dates of sowing with respective rice genotypes is given in Table 5.9. Disease incidence for false smut was different for all the five genotypes with maximum in Moudhamini (Fig. 5.5). Low false smut severity was observed in early and late sown conditions, but significant yield reduction was observed in late sown conditions, which indicatesthat early sowing may help in reducing the loss from false smut disease in rice.

Table 5.9 False smut severity for different dates of sowing and genotypes

SN	Genotypes	False smut severity (smut ball per five hills) for different dates of sowing				
		21/05/22	05/06/22	20/06/22	05/07/22	20/07/22
1	IR11F195	11.10	20.41	25.50	21.25	0.0
2	IR09L 342	9.16	15.25	19.75	29.00	0.8
3	Moudhamini	54.30	141.00	126.75	43.75	NF
4	Swarna Shreya	2.25	8.30	12.50	5.50	0.8
5	Swarna Samridhi	13.00	36.50	20.67	6.00	1.5

Collar Rot Incidence in Different Dolichos Bean Germplasm

Thirty-two Dolichos bean germplasms collected from different locations were screened for collar rot disease at the early vegetative stage. Different germplasms showed different reactions to the disease. Maximum disease incidence was observed in Arka Sambram and minimum in Arka Adarah (Table 5.10).

Fig. 5.5 False smut severity in Moudamini sown on 5 June, 2022

Table 5.10 Collar rot incidence for different Dolichos bean genotypes

Sl. No.	Genotypes	Percentage incidence
1	RCPD-24	8.00
2	RCPD-15	21.15
3	Dasarwal	12.50
4	Arka Bhavani	10.53
5	Arka Joy	18.18
6	Swarna Rituvar	19.35
7	Arka Vistar	18.18
8	Deepaliwal	15.00
9	Arka Vijal	6.25
10	IC-556786	30.00
11	Arka Saumya	30.77
12	Arka Sambhram	37.38
13	IC-556709	8.70
14	Arka Swagath	25.00
15	Arka Amogh	27.27
16	J-37	37.50
17	Arka Krishna	36.84
18	IC-556787	28.21
19	Arka Pradhan	37.50
20	Arka Supriya	27.27
21	Purple poded	7.5
22	Arka Adarsh	3.70
23	RCPD-26	16.67
24	Hima	16.22
25	Grace	15.15
26	Arka Prashidhi	24.24
27	IC-55682	15.15
28	RCPD-16	15.17
29	RCPD-1	9.82
30	RCPD-14	40.30
31	RCPD-12	31.18
32	RCPD-5	21.31

Table 5.11 Disease reaction and disease score of yard long bean genotypes

Sl. No.	Genotype	Dis. Score	Dis. Reaction
1	IC-630377	9	HS
2	IC-622601	9	HS
3	IC-626147	9	HS
4	IC-626153	9	HS
5	IC-626147	7	S
6	IC-636379	7	S
7	IC-626153	7	S
8	IC-626154	5	MS
9	NP-57	7	S
10	Sumanth	3	MR
11	Gomati	1	R
12	IC-626143	1	R
13	RCPY-1	1	R
14	RCPY-2	3	MR
15	YP-7	3	MR
16	Kashi Kanchan	3	MR
17	Kashi Nidhi	3	MR
18	Arka Mangal	7	MS
19	Pusa Komal	5	MS
20	Pusa Sukomal	3	MR
21	CHCP-11	1	R
22	CHCP-2	3	MR
23	CHCP-1	3	MR
24	RCPY-12	1	R
25	RCPY-11	1	R
26	RCPY-10	1	R
27	RCPY-09	5	MS
28	IC-626145	5	MS
29	IC-630376	7	S
30	IC-626138A	7	S
31	IC-626140	7	S
32	IC-622598	5	MS

Screening of Yard Long Bean Genotypes for Yellow Mosaic Resistance

Fifty-two-yard-long bean genotypes from different locations were planted during the *Kharif* 2022 at ICAR RCER Patna. Genotypes Gomati, IC-626143, RCPY-1, CHCP-11, RCPY-10, RCPY-11, RCPY-12, and Sree Ma showed resistance reaction however Sumanth, RCPY-2, YP-7, Kashi Kanchan, Kashi Nidhi, Pusa Sukomal, CHCP-1, CHCP-2, RCPY-6, RCPY-14, and P-57 were found to be moderately resistance (Table 5.11).

Sl. No.	Genotype	Dis. Score	Dis. Reaction
33	IC-626146	7	S
34	RCPY-3	7	S
35	RCPY-5	7	S
36	IC-630378	5	MS
37	RCPY-6	3	MR
38	JNS	9	HS
39	RCPY-13	9	HS
40	IC-626142	7	S
41	IC-626139	7	S
42	RCPY-3	9	HS
43	IC-626138	9	HS

Sl. No.	Genotype	Dis. Score	Dis. Reaction
44	RCPY-8	9	HS
45	RCPY-8	9	HS
46	IC-626139	9	HS
47	YB-7	7	S
48	RCPY-15	7	S
49	RCPY-14	3	MR
50	P-57	3	MR
51	Sree Ma	1	R
52	RCPY-7	5	MS

HS: Highly susceptible, MR: Moderately resistant, R: Resistant, S: Susceptible

Characterization of Phytoplasma Causing Phyllody in Chickpea.

Floral virescence, phyllody and extensive proliferation of the branches in chickpea genotype Pusa 256 was observed during 2021-22 at ICAR RCER Patna. Two samples from symptomatic plants were collected and DNA was isolated. The extracted DNA was used as template in nested PCR assay by utilizing primer pairs, P1/P7 and R16F2n/R16R2 for 16S rRNA gene. 16S rRNA gene sequences from symptomatic plants were deposited in GenBank. Blast analysis revealed that sequence was related with Candidatus Phytoplasma asteris related strain (16SrI-B).

6 Pulses

Evaluation of Short Duration Pigeon Pea Germplasm

The pigeon-pea germplasm ICPL-92047, ICPL-81-3, ICPL-88034 and ICPL-20325 which were found promising among short duration group during last year were evaluated with respect to yield and yield characters. Among them, ICPL-81-3 and ICPL-92047 are the best suited for the eastern plateau and hill region and can be harvested in five months (Table 6.1).

Table 6.1 Evaluation of promising genotypes of pigeon pea (short duration)

Genotype	Days to 50% flowering	Plant height (m)	Days to harvest	Pod bearing length (m)	Yield (q/ha)	Shelling (%)	No. of seeds per Pod	100 seed weight (g)
ICPL-92047	77	2.2	154	1.4	8.88	72.0	3.6	7.01
ICPL-88034	78	2.7	154	1.7	7.01	65.0	4.0	10.10
ICPL-81-3	84	2.5	164	1.4	11.09	74.0	3.7	7.53
ICPL-20325	78	2.15	154	1.35	11.58	78.0	3.6	8.03

Twenty-two short-duration genotypes collected from Minicore collections of ICRISAT, Hyderabad were evaluated with respect to yield and yield characters. Among them, ICP-11477, ICP-14900, ICPL-20329, ICP-20338, ICP-14638, ICP-3046, ICP-11690 and ICPL-13828 were found to be promising for short duration and high yield (Table 6.2).

Table 6.2 Evaluation of twenty-two short-duration genotypes of pigeon pea for yield and yield characters

Genotype	Days to 50% flowering	Plant height (m)	Days to harvest	Pod bearing length (m)	Yield (q/ha)	100 seed weight (g)
ICP-11477	83	2.7	164	1.7	9.40	6.97
ICP-14900	79	2.6	214	1.8	9.37	7.62
ICPL-20329	64	2.0	154	1.1	9.98	8.67
ICPL-20338	51	1.1	164	0.7	4.17	8.41
ICP-14638	100	2.5	283	1.8	25.67	9.81
ICP-3046	214	3.1	292	2.0	20.99	7.82
ICP-11690	205	2.3	283	1.5	20.22	8.56
ICPL-13828	163	3.1	297	2.2	22.00	10.62
CV	53.93	26.90	27.67	30.58	51.55	13.82

Diversity Studies in Long Duration Genotypes of Pigeon Pea Using Molecular Markers

Molecular diversity studies were done in 12 long-duration genotypes of pigeon-pea which were evaluated during last five years. Twenty RAPD primers were used to study the polymorphism (Fig. 6.1). Dendrogram revealed two main clusters with two genotypes *viz*., Type-7 and Pusa-9 in one cluster and the remaining ten genotypes in another cluster. Subcluster was again divided into clusters with PA-2 in one cluster and remaining nine genotypes in the other (Fig. 6.2).
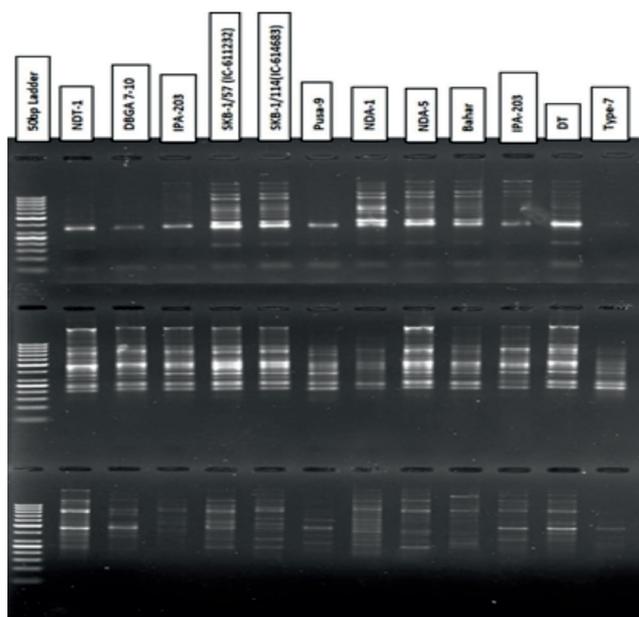
Fig. 6.1 PCR product of markers OPX-1, OPX-5 and OPX-6 in 12 long duration pigeon pea genotypes
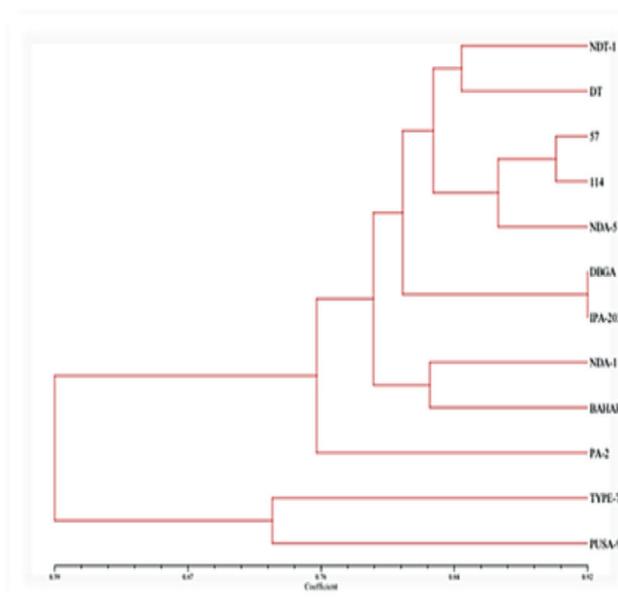

Fig. 6.2 Cluster diagram of pigeon pea germplasm

Development of High Moisture Tolerant Pigeonpea

Multiplication of promising excess moisture tolerant pigeonpea line

Promising moisture tolerant pigeonpea lines *viz.*, ICAR PP 01, ICAR PP 02 and ICAR PP 03 were multiplied under filed condition (Fig. 6.3).

Fig. 6.3 Multiplication of pigeonpea lines developed by ICAR RCER Patna

All three promising pigeonpea lines has been deposited to NBPGR, New Delhi and the Indigenous collection number (IC Number) has been assigned to all three line /accessions.

Sl. No.	Collector No	Institute No	IC No
1	1.AKS/01/22	ICAR PP 01	647556
2	2.AKS/01/22	ICAR PP 02	647557
3	3.AKS/01/22	ICAR PP 03	647558

Diversity in Vegetable Pigeonpea

Segregating several pigeonpea lines of vegetable type has been evaluated at our research farm under controlled conditions in open top chamber (OTC). Variability in flower colour, and seed coat colour has been recorded (Fig. 6.4 & 6.5). Among seed coat colour, primarily it was found green, black brown and intermediate with variation in no. of seeds per pod.

Fig. 6.4 Variation in seed coat colour in vegetable type pigeonpea

Fig. 6.5 Field view of maturing vegetable type pigeonpea line under OTC condition

Performance of Advance Breeding Lines in AICRP/ State Trials

• In Chickpea, one entry 'DBGC 3' (ICC13124×WR 315) was promoted to AVT-2 of AICRP on Chickpea for timely sown based on its performance during

crop season 2021-22. The same genotype also excelled in SVT and has been promoted for the next stage of testing during 2022-23.

• Two new entries *viz.* 'RCEC 3' (Pusa 256 × ICC 4958) and RCEC 6003 ((GNG 1958 × IPC 07-09) × (CSJ 15 × GNG 1581)) were contributed to AICRP on Chickpea for evaluation in IVT during cropping season 2022-23.

• One new chickpea entry 'DBGC 1' (BGD 256 × WR 315) was contributed to SVT for evaluation during the crop season 2022-23.

• In lentil, one entry 'DBGL 105' (DPL 15 × ILL 864) was promoted from IVT to AVT-1 of AICRP on MULLaRP for evaluation during 2021-22.

• One new entry 'RCEL 59025' (99/209 × LIRL-22-107) was contributed to the AICRP on MULLaRP for evaluation in IVT during the crop season 2022-23.

Performance of Advanced Breeding lines in Wilt Sick Nursery

Five genotypes, each of chickpea (DBGC 3, RCEC 3, RCEC 2310, RCEC 6003 and RCEC 6059) and lentil (RCEL 59017, RCEL 59025, RCEL 59037, RCEL 59047 and RCEL 19-1) were put to pathological trials for assessment of wilt reaction at Tirhut College of Agriculture, Dholi during 2021-22. Plant mortality data showed that chickpea genotypes showed moderate (DBGC 3 and RCEC 3) to resistant (RCEC 2310, RCEC 6003 and RCEC 6059) wilt reactions (Table 6.3). In lentil, all genotypes except 'RCEL 19-1' showed moderate wilt reaction. The genotype 'RCEL 19-1' showed substantially greater mortality percent (96.7%) than susceptible check 'Sehore 74-3' (53.3%), indicating that 'RCEL 19-1' could be a better susceptible check than the existing one (Sehore 74-3) for assessing wilt sick reaction of lentil genotypes in AICRP pathological trial.

Table 6.3 Wilt reaction of chickpea and lentil genotypes at TCA, Dholi (2021-22)

Chickpea			Lentil		
Test genotypes	Mean wilting (%)	Wilt reaction	Test genotypes	Mean wilting (%)	Wilt reaction
DBGC 3	12.91	MR	RCEL 59017	13.33	MR
RCEC 3	11.84	MR	RCEL 59025	11.67	MR
RCEC 2310	8.16	R	RCEL 59037	15.00	MR
RCEC 6003	8.21	R	RCEL 59047	20.00	MR
RCEC 6059	6.70	R	RCEL 19-1	96.67	S
JG 62 (S-check)	85.48	S	Seohore 70-3 (S-check)	53.33	S

R: resistant; MR: Moderately resistant; S: susceptible

Promising Genotypes of Chickpea and Lentil Multiplied for Evaluation in the AICRP system

Chickpea (09) and lentil (01) genotypes were multiplied.

The main characteristics of the genotypes are given below in the Table 6.4.

Table 6.4 Yield and other attributes of promising chickpea and lentil genotypes

Genotypes	Yield (kg/ha)	100 seed wt (g)	Maturity duration (days)	Zn (ppm)	Fe (ppm)
RCEC 13125	1830	28.45	140	65.60	52.40
RCEC 13132	2031	25.66	139	57.45	50.08
RCEC 13222	1915	29.50	139	72.20	49.95
RCEC 13226	1889	27.37	139	74.25	55.35
RCEC 3	2306	22.20	135	28.93	47.47
RCEC 2310	1805	19.32	140	41.37	46.90
RCEC 17-4	2032	27.50	138	38.27	37.75
RCEC 6003	2311	24.74	140	35.70	44.50
RCEC 6059	1985	20.55	140	47.50	42.30
RCEL 59025	**1102**	**1.97**	**129**	75.40	86.00

Grass pea Station Trial (2021-22): Seven low ODAP advance breeding lines of grass pea (selected from ICARDA Nursery) were evaluated in the station trial along with two checks (Ratan and Mahateora) following RCBD. Details of yield and other agronomic data are given in Table 6.5.

In addition, quality seeds (F/S and T/L) of mungbean (Virat, Shikha, IPM 2-3 and IPM 2-14) were also taken up. At KVK, Buxar, quality seeds of red gram (IPA 203), chickpea (Pusa 3043 and RVG 202) and lentil (IPL 316 and IPL 220) were taken up in participatory mode (Table 6.6).

Table 6.5 Performance of advance breeding lines of grass pea in the station trial (2022-23)

Genotypes	Yield (kg/ha)	100 seed wt. (g)	Maturity duration (days)
75016	1768	8.51	137
75017	1648	7.40	136
75022	1327	7.16	137
75024	1864	6.52	139
75040	1236	7.00	136
75046	1101	7.21	138
75049	668	6.50	138
Ratan	1900	7.33	135
Mahateora	1150	7.35	134
LSD (P=0.05)	178	1.01	1.20

Table 6.6 Quality seeds of pulses produced in Pulse Seed Hubs during 2022

Crop	Variety	Class of Seed	Seed production (q)
Mungbean	IPM 2-3	F/S, TL	10
	Virat	F/S, TL	05
	IPM 2-14	F/S, TL	05
	Shikha	F/S, TL	05
Chickpea	Pusa 3043	B/S	30
		F/S	90*
	GNG 2299	F/S	15
	RVG 202	C/S	7.2*
		T/L	4.4*
Lentil	IPL 220	C/S	56
		C/S	1.5*
	PL 8	TL	05
	IPL 316	C/S	108.5*
Pigeonpea	IPA 203	B/S	30
	IPA 206	F/S	70*
		B/S	02
		Total	**444.6**

Pulse Seed Hub

Under aegis of NFSM funded mega project on "Creation of seed hubs for increasing indigenous production of pulses in India", Breeder seed production of pigeonpea (IPA 203) and chickpea (Pusa 3043) was taken up at ICAR RCER, Patna during 2021-22. In lentil, certified seeds of 'IPL 220' and TL seeds of 'PL 8' were produced.

B/S: Breeder seed; F/S: Foundation seed; CS: Certified seed; T/L: Truthfully labelled seed; *: Seed produced under Pulse seed hub, KVK, Buxar

7 Fruits

Screening of Litchi Seedling Population Based on Seed Size

Litchi has a very narrow genetic base and small-seeded litchi germplasm is very limited in the Indian litchi germplasm collection. Keeping this in view, the seedling population of litchi was raised to create the variability in litchi germplasm. During 2021-22, fruiting was observed in 44 litchi germplasm which was screened for seed size. The seed size varied from 0.67g (ICAR RCER LS 16/4) to 3.66g (ICAR RCER LS 12/1). On the basis of two check varieties (Bedana and Swarna Madhu), six litchi seedlings were selected which showed smaller seed sizes than check varieties (Fig. 7.1). Among the small seeded litchi seedlings, ICAR RCER LS 16/4 had the lowest seed weight (0.67g), fruit weight (14.86g), fruit length (34.4mm), fruit diameter (29.4mm), pulp (77.68%) and TSS (17.50°B) (Fig. 7.2).
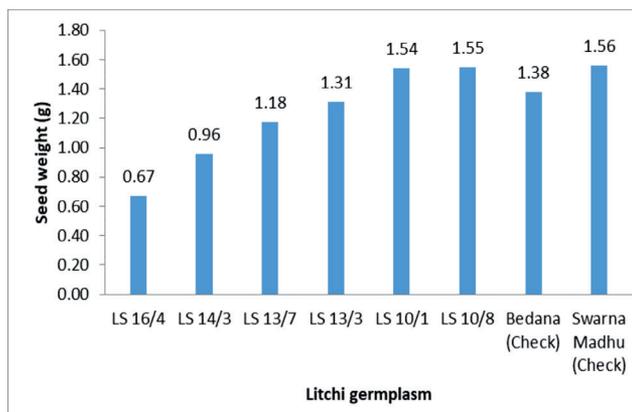
Fig. 7.1 Small seeded litchi germplasm with their seed size

Fig. 7.2 (A) Fruit bunch (B) Fruit and seed of the germplasm ICAR RCER LS 16/4

Understanding the Fruit Cracking Mechanism in Bael Using Biochemical and RNA-Sequencing

A wide variability in bael fruit cracking was observed among the 37 selected genotypes. Overall, fruit cracking ranged between 0 to 89.94% among the genotypes/accessions with standard deviation of 27.64% and a coefficient of variation of 60.53%. Among different genotypes/ accessions, the highest overall fruit cracking was observed in Pant Aparna (89.94%), followed by ICAR-RCER BS 8-3 and ICAR-RCER BS 10-1 whereas the genotypes ICAR-RCER BS 6-4, ICAR-RCER BS 6-6, ICAR-RCER BS 7-2, ICAR-RCER BS 7-3, ICAR-RCER BS 8-5, ICAR-RCER BS 9-6 showed no cracking during 2021-2022. Among the different cracking patterns, the mean transverse pattern (41.80%) was observed predominantly followed by a longitudinal/radial (31.74%), longitudinal + transverse (6.77%) and irregular cracking pattern (3.48%).

Based on the overall fruit cracking percentage, genotypes/accessions were grouped into three categories: highly susceptible (>30%), moderately susceptible (>0 to ≤30) and tolerant (no cracking). From the 37 genotypes, 9 genotypes were selected for detailed study where 3 genotypes represented each of the cracking categories. Higher levels of total phenols, vanillic acid, flavonoids, antioxidants, and total carbohydrates were found to have a direct effect on fruit cracking in bael as these biochemical parameters were found higher in the susceptible genotypes compared to the tolerant genotypes. Similarly, low levels of proline, Ca and B contents also impacted cracking in susceptible genotypes. Overall, the Differentially Expressed Genes (DEGs) associated with the cell wall and polysaccharide metabolism, phenolics and flavonoids biosynthesis, plant hormone biosynthesis and signalling, nutrient transport, and MAPK signalling were significantly down regulated in fruit cracking susceptible genotype as compared to fruit cracking tolerant genotype (Fig. 7.3).
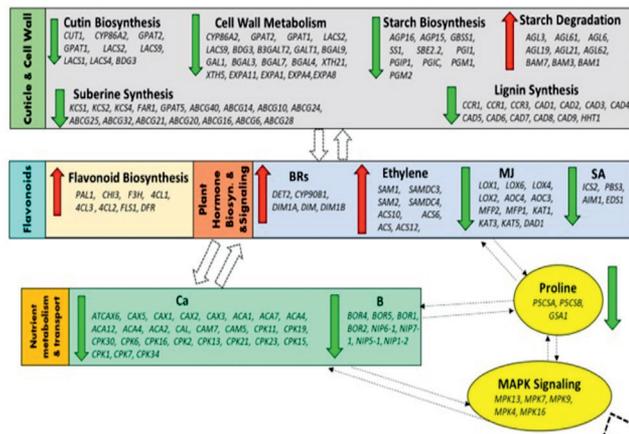
Fig. 7.3 Overview of possible mechanisms involved in cracking of bael fruit

Multitier Cropping System for Rainfed Uplands of Eastern Plateau and Hills

The performances of main, filler and intercrops were monitored under different six-year-old multitier cropping system for rainfed uplands. The highest paddy equivalent yield was recorded under mango + mahogany + peach + rice followed by mango + mahogany + peach + ragi system (Fig. 7.4). The mango yield varied from 29.75 kg/plant to 36.00 kg/plant under different systems. The filler crop peach yield (50 t/ha) was higher under mango + mahogany + peach + rice system whereas fruiting was not observed in the case of other filler plants such as aonla and pomegranate. The total soil organic carbon stock was highest (62.8 Mg/ha) under the multitier systems having aonla as filler trees in the entire soil depth of 0-60 cm. Similarly, all the fractions and pool of soil organic carbon were also higher under the multitier systems as compared to the rice crop and uncultivated control. The very labile carbon stock was highest of 22.2 t/ha in mango + mahogany + aonla + rice multitier systems.
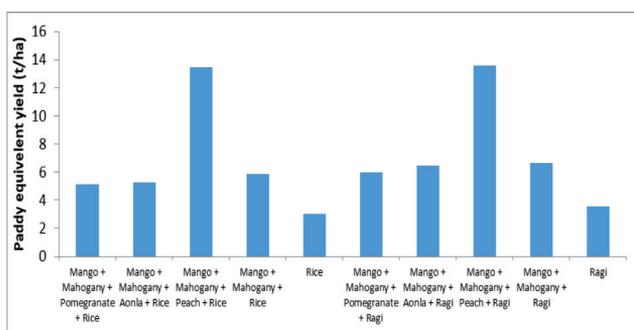
Fig. 7.4 Paddy equivalent yield under different multitier systems

Vegetable Purpose Jackfruit Genotype Identified

Physico-chemical characterization of twenty jackfruit genotypes was carried out on the basis of physical and gravimetric tests, colour attributes, textural analysis and mineral profiling. Best jackfruit genotype for vegetable purpose was selected using principal component analysis (PCA) where pulp content (indicator of marketable yield), cutting force (indicator of ease in cutting), peak force after boiling (indicator of softening after cooking) and ΔE (indicator of browning after cutting) were contributing significantly (Fig. 7.5). The genotype ICAR-RCER JS-4/2 (pulp content: 51.23%; cutting force : 37.24 N; peak force after boiling: 35.16 N and ΔE: 4.62) was identified most suitable for vegetable purpose.
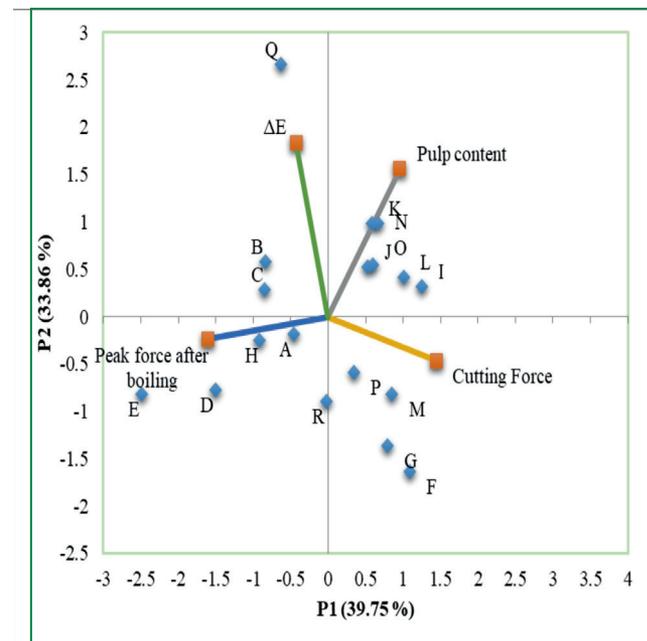

Fig.7.5 Plots of principal components for quality traits

Development Process for Jackfruit Pulp Bar

Ripe bulbs of jackfruit (ICAR-RCER JS10/3 & 9/1) were manually separated and grounded to obtain the homogenised pulp. Sugar syrup of different concentrations were 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 process of jackfruit bar preparation is shown in Fig. 7.6. The results indicated that the pulp mixture at 30°Brix, drying temperature as 70°C and pulp thickness of 4 mm produced better quality jackfruit bar in terms of colour, texture and sensory attributes.

Fig. 7.6 Process of jackfruit bar preparation

Diversity and Abundance of Insect Pollinators of Litchi and their Relations to Abiotic Factors

A total of 19 insect species belonging to four orders and ten families of the class Insecta were attracted and acted as pollinators on litchi flowers. Insects form Hymenoptera order were the most abundant with representation from six species from three distinct families (Apidae, Halictidae, and Vespidae). Among them, Apidae family was the most populous, with four honey bee species namely *Apis mellifera*, *Apis dorsata*, *Apis cerana* and *Apis florea* (Fig. 7.7). Pollinators belonging to Diptera were the second most abundant insect order, where six species of three distinct families (Syrphidae, Muscidae, and Calliphoridae) visited on litchi flowers. Six Lepidoptera species belonging to families Pieridae, Nymphalidae, and Erebidae were observed. Coleoptera was observed on litchi flowers, with only one species, the lady bird beetle, *Ortalia horni* of the Coccinellidae family. Data of pollinators and weather parameters were visually analysed when the pollinator activity was maximum (0800 to 1000 Hrs) (Fig. 7.8). Optimum ecological ranges for Apis species required 30 to 32°C temperature, 48 to 52% relative humidity and 2 to 8 m/s wind velocity while non-Apis species required 28 to 30°C temperature, 40 to 45% relative humidity and 2 to 8 m/s wind velocity below and above which pollinators activity lowered down.
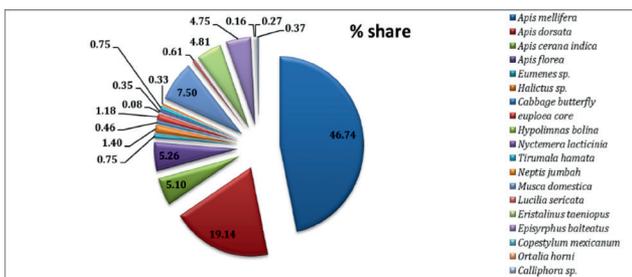

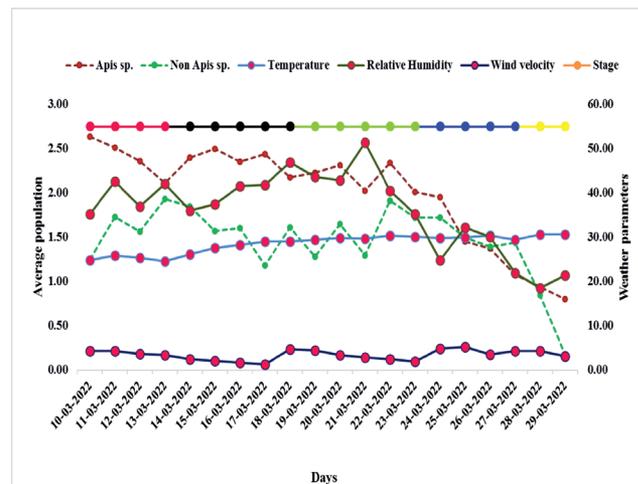**Fig. 7.7 Relative proportions of pollinators foraging on litchi flowers**

Fig. 7.8 Pollinators activity with respect to weather parameters at 8 to 10 AM

Biointensive Pest Management of Litchi Stink Bug (*Tessaratoma javanica*)

The spray of insecticides profenophos 50 EC (1.5ml/L) + thiacloprid 21.7 SC (0.5ml/L) and imidacloprid 17.8 SL (0.3 ml/L) were found effective against Tessratoma javanica (Fig. 7.9) and comparatively less toxic towards natural enemies and pollinators. The treatments including biopesticides emamectin benzoate, *Beauveria bassiana*, *Lecanicillium (Verticillium) lecanii*, *Metarhizium anisopliae* and azadirachtin were very less effective with less than 50% mean reduction values
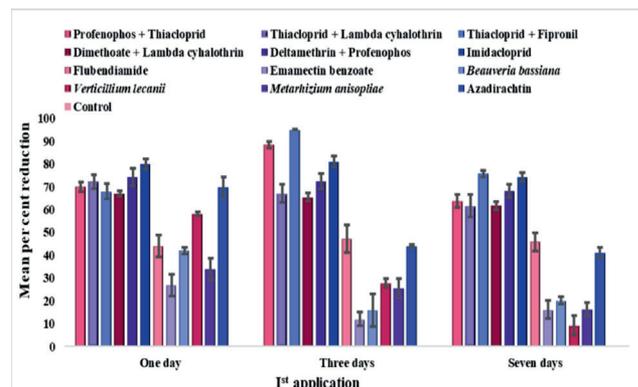

Fig. 7.9 Bioefficacy of different insecticides against litchi stink bug (*Tessaratoma javanica*)

8 Vegetables

Evaluation of French Bean for Disease Resistance and Horticultural Traits

A total of two hundred thirty-three lines of French bean (72 germplasm and 161 F_2 progenies) including 2 commercial checks were evaluated during 2022 for incidence of rust in the spring-summer season and incidence of anthracnose and angular leaf spot during *Kharif* and *rabi* seasons. Disease reactions were recorded for disease severity and disease incidence.

Genotypes which showed higher degree of resistance or tolerance under field condition were subjected to artificial inoculation for rust under controlled condition. Disease reactions of promising genotypes are presented in Table 8.1. These promising germplasm lines were selected for further evaluation and as a source of resistance for major diseases (Fig. 8.1). Based on the evaluation, the progenies were selected for advance breeding lines.

Table 8.1 Disease reactions of promising French bean genotypes

Sr. No.	Genotype/ Advanced breeding lines	Reaction to anthr acnose	Reaction to angular leaf spot	Reaction to rust	Yield potential (t/ha)
1	HAFB-6	S	S	R	5.70
2	HAFB-14	S	S	HR	3.00
3	HAFB-15	S	T	HR	2.30
4	HAFB-37	R	R	R	2.20
5	HAPB-3	T	T	R	5.00
6	HAPB-10	T	T	R	2.10
7	HAPB-24	S	T	S	3.12
8	HAPB-33	T	T	T	6.30
9	RCRPB-74-1-23	T	T	R	11.40
10	RCRPB-74-1-31	T	T	T	10.88
11	RCRPB-74-1-35	T	T	T	6.16
12	RCRPB-74-1-38	T	T	T	6.40
13	RCRFB-74-1-51	T	T	S	9.00
14	RCRPB-74-1-62	T	T	T	7.20

*S=susceptible, T= tolerant, R= resistant, HR= highly resistant

Fig. 8.1(a) Segregation for pod traits and (b) Individual plant selection (RCRPB-74-1-31) of F2 population of IC632961 × IC525260.

Development of Multiple Disease-resistant Hybrids in Solanaceous crops

Brinjal

Among 18 genotypes of brinjal collected from ICAR NBPGR and local sources for bacterial wilt resistance, nine genotypes *viz.*, EC-467271, HAB-921, HAB-923, HAB-924, HAB-925, HAB-926, HAB-927, HAB-928 and HAB-929 showed resistance to bacterial wilt under artificial wilt sick conditions. These resistant genotypes will be utilized in resistance breeding programme and interspecific grafting in tomato. Among 12 crosses developed using six lines *viz.*, IC-261786, HAB-905, HAB-906, HABR-6, RCBR-22, Swarna Mani and two

testers *viz.*, HAB-921, HAB-792, only four crosses *viz.*, IC-261786 x HAB-792, IC-261786 x HAB-921, HAB-905 x HAB-792 and HAB-906 x HAB-921 were found resistant to bacterial wilt under wilt sick plot conditions. These resistant crosses will be evaluated for yield and

yield components. Among the eleven F₅s developed from HAB-917 x IC 261786 and HAB x IC-545901 and HAB-917 x HAB-901, six advance breeding lines were selected for further evaluation based on yield, fruit quality and bacterial wilt resistance (Fig. 8.2)

| **HAB-917 x IC-261786-4-2-F₅** | **HAB-917x IC-545901-1-1-F₅** | **HAB-917x HAB-901-1-1-F₅** | **HAB-917x IC-261786-3-2-F₅** |
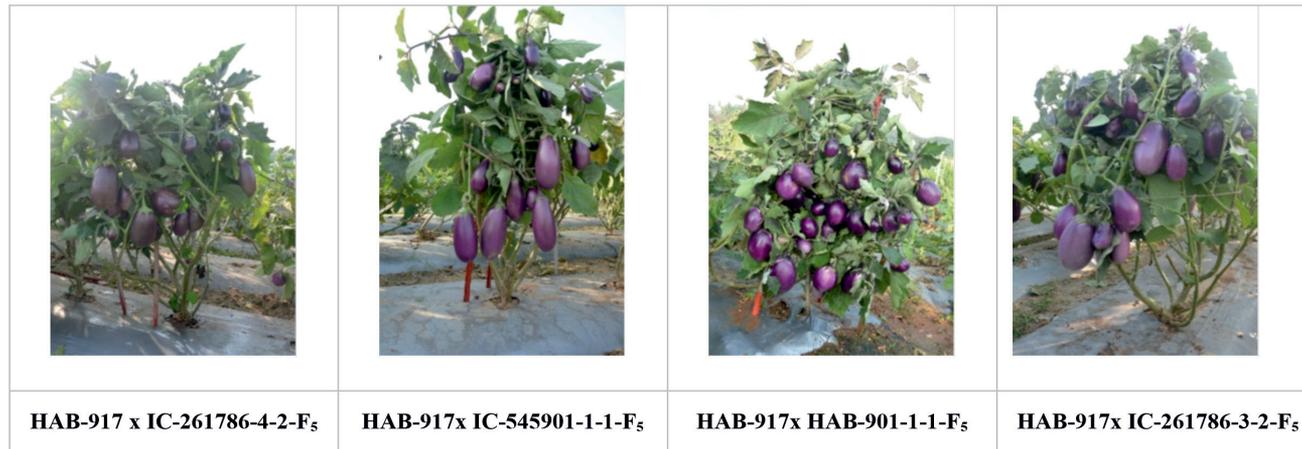
Fig. 8.2 Advance breeding lines in Brinjal

Tomato

Five genotypes of tomato *viz.*, RCDT-1116, RCDT-1128-1, RCDT-1128-2, RCDT-1225, RCDT-1226 were evaluated for bacterial wilt resistance. Among them, RCDT-1116, and RCDT -1128-1 were found wilt resistant during 2021-22. The line RCDT-51 (progeny from F6 generation of HADT-296 x HAT-311) showed bacterial wilt resistance with high yield (49 t/ha) (Fig. 8.3). Bacterial wilt resistant genotype HAB-901 of brinjal

was used as rootstock for intergeneric grafting of tomato hybrid 'Swarna Baibhav' (high yielding, good quality fruits, susceptible to wilt) by Cleft grafting procedure. Graft compatibility upto 80% was observed and grafted plants were vigorous, resistant to bacterial wilt and extended harvesting duration of the crop around 195 days (September to March) when compared to non-grafted plants. An average yield of 6.6 kg/plant and a total yield of 109.97 t/ha were recorded in grafted tomato (Fig. 8.4).

Fig. 8.3 Advance Breeding line of Tomato RCDT-51

Fig. 8.4 Intergeneric grafting in tomato using bacterial wilt resistant rootstock of brinjal

Chilli

Among 50 genotypes of chilli collected from ICAR NBPGR, ten genotypes *viz.,* IC-214965, IC-214966, IC-410423, EC-378632, EC-390029, EC-566920, EC-599969, IC-447065, IC-561622, IC-561626 were found resistant to bacterial wilt under wilt sick plot conditions. These resistant genotypes will be utilized in resistance breeding programme. In another trial twenty-one crosses were developed with seven testers *viz.,* Haldi pada, Kullu Local, Pusa Jwala. Aparna, Pusa Sadabahar, Swarna Apoorva, HC-80 and three testers *viz.,* Swarna Praphulya, Swarna Arohi, Ujwala in LxT design for developing multiple disease/pest resistant hybrids in chilli during 2021-22.

Genetic Resource Management in Vegetable crops

Evaluation of F₄ Segregants of bottle Gourd for Fruit Shape and Disease Resistance

Three F_4 segregants were selected with different fruit shapes based on market demand and disease reaction to fusarium wilt as mentioned in Table 8.2. Three lines HABOG-38 x Swarna Sneha -1-3-1, HABOG-38 x Swarna Sneha-3-6-2 and HABOG-38 x Swarna Sneha -11-1-1 showed resistance against disease resistance (Fig. 8.5).

Table 8.2 Evaluation of F4 segregants of bottle gourd for fruit shape and disease resistance

F4 segregants	Node at which 1st female flower appears	Days to 50% flowering (DAS)	Avg. Fruit Weight (kg)	Fruit shape	Disease reaction to Fusarium wilt
HABOG-38 x Swarna Sneha -1-3-1	5	70	1.10	Cylindrical	Resistant
HABOG-38 x Swarna Sneha -3-6-2	6	71	0.85	Round	Resistant
HABOG-38 x Swarna Sneha -11-1-1	5	70	1.10	Long	Resistant

HABOG-38 x Swarana Sneha-1-3-1

HABOG-38 x Swarana Sneha-3-6-2

HABOG-38 x Swarana Sneha-11-1-1

Fig. 8.5 Segregants of Bottle gourd

Evaluation of F₉ Segregants of Cucumber for high Yield and Disease Resistance

Six F₉ segregants of cucumber from RCCV-170 and Swarna Sheetal were identified to be resistant to downy mildew having 15-20% male flowers and female flowers on main stem at 4th – 5th node with green fruits, juicy pulp and absence of hollowness (Fig. 8.6).
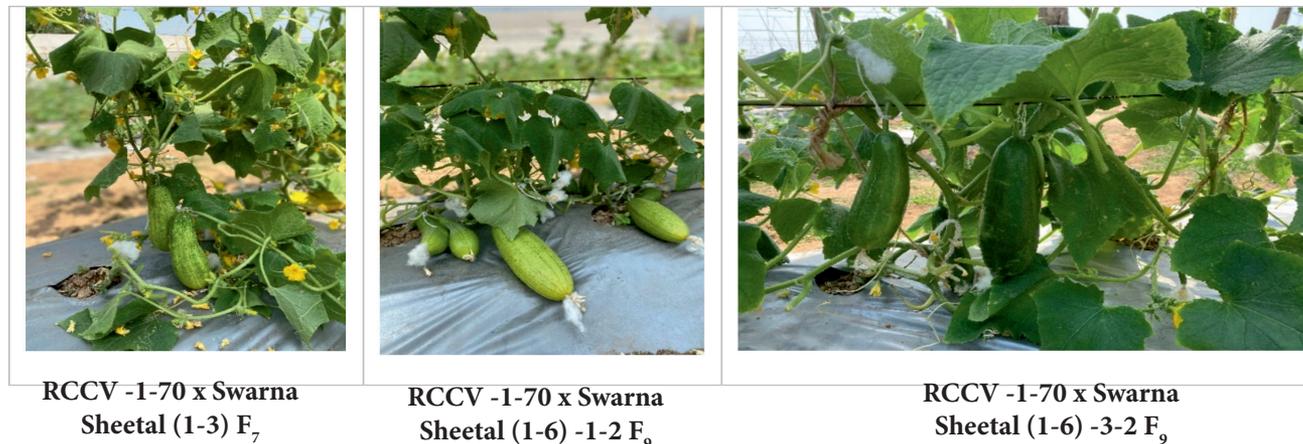

| RCCV -1-70 x Swarna Sheetal (1-3) F_7 | RCCV -1-70 x Swarna Sheetal (1-6) -1-2 F_9 | RCCV -1-70 x Swarna Sheetal (1-6) -3-2 F_9 |

Fig. 8.6 Segregants of cucumber

Morphological and Molecular Characterization of Bottle Gourd Wilt Complex

A survey was conducted in eight different districts of Jharkhand during summer-2022 to assess the disease incidence severity in bottle gourd and 12.6 to 37.5% disease incidence was reported from survey. Minimum wilt incidence was recorded from Ramgarh district while Ranchi was recorded for maximum incidence (Table 8.3). Pathogenicity test confirmed that all the isolates were pathogenic to bottle gourd and isolated organisms were identified as Fusarium oxysporum which cause wilt symptoms after 13-23 days of infection (Fig. 8.7). Plants inoculated with pathogen had typical symptoms of yellowing of leaves, drooping and wilting of plants. Microscope observations revealed the presence of micro-conidia, macro-conidia and chlamydospore like structure in all isolated fungus (Fig. 8.8).

Table 8.3 District wise wilt incidence on bottle gourd during summer, 2022

District	Wilt incidence (%)
West Singhbhum	36.0
East Singhbhum	22.8
Bokaro	17.5
Ramgarh	12.6
Saraikela	27.9
Chatra	15.4
Latehar	23.7
Ranchi	37.5
CD at 5%	7.1

Fig. 8.7 Bottle gourd field affected by wilt

Culture of isolates   Hyphae   Macro-conidia   Micro-conidia
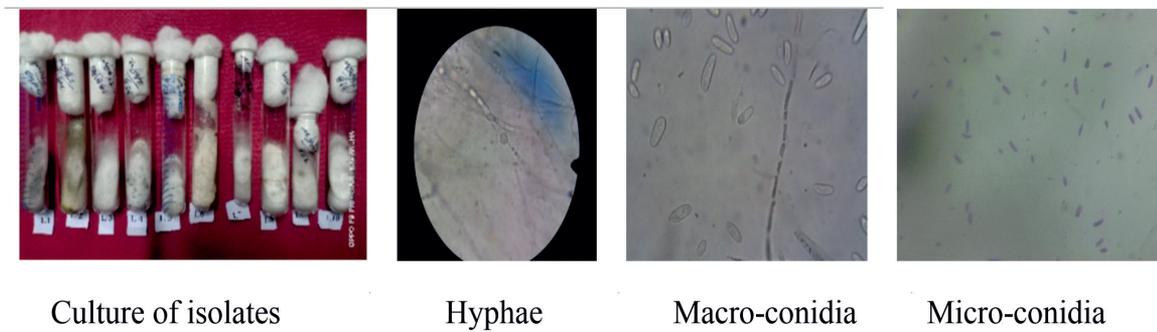
Fig. 8.8 Microscopic structure of fungus collected from different districts

Molecular characterization (18S rRNA gene) and phylogenetic analysis described isolates 7 B (Ranchi), 11B (Garhwa), 37 JK (Bhagalpur) as *Fusarium oxysporum* while the isolate 30JK (Pakur) was identified as *Plectosphaerella cucumerina* (Fig. 8.9).
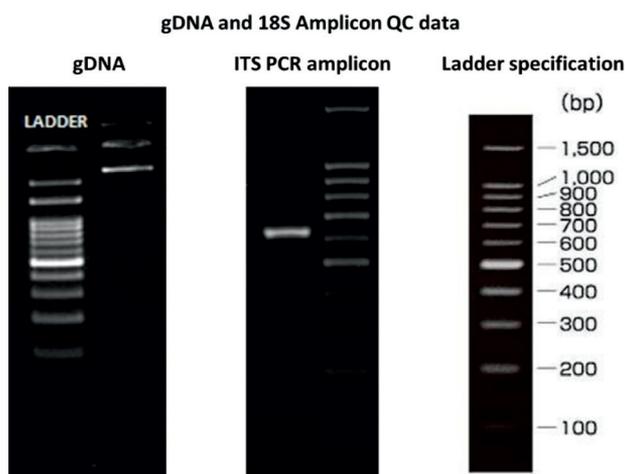

Fig. 8.9 Gel purified PCR product of the isolated fungus sample (37JK- Bhagalpur)

Evaluation of Vegetable Soybean for Horticultural and Nutritional Traits

Thirty-four genotypes of vegetable soybean were evaluated in replicated trial during *Kharif* season of 2022. Among the lines evaluated, the released non-Basmatic variety Swarna Vasundhara and Basmatic line AGS-458 (Fig. 8.10 & 8.11) were top yielders and performed at par which recorded graded green pod yield of 13.14 t/ha and 13.07 t/ha, respectively. The Basmatic line AGS-459 (12.67 t/ha), AGS-331 (12.48 t/ha) and AGS-404 (12.42 t/ha) also exhibited their better performance for graded green pod yield. However, graded green seed yield of 7.12 t/ha, 6.70 t/ha and 5.98 t/ha were recorded for AGS-458, Swarna Vasundhara and AGS-404, respectively. The high yielding line AGS-458 was promising for its earliness and boldness of green seeds as its green pods became ready for 1st harvest in 60 days after sowing and 100-green seed weight was recorded 71.75 g. Regarding nutritional parameter status (Table 8.4), the highest total protein content was recorded in the genotype EC595823 (12.23%) which was on par with the genotypes AGS-447 (12.18%), AGS-292 (11.98%), AGS-357 (11.60%), AGS-338 (11.42%), AGS-339 (11.34%), AGS-331 (11.20%) and AGS-329 (11.14%). AGS-458 had recorded a maximum soluble protein content of 366.89 mg/100g in edible unripe fresh shelled green beans. The genotype EC595824 recorded the maximum crude fat of 12.33% which was followed by AGS-292 (10.69%) and AGS-456 (9.52%). The lipoxygenase enzyme activity which is responsible for beany flavor was the lowest in the genotype AGS-404 (6.33 dA/min/mg soluble protein X 10-3). The highest vitamin C content was recorded in the genotype AGS-461 (25.17 mg/100g) followed by Swarna Vasundhara (24.55 mg/100g). The genotype AGS-458 recorded a maximum total carbohydrate of 11.79%, which was on par with the genotype EC595823 (11.66%). The maximum total sugar content was reported in EC595823 (9.59%), which was at par with Swarna Vasundhara (9.48%) and AGS-458 (9.44%). The maximum non-reducing sugars were reported in the genotype EC595823 (8.12%), which was on par with Swarna Vasundhara (7.81%). AGS-458 had recorded the highest value for reducing sugars of 1.80%, followed by Swarna Vasundhara (1.68%), AGS-610 (1.47%), EC595823 (1.47%) and Karune (1.45%).

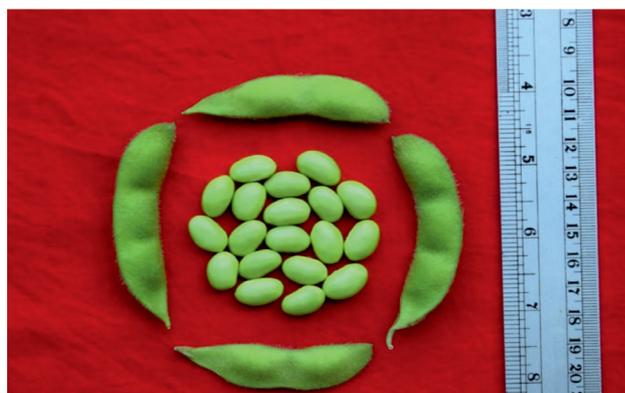**Fig. 8.10 Plant, pod and shelled seed of vegetable soybean variety Swarna Vasundhara**

Fig. 8.11 Plant, pod and shelled seed of promising Basmatic vegetable soybean line AGS-458

Table 8.4 Nutritional parameters recorded from shelled green seeds of thirty four vegetable soybean lines

Nutritional parameters	Range	Mean
Total carbohydrate (%)	6.80-11.79	8.48
Total protein (%)	7.27-12.23	10.16
Total fat (%)	5.01-12.33	8.10
Total sugars (%)	5.33-9.59	7.42
Reducing sugars (%)	0.63-1.80	1.10
Non-reducing sugars (%)	4.59-8.12	6.32
Soluble protein ((mg/100g)	108.02-366.89	181.64
Vitamin C ((mg/100g)	12.91-25.17	17.70
Total Phenol ((mg GAE/100g)	162.80-509.40	292.30
Lipoxygenase enzyme activity (dA/min/mg of protein)	6.33-35.07	14.09

All India Coordinated Research Project (Vegetable Crops)

Tomato

Seven trials were conducted during 2021-22. All entries died due to bacterial wilt in Tomato Cherry Varietal IET and Tomato Varietal (Indetm) AVT-I. Under Tomato (Det) Hybrid AVT-II, 2019/TODHYB-1 was highest yielding (556 q/ha) among the eight entries. Under Tomato (Det) Hybrid AVT-I, 2020/TODHYB-2 was promising with yield 532 q/ha among the seven entries. Under Tomato (Det) Hybrid IET, 2021/TODHYB-1 was promising with yield 140 q/ha among the six entries. Entry 2019/TODVAR-2 was found promising (165.3 q/ha) among the nine entries under Tomato (Det) Varietal AVT-II trial. Among the six entries, 2021/TODVAR-4 was high yielding (136.7 q/ha) under Tomato (Det) Varietal IET trial.

Brinjal

Amongh the six enteries under Brinjal Long Hybrid AVT-I the line, among twelve enteries under Brinjal Round Varietal AVT-II, the line 2019/BRRVAR-7 (256.7 q/ha) and among five enteries under Brinjal Hybrid AVT-II the line 2019/BRRHYB-5(140.0 q/ha) were found promising.

Chilli

Entries 2021/CHIVAR-14 (68 q/ha) among fourteen entries under Chilli Varietal IET, and 2020/CHIVAR-4 (96 q/ha) among thirteen entries under Chilli Varietal AVT-I were found promising.

Cabbage, Cauliflower and Carrot

Three trials one each in cabbage, cauliflower and carrot were conducted during 2021-22. Entries 2021/CABHYB-7 (215.8 q/ha) under Cabbage Hyb IET, 2021/CAUMHYB-7 (51.67 q/ha) under Cauliflower Hybrid (Mid) IET and 2021/CARTHYB-6 (390.78 q/ha) under Carrot Hybrid Tropical IET were found promising.

Cucurbitaceous vegetables

A total of seven trials were conducted in cucurbitaceous vegetables under AICRP(VC) during 2021-22. Among seven entries under Cucumber Varietal IET, entry 2021/CUCUVAR-3 (150.42 q/ha) was found high yielding, among six entries under Cucumber Hyb IET, 2021/CUCUVHYB-7 (145.22 q/ha), among seven entries

under Ridge gourd Var IET, 2021/RIGVAR-4 (120 q/ha), among seven entries under Ridge gourd Varietal AVT-II, 2019/RIGVAR-7 (106 q/ha), among six entries under Sponge gourd Varietal IET, 2021 /SPGVAR-4 (100.3 q/ha), among seven entries under Sponge gourd Var AVT-I, 2020 /SPGVAR -3 (208.3 q/ha) and among seven entries under Pumpkin Var IET, 2021/PUMVAR-5 (141.6 q/ha) were found promising.

Enhancing Nutritional Security of Rural Households through Vegetable Based Nutri Garden

Year-round Nutri-garden vegetable pattern

In 100 m² Nutri Garden model, 20 vegetables were selected for year-round vegetable cultivation (Table 8.5). The year-round vegetable patterns were divided into three cropping seasons per year including *rabi* (mid-October to mid-March), summer/zaid (mid-March to mid-June) and *Kharif* (mid-June to mid-October). Some vegetables were grown only in one season (e.g. carrot in *rabi* only), some were grown in two seasons (e.g. radish in *rabi* and *Kharif*) and some were grown round the year (e.g. kalmi saag and basella). Mustard green, french bean, pea, red amaranth, palak, cauliflower, cabbage, and broccoli were planted in *rabi* whereas yard long bean, okra, pumpkin and brinjal were grown in both summer /zaid and *Kharif* respectively.

Table 8.5 Year-round production pattern and yield in Nutri-garden model (in kg)

S. N	Cropping System	*Rabi*	Summer/Zaid	*Kharif*	Total
1	Mustard green- Radish (leaves+root)- Pumpkin	12.5	15.9	18.6	47
2	Radish (leaves+root)-YLB*-Brinjal	18.6	13.5	14	46.1
3	French bean-Okra-YLB	10.1	18.2	15.3	43.6
4	Pea- Red Amaranth -Brinjal	14.2	10.8	14.3	39.3
5	Sem-Okra-Red Amaranth (Leaves+ Stem)	17.9	16.8	11.6	46.3
6	Palak-YLB-Pumpkin	15.8	14.4	12.6	42.8
7	Carrot-Water spinach-Water spinach	15.2	11.2	14.9	41.3
8	Cauliflower-Basella-Basella	14.8	10	18.2	43
9	Cabbage-Bitter gourd-Okra	15.5	9.8	19.7	45
10	Broccoli-YLB-Okra	15.4	14.5	17	46.9

*YLB-Yardlong bean plot size 12 m²

The highest yield potential was found in cropping system mustard green- radish (leaves +root)-pumpkin (47 kg) followed by broccoli-Yard Long Bean (YLB)-Okra (46.9 kg) and sem-okra-red amaranth (Leaves+ stem) (46.3 kg).

Package of Practices for Upland field Water Spinach (*Ipomoea aquatica Forsk.*) in Bihar

An attempt was made for cultivation of water spinach in upland field conditions and promising results were obtained for the same. This technology can prove to be simple and be cultivated round the year (Fig. 8.12), which can serve as boon for the socio-economic upliftment of farmers
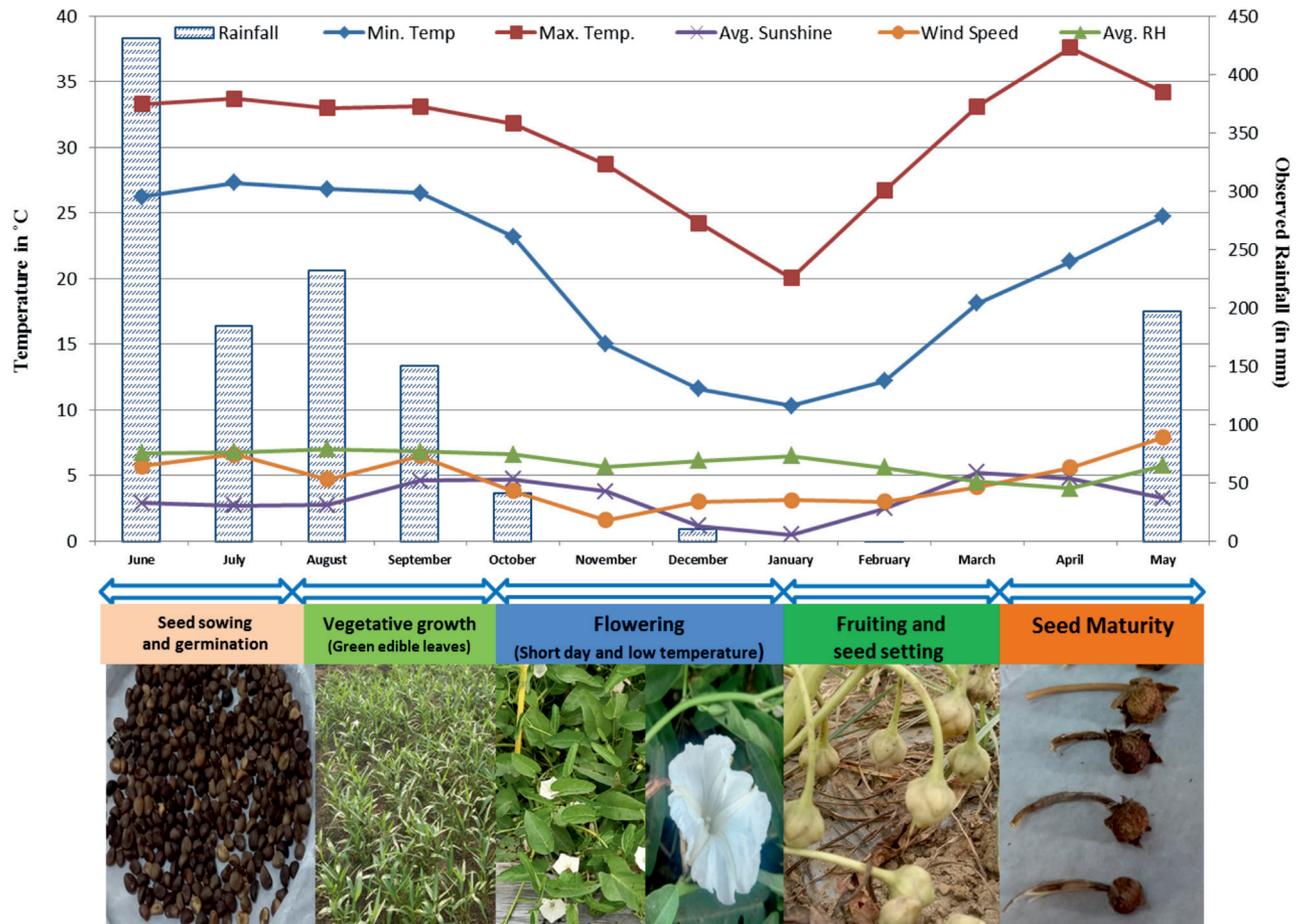

Fig. 8.12 Different growth stages of *Ipomoea aquatica Forsk.* (water spinach) and its relationship with various weather parameters

Genetic Enhancement of Selected Vegetable Legumes for Eastern India

Forty genotypes of dolichos bean including three checks and thirty five genotypes of yardlong bean including five checks were evaluated and characterize in augmented block design. Variability was observed for agro-morphological traits such as earliness, growth habit, maturity time, photosensitivity, pigmentation and disease resistant (Collar rot in dolichos and Yellow mosaic disease (YMD) in yardlong bean). Following are some promising genotypes identified for important traits:

S. No.	Genotypes	Important Traits
Dolichos bean		
1	**RCPD-1**	Extra Early Genotype, Dwarf growth habit, produce 105-110 pods/plant, Synchronous maturity, thus suitable for single picking, Photo-insensitive line, Tolerant to collar rot
2	**RCPD-12**	Medium maturity and prolific bearer (125-130 pods/plant), Pole growth habit, Photo-insensitive line, Anthocyanin rich –line
Tolerant to extreme cold		
3	**RCPD-15**	Medium maturity and prolific bearer (140-145 pods/plant), Pole growth habit, Photo-insensitive line, Anthocyanin rich –line, Resistant to Collar rot
4	**RCPD-16**	Extra Early Genotype (Suitable for Rice-fallow area), Dwarf growth habit, produce 95-110 pods/plant, Synchronous maturity Photo-insensitive line, Tolerant to collar rot
Yardlong bean		
1	**RCPY-1**	Early Genotype, Dwarf growth habit and prolific bearer, Resistance to Yellow mosaic disease, Suitable for growing in pre *Kharif* and Kharif season
2	**RCPY-2**	Early Genotype, Dwarf growth habit, Resistance to Yellow mosaic disease, Suitable for growing in pre Kharif and Kharif
3	**RCPY-15**	Early Genotype, Dwarf growth habit, Long attractive pod, Suitable for growing in pre Kharif and Kharif

RCPD-1

RCPD-12

RCPD-15

RCPD-16

Fig. 8.13 Promising genotypes of dolichos bean

Morphological and Molecular Characterization of Wild Edible Mushroom Germplasm

Surveys were conducted in the forest areas and local markets of Ranchi, Ramgarh, Bokaro, East Singhbhum, Simdega, Latehar, Palamu and Garhwa district of Jharkhand during 2022. Eight wild edible germplasm were collected, identified and preserved (Fig. 8.14). The DNA of the preserved mushroom strains were isolated from the culture and the fragment of ITS region was amplified by PCR. The ITS region sequence was used to carry out BLAST with the database of NCBI Genbank (Fig. 8.15). Morphological and molecular characteristics of mushroom species are presented in Table 8.7.

Pleurotus pulmonarius	*Clitocybe candicans*	*Termitomyces clypeatus*	*Pisolithus arrhizus*
Rugra (White) Pisolithus arrhizus	*Jamun Khukhri (Boletus edulis)*	*Ganoderma lucidum*	*Funalia subgallica*

Fig. 8.14 Strains of mushroom collected, characterised and preserved
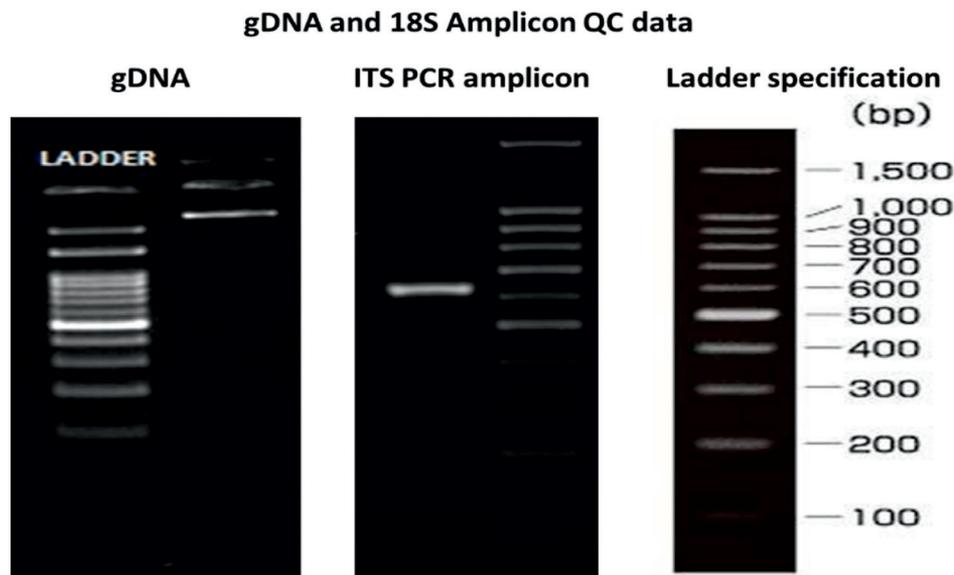

Fig. 8.15 Gel purified PCR product of the isolated mushroom samples *(Pleurotus pulmonarius)*

Table 8.7 Morphological and molecular characteristics of mushroom species

Strain	Order/ Family	Description	Habitat	DNA BLAST analysis
Pleurotus pulmonarius	*Agricales* *Pleurotaceae*	• Cap: 20-25 cm wide • Pileus: Convex to flat • Stipe: short and offset • Spore	Temperate and subtropical forests of India	*99.85%* homology with *Lentinus sajor-caju and Pleurotus pulmonarius*
Clitocybe candicans	*Agricales* *Tricholomatac eae*	• Cap: 1.5 cm wide • Cap and gills: white, off-white. • Stalk: 7-8 cm	Grows in groups, generally on decomposed wood	*98.63%* homology with *Clitocybe candicans*
Termitomyces clypeatus	*Agricales* *Lyophyllaceae*	• Delicious mushroom • Pileus: obtuse in shape with 12 cm diameter. • Stipe: 14 cm	Grows exclusively on termite nests	*99.91%* homology with *Termitomyces clypeatus*
Pisolithus arrhizus (Black Rugra)	*Boletales* *Sclerodermata ceae*	• Shape: Potato type with 2.5-5.0 cm diameter. • Outer layer 1-3 mm thick, tough, blackish in cross section. • Inner tissue brown or black in colour	Soils near various trees including saal, oak tree etc.	*98.68%* homology with *Pisolithus arrhizus and 98.02%* homology with *Scleroderma leave*
Pisolithus arrhizus (White Rugra)	*Boletalaes* *Sclerodermata ceae*	• Shape: Potato type with 1.5-5.0 cm diameter. • Outer layer 1-3 mm thick, tough, whitish in cross section. • Inner tissue brown or whitish in colour	Soils near various trees including saal, oak tree etc.	*98.15%* homology with *Pisolithus arrhizus and 97.47%* homology with *Scleroderma leave*
Boletus edulis (Jamun Khukhri)	*Boletalaes* *Boletaceae*	• Fruiting body: 300g, • Diameter: 13 cm. • Cap: convex to flat, brown to olive with bluish discoloration	Grows any time after rain. Found on soil near Jamun, mango tree.	--
Ganoderma lucidum (Rishi Mushroom)	*Polyporalese* *Ganodermataceae*	• basidiocarps that are large, perennial, woody brackets • smooth whitish surface • Lower area dark brown to black • Rings on lower area.	Typically grow in fan like form on the trunks of living or dead trees	*100%* homology with *Ganoderma lucidum.*
Funalia subgallica	*Polyporalese* *Polyporaceae*	• Strong mushroom odour when fresh, • Hard corky and light in weight when dry	Grows on trunks of dead trees. Generally found in tropical and sub-tropical regions	*99.91%* homology with *Funalia subgallica.*

Evaluation of Oyster Mushroom on Wheat and Paddy Straw

Advance varietal trial of ten high yielding strains of Oyster Mushroom (*Pleurotus pulmonarius*) grown on wheat straw was conducted from December, 2021 to February, 2022 (Fig. 8.16). Among the evaluated strains, the highest biological efficiency was recorded in PL-21-06 (78.2 %) which was statistically at par with PL-21-05 (75.4 %). Highest weight of fruiting body was recorded in PL-21-05 (11.4 g) followed by PL-21-09 (11.0 g).

The best strains identified for paddy straw are shown in Fig.18. On paddy straw, highest biological efficiency was found in PL-21-10 (72.0 %) which was statistically at par with biological efficiency recorded for the strains PL-21-06 (70.2 %) and PL-21-09 (68.8 %). Highest weight of fruiting body was recorded in PL-21-05 (15.6 g) followed by PL-21-07 (12.0 g). Time taken for first harvest was minimum in strain PL-21-06 (29.0 days) followed by PL-21-05 (29.2 days) (Table 8.8).

Table 8.8 Performance of strains of *Pleurotus pulmonarius* on wheat and paddy straw

| Strains	Yield (kg/100kg dry straw)		Time to first harvest (day)		Average weight of fruiting body (g)	
	Wheat straw	Paddy straw	Wheat straw	Paddy straw	Wheat straw	Paddy straw
PL-21-01	68.4	55.6	30.8	31.8	7.8	9.0
PL-21-02	71.8	62.8	31.4	30.8	8.2	10.0
PL-21-03	61.7	63.6	30.4	31.6	9.6	10.0
PL-21-04	65.8	66.6	31.0	30.4	9.4	10.0
PL-21-05	75.4	67.6	28.8	29.2	11.4	15.6
PL-21-06	78.2	70.2	32.2	29.0	9.4	11.0
PL-21-07	64.4	64.0	33.4	31.6	7.6	12.0
PL-21-08	66.4	66.6	34.6	35.6	9.0	9.0
PL-21-09	67.6	68.8	31.8	31.0	11.0	10.0
PL-21-10	71.0	72.0	31.0	34.6	8.8	9.6
CD at 5 %	4.5	4.7	NS	3.7	1.5	1.9

PL-21-10

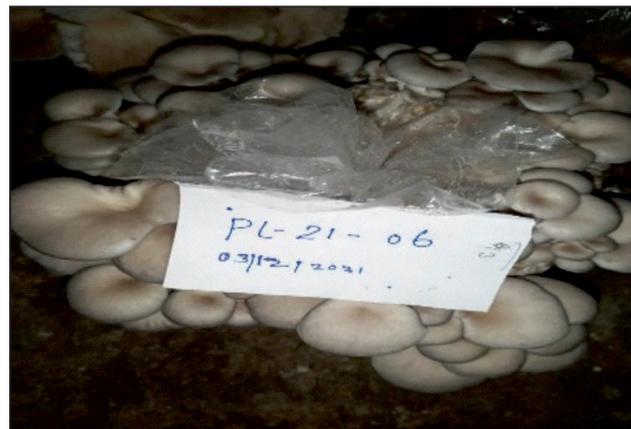**PL-21-06**

PL-21-02
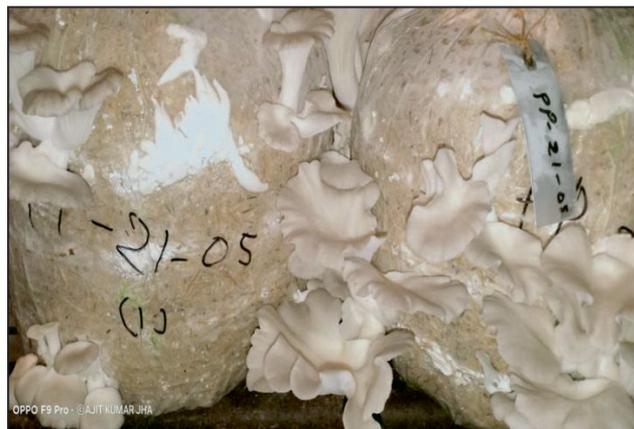
PL-21-05

Fig. 8.16 Promising strains of *Pleurotus pulmonarius* on wheat straw at Ranchi, Jharkhand

PL-21-05

PL-21-06

PL-21-09

PL-21-10

Fig. 8.17 Promising strains of *Pleurotus pulmonarius* on paddy straw at Ranchi, Jharkhand

⑨ Makhana

Research Centre for Makhana (RCM), established in the year 2002, has made immense contributions towards improving the productivity and quality of this fast growing super food, enhancing thereby farmers' income and livelihood opportunities through cultivation, processing and value addition of this high value aquatic crop. Swarna Vaidehi, the first ever variety of Makhana, was developed by the RCM which has yield potential of 2.8-3.0 t/ha as compared to 1.4-1.6 t/ha observed with conventional cultivars in farmers field. Field cultivation of Makhana was introduced (Fig. 9.1) with as less as 30 cm of water depth requirement compared to conventional pond system of cultivation, with better control on nutrients and pest management and much higher harvesting efficiency. The research and extension efforts undertaken by RCM, Darbhanga, coupled with growing commercial interest in Makhana, the area under Makhana cultivation has more than doubled in past 5 years (From 15,000 ha to nearly 35,000 ha). Productivity has increased from 14-16 q/ha to over 25 q/ha. Net income from Makhana farming rose from Rs. 45-50,000/ha to more than Rs. 1.25 lakh/ha. Number of farmers and entrepreneurs has also witnessed tremendous growth over the past 5 years making Makhana production and processing an attractive option of livelihood improvement. Makhana has been proved to be 5-7 times more remunerative than other conventional crops like paddy. Makhana is now being grown in cropping system mode, boosting cropping intensity up to 300%. Makhana based IFS models have been developed which improved food, nutrition, income, and employment security of the resource poor farmers in eastern India and beyond.

Fig. 9.1 Field cultivation of makhana and its harvesting at RCM, Darbhanga

Effect of Secondary and Micronutrients on Yield and Quality of Makhana

A field experiment was conducted at ICAR-RCER, RCM, Darbhanga, India, with seven treatment combinations laid out in randomized complete block design with three replications. The treatments comprised of T1: control (no fertilization); T2:100% NPK @100, 60 and 40 kg/ha applied through urea, DAP and MOP, respectively; T3: NPK+Mg @ 5.0 kg/ha applied through MgSO4; T4-NPK+Zn@ 5.0 kg/ha applied through ZnSO4; T5 : NPK+Cu@ 0.1% foliar spray with CuSO4 solution; T6: NPK+B @ 1.0 kg/ha applied through borax, and T7: NPK+Mg+Zn+Cu+B, with the doses and sources as described in treatments T2-T6. Nutrient applications did improve the seed yield and quality of fox nut, though there were differential responses to primary (NPK), secondary (Mg) and micronutrients (Zn, B & Cu) applications. Soil application of NPK combined with foliar application of Cu (T5) produced better results than the nutrients' combinations with NPK. Sole foliar application of Cu proved to be more effective than the soil application of Mg, Zn or B in terms of yield improvement. Combining all four nutrients with NPK (T7) led to the best yield improvement in the study (Table 9.1).

Table 9.1 Effect of nutrients' application on seed yield and yield parameters of fox nut

| Treatments	Number of fruits/ plant	Number of seeds/ fruit	Test weight (100 seed wt.) (g)	Seed yield (t/ha)
T1 (Control)	7.33[b]	55.3[b]	73.2[d]	1.81[e]
T2 (NPK)	7.63[ab]	59.1[b]	84.6[c]	2.28[d]
T3 (NPK+ Mg)	7.78[a]	66.3[a]	93.1[b]	2.65[c]
T4 (NPK+ Zn)	7.76[a]	67.2[a]	92.6[b]	2.71[c]
T5 (NPK+ Cu)	7.86[a]	68.3[a]	103.8[a]	2.93[b]
T6 (NPK+ B)	7.68[a]	67.7[a]	91.2[b]	2.66[c]
T7 (NPK+Mg +Zn+Cu+B)	7.82[a]	71.3[a]	109.5[a]	3.27[a]
CD at P = 0.05	0.41	5.3	6.2	0.21

Values within a column with common letter/s as superscript are not significantly different at P=0.05

Primary (NPK), secondary (Mg) and micronutrients' (Zn, B, and Cu) application also caused improvement in their respective concentrations in seed and soil. Except for Fe and to some extent K, concentrations of protein (ranging from 9.45% to 10.35%) and all other nutrients under study showed significant improvement over control, though differences in treatments' effects (T2-T7) on quality parameters were not as discernible as that on seed yield at P≤0.05. It may be noted that increase in yield are usually accompanied by concurrent decline in plant nutrient concentrations due to dilution effect. In the present study, however, application of N, Mg and micronutrients denied any such possibility of reduced nutrient content in seed even at higher levels of crop yield, which can be construed as a quality sustaining effect of secondary and micronutrients in fox nut.

Effect of Nutrient Application Methods on Makhana Productivity

In order to explore the effect of nutrient application methods on Makhana productivity, a field experiment was conducted with nine treatment combinations comprised of: T1:Control: (no application of nutrients); T2: 100% RD of NPK (@100, 60, 40kg/ha, respectively, through soil application); T3: 50% RD of NPK (soil) + Foliar spray of NPK (0.5% urea, 1% DAP, 1% MOP); T4:T3+ Mg spray (as 1% MgSO₄ solution; T5: T3+ Zn spray (as 0.2% ZnSO₄ solution); T6: T3+ Cu spray (as 0.1% CuSO₄ solution); T7: T3+ B spray (as 0.4% B through Borax); T8: T3+ Ni spray (as 0.2% NiSO₄. 7H₂O Solution); T9: T3+ Mg+Zn+Cu+B+Ni (dose & source as above).

Soil application of NPK improved Makhana yield by 23%, while its soil + foliar application improved the yield
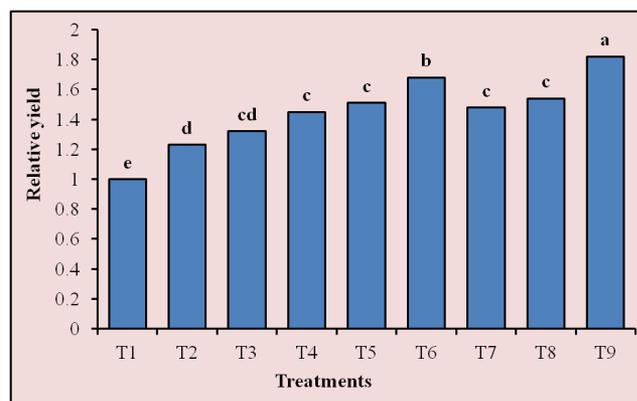
Fig. 9.2 Effect of Nutrient application methods on Makhana Productivity

by 32%. NPK (T3)+ Mg spray improved yield by 45%, whereas NPK+ micronutrients spray enhanced seed yield by 48-68%. Application of NPK + Mg + micronutrients spray (T9) led to a yield improvement of 82% (Fig. 9.2).

Studies on Soils in Relation to Makhana Production in North Bihar

Analysis of 36 composite soil samples collected from the Makhana fields of north Bihar, and the correlation of soil properties with Makhana yield on respective soils showed the strongest correlation of seed yield with soil organic carbon (r = 0.92) and DTPA-Cu (r = 0.92) followed by DTPA-Zn (r = 0.88), available N (r = 0.86), Hot water extractable B (r = 0.84) and available P (r = 0.81). The range of soil pH was not sufficient to get a meaningful correlation with Makhana yield. These results suggest the necessity of organic manure, N and P application to improve Makhana yield in soil conditions of North Bihar. Among the micronutrients, Cu, Zn and B were found most important in determining the Makhana yield in soils of north Bihar.

Nutritional Quality Evaluation of Water Chestnut Growing under diverse Nature of Water Bodies

The soils of the water chestnut field/pond have exhibited the soil properties as pH 6.5-7.5, EC 0.24-0.40 dS m⁻¹, organic carbon 0.58-0.85%, Av. N 230-425 kg/ha, Av. P 32-35 kg/ha and Av. K 237-325 kg/ha (Table 9.2). The above soil properties revealed that sole water chestnut pond or water chestnut integrated with fish maintained the soil reaction in neutral range which could be maintained due to continuous flooding of soil and deposition of organic matter into the soil. The electrical conductivity was also recorded far below the hazardous level. The organic carbon value ranged in the sufficiency level i.e., above the critical concentration. Water chestnut cum fish integration was highly beneficial in maintaining the available phosphorus and potassium contents in optimum level of fertility of the pond soil.

Table 9.2 Soil fertility status of water chestnut (Mean data of 1ˢᵗ year)

Treatments (Location)	pH	EC (dS/m)	Org. C (%)	Average N (kg/ha)	Average P (kg/ha)	Average K (kg/ha)
Darbhanga						
Office water chestnut field	7.3	0.24	0.58	230	32	237
Near RCM	7.5	0.32	0.62	250	38	252
Gopalpur village, Sadar block	7.5	0.30	0.58	245	40	260
Ranipur Pond (Opposite RCM, Office)	6.8	0.40	0.85	425	55	325
Sundarpur Sahani tola	6.5	0.38	0.80	410	52	285
Bira Sundarpur Darbhanga	6.5	0.40	0.75	386	48	275
Patna city						
Zero Mile New Bypass Road	6.5	0.38	0.80	410	52	285
Opposite of Ford Hospital, Khemnichak	6.8	0.40	0.85	425	55	325
Near Patna Central School	6.5	0.38	0.80	410	52	285

Response of Nutrients on Productivity of Water Chestnut and Indian Lotus

Nutrient uptake pattern of lotus showed that leaf tissues contained comparatively the greater concentration of nitrogen (N) and magnesium (Mg). The petioles part of the plant recorded maximum content of potassium (K) and sulphur (S). Among the primary nutrients, only sulphur was concentrated in maximum amount in the seed tissues. Except the major transfer of nutrient elements such as N and P to the seed tissues, the other primary (K) and secondary nutrients (Ca, Mg & S) were observed to be least transported in it. In contrary to seed tissues, the fruit sheath was noted to contain the lowest concentration of N and P. The Ca accumulated in maximum quantity in fruit sheath part of lotus plant. In case of accumulation of micronutrients, the maximum concentrations of Fe and Mn were registered with leaf tissues while the same was lowest in seed tissues. Pertaining to accumulation of Cu and Zn, the seed coat tissues ranked the highest one. The cultivation practices of Indian Lotus have been standardized. The yield potential of the plant has been recorded nearly 0.4 t/ha. The best dose of primary nutrients of NPK is 120:60:60 kg/ha.

Nutrient accumulation pattern in different parts of lotus:

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 (29.2 mg/kg > fruit sheath (25.6 mg/kg) > leaf (23.2 mg/kg) > seed (22.6 mg/kg) > petiole (16.2 mg/kg)

Zn: seed coat (105.8 mg/kg) > petiole (88.7 mg/kg) > fruit sheath (71.4 mg/kg) > seed (69.7 mg/kg) > leaf (61.9 mg/kg)

10 Medicinal and Aromatic Plants

Development of Medicinal Plants-Based Agroforestry Model

Screening of twenty-three species of medicinal plants was carried out under two different multipurpose tree (MPT) based agroforestry systems (Teak+Karanj and Mahogony+Karanj) for rainfed condition (Table 10.1). Among all the medicinal plants, species like Giloe, Tulsi, Sadabahar, Hadjor, Aparajita, Shatavari, Vidanga and Vasaka performed well without any mortality. While highest mortality (> 90%) was recorded in Spearmint, Kalmegh and Punarnava. Based on the plant growth performance and market value, four medicinal plants *viz.*, Giloe, Shatavari, Hadjor, and Sarpagandha were selected for plantation and under Teak+Karanj and Mahogony+Karanj systems (Fig. 10.1 and Fig. 10.2).

Fig. 10.1 Medicinal plant block for screening best performing species at Ranchi

Table 10.1 Growth performance of medicinal plants under rainfed conditions

Species	Scientific Name	Family	Plant type	Plant mortality (%)	Shoot:Root ratio
Anantmool	*Hemidesmus indicus*	Periplocaceae	Perennial creeper	58.33	3.03
Aparajita	*Clitoria ternatea*	Fabaceae	Perennial	0.00	12.49
Ashwagandha	*Withania somnifera*	Solanaceae	Annual herb/ small shrub	46.15	2.04
Brahma manduki/ Beng sag	*(Centella asiatica)*	Apiaceae	Perennial	46.67	2.85
Bhringraj	*Eclipta prostrata*	Asteraceae	Annual herb	90.00	2.43
Bryophyllum	*Kalanchoe pinnata*	Crassulaceae	Perennial	0.00	9.61
Gandh Prasarini	*Paederia foetida*	Rubiaceae	Perennial climber	83.33	7.46
Giloe/ Giloy	*Tinospora cordifolia*	Menispermaceae	Perennial climber	0.00	8.75
Hadjor	*Cissus quadrangularis*	Vitaceae	Perennial	6.67	9.75
Hathikan/ Hathisura	*Leea macrophylla*	Vitaceae	Perennial	8.33	8.60
Insulin	*Costus igneus*	Costaceae	Perennial	0.0	0.81
Kali Haldi	*Curcuma caesia*	Zingiberaceae	Perennial herb	0.00	2.47
Kalmegh	*Andrographis paniculata*	Acanthaceae	Perennial	96.00	2.25
Spearmint	*Mentha spicata*	Lamiaceae	Perennial	91.67	3.48

Species	Scientific Name	Family	Plant type	Plant mortality (%)	Shoot:Root ratio
Punarnava	*Boerhavia diffusa*	Nyctaginaceae	Perennial creeper	94.00	4.93
Vasaka (Ram)	*Adhatoda vasica*	Acanthaceae	Perennial	0.00	7.40
Sadabahar	*Catharanthus roseus*	Apocynaceae	Perennial	0.00	9.32
Sarpagandha	*Rauvolfia serpentina*	Apocynaceae	Perennial	43.33	2.57
Shatavari	*Asparagus racemosus*	Asparagaceae	Perennial climber	0.00	0.91
Tulsi (Shyam)	*Ocimum tenuiflorum*	Lamiaceae	Perennial	0.00	8.88
Van Kapas	*Urena sinuate*	Malvaceae	Perennial	33.33	8.00
Vana Tulsi	*Ocimum gratissimum*	Lamiaceae	Perennial	0.00	2.51
Vidanga	*Embelia ribes*	Primulaceae	Perennial climber	0.00	3.59

Shatavari

Hadjor

Vasaka

Sadabahar

Tulsi

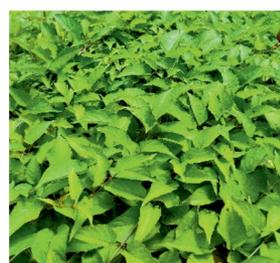
Aparajita

Giloe

Sarpagandha

Hathikan

Gandh Prasarini

Van Kapas

Bryophyllum

Fig. 10.2 Some important medicinal plants

11 Farming System Research

Development of Location-Specific IFS Models for Small & Marginal Farmers of Bihar

One acre integrated farming system (IFS) model comprising crop + goat + poultry + mushroom and a two-acre IFS model (crop + dairy + fish) were developed for midland irrigated and lowland irrigated areas where more than 80% of farmers have an average land holding size of 0.32-0.48 ha and could not fulfill their family needs by growing crops alone. In developed models, allocation of the area under crops, livestock, fishery, horticulture, and other enterprises has been made in such a way that it could fulfill demand and needs for farm families (nutrition and income) and sustain system (nutrient/resource recycling) at the same time. Under crop components, rice-wheat, rice-maize, rice-gram, and rice-mustard-moong (cereal-based cropping system) and cowpea-okra-tomato, okra-cabbage-cucurbits-cabbage, and okra-cauliflower-onion (vegetable-based cropping systems) were followed. Around field bunds, pigeon pea plantation was done to enrich the soil and to supplement additional protein to the farm families. Under the one-acre model, the cowpea-cauliflower-onion cropping system along with poultry+mushroom+goatry fetched the highest net income of Rs. 1,09,528/annum (Rs. 300/day, B: C: 2.1) with an initial investment cost of Rs.1,59,970/-
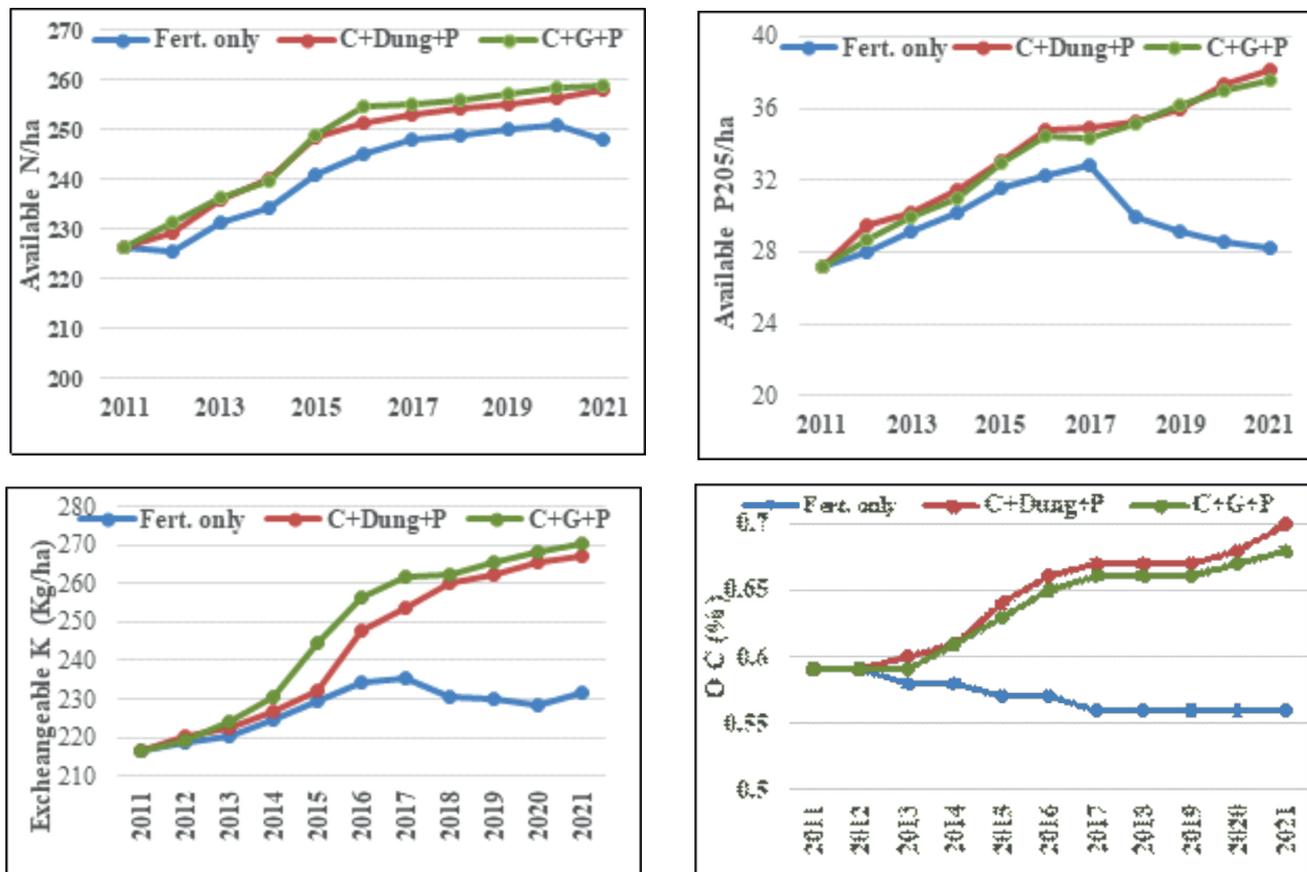

Fig. 11.1 Change in soil fertility status due to nutrient

Likewise, under the two-acre IFS model, a net return of Rs. 1,69,620/annum (Rs. 465/day, B:C, 1.9) was achieved with an initial investment of Rs.2,05,500. An additional employment of 85 and 134 man-days were generated under the one-acre and two-acre IFS model, respectively. Studies on nutrient recycling under one acre IFS model had 47.2 kg of N, 36.8 kg of P, and 40.6 kg of K, while the two-acre IFS model had 68.6 kg of N, 52.7 kg of P and 44.7 kg of K to the soil from farm waste recycling within system. NPK & organic carbon (OC) status of soil in IFS systems was found in an increasing trend over rice-wheat systems where organic carbon and NPK status was in decreasing trend (Fig. 11.1).

IFS model (crop + dairy + fish) was developed for midland irrigated and lowland irrigated areas where more than

Table 11.1 GHG emission in IFS models (CO$_2$ eq.) (kg)

C-source	Enterprises	CO2-e (Two-acre IFS)	CO2-e (One-acre IFS)
Cropping System			
CS1	Rice-wheat	84.9	145.6
CS2	Rice-maize	59.3	130.1
CS3	Rice-lentil	44.1	111.7
CS4	Rice-linseed	50.8	98.3
	Fruit-vegetable crops	128.2	69.6
	Paddy-special	75.6	151.2
	Goat/Livestock	396.9	1552.3
	Poultry/Duck	542.5	4.5
	Kitchen garden	170.8	178.7
	Pond- fishery	0.0	828.0
C- sink	Agroforestry-sink	1378.6	2439.0
	Biomass added	1433.2	2500.5
	Total SOURCE	1553.2	3270.1
	Total SINK	2811.8	4939.5

80% of farmers have an average land holding size of 0.32-0.48 ha and could not fulfill their family needs by growing crops alone. In developed models, allocation of the area under crops, livestock, fishery, horticulture, and other enterprises has been made in such a way that it could fulfill demand and needs for farm families (nutrition and income) and sustain system (nutrient/resource recycling) at the same time. Under crop components, rice-wheat, rice-maize, rice-gram, and rice-mustard-moong (cereal-based cropping system) and cowpea-okra-tomato, okra-cabbage-cucurbits-cabbage, and okra-cauliflower-onion (vegetable-based cropping systems) were followed. Around field bunds, pigeon pea plantation was done to enrich the soil and to supplement additional protein to the farm families. Under the one-acre model, the cowpea-cauliflower-onion cropping system along with poultry +mushroom +goatry fetched the highest net income of Rs. 1,09,528/annum (Rs. 300/day, B:C 2.1) with an initial investment cost of Rs.1,59,970/only.

To know the environmental impact, greenhouse gas emission (CO$_2$-e) were estimated with help of GHG Estimator software developed by IIFSR, Modipuram. For this study, C-source and C-sink were calculated upon from crop biomass, residues and inputs used within each system of IFS in both the models and it was found that both IFS models are carbon negative (Table 11.1) which advocates that system is eco-friendly and still there is scope for addition of some more enterprises to enhance productivity and income per unit area.

Location Specific Integrated Farming System Model for Rainfed Ecosystems

An IFS model (crop + horticulture + dairy) was developed for the rainfed ecosystems of Eastern plateau and hill region with the objective to ensure food security of a family under rainfed ecosystem. The model (Fig.11.2) had livestock (2 cow + 2 calves), fruit crops (guava and badhal) integrated with cereals, pulses and oilseeds. During 2022, one acre rainfed area was found sufficient for fruits and milk for fulfilling the daily dietary requirement of a family whereas production of cereals, oilseeds, pulses and vegetable were insufficient. The rainfall received during June and July was 49% of the normal rainfall for that period. There was no winter season rainfall after October which hampered the

germination of *rabi* crops. The one-acre area yielded 230 kg guava, 821.9 l milk, 43 kg pulses, 366 kg cereals, 13 kg oil from oilseeds and 225 kg vegetables (Table 11.2). It was found that during Kharif, maximum area should be devoted for cultivation of cereals (38%) followed by pulses (30.6%). In *rabi* season, maximum area should be allotted under pulses (48.1%) followed by oilseeds (25.5%) (Fig. 11.3). The total manure production was 5.4 t/year while the cow urine production from two cow and two calves was recorded as 4123 l/year. The total green fodder production was 3.4 t/year which can further be utilized for energy production or for nutrient supply to field
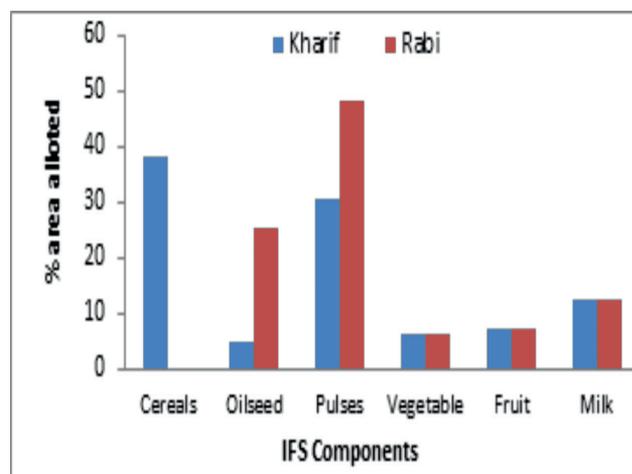

Fig. 11.3 Percent area allotment under different components in one-acre model.

Optimization of Land Allocation of Different Integrated Farming Systems Components to Maximize Resource use Efficiency and Net Income.

Data were collected from Mirzapur village of Nalanda, Bihar for optimization of net income in the IFS model. The net income was Rs.1,55,525/ before the optimization of land allocation. After the optimized reallocation of land among different components in IFS, the optimized net income was Rs.1,89,570/ which increased by 22% as well as resource recycling from one component to another component was also found, which reduced input cost and overall resource use efficiency was enhanced. Linear programming using the lpsolve algorithm in 'R' software was used as optimisation technique.

Objective function: maximize net income (ZNI)

Max: ZNI = ICXAC +IHXAH + ILXAL + IFXAF

Four components *viz.* crop, horticulture, livestock and fishery are being taken in this IFS model but components/enterprises may vary according to requirement where IC, IH, IL and IF are the net income from the crop, horticultural crop, livestock and fish. Ac: Area in the crop, AH: Area in horticulture, AL: Area in livestock, AF: Area in fish, LC: Labour in crop (in mandays), LH: Labour in horticulture, LL: Labour in livestock, LF: Labour in fish, CO: Outside purchase in crop, HO: Outside purchase in horticulture, LO: Outside purchase in livestock, FO: Outside purchase in fish, CR: Recycled waste in crop, HR: Recycled waste in horticulture, LR: Recycled waste in livestock, FR: Recycled waste in fish

Fig.11.2 Site view of the Integrated Farming System unit

Table 11.2 Production, deficit and surplus of produce from 1-Acre IFS model under rainfed ecosystems

IFS Components	Production (Kg)	Requirement of a family (kg)	Deficit (-) / surplus (+) (kg)
Cereals	366	438.0	-72
Oilseed	13	43.8	-30.8
Pulses	43	104.0	-61
Vegetable	225	328.5	-103.5
Fruit	230	146.0	+84
Dairy unit			
(Cow + fodder)	822.0 L milk	584.0 L milk	+238.0 L milk

Table 11.3 2-Acre model data from Mirzapur village, Nalanda

Variable	Crop	Horticulture	Livestock	Fish	Constraints
Land (acre)	1.2	0.3	0.08	0.42	≤ 2
Labour (mandays)	52	45	115	38	≤ 250
Outside purchase	3500	7000	16000	4000	≤ 30500
Recycled within the system	3000	5000	26000	6000	≤ 40000
Gross income (Rs.)	54725	78840	117850	96750	348165
Total input cost (Rs.)	32860	43980	77940	37860	192640
Net income (Rs.)	21865	34860	39916	33795	155525

Table 11.4 Optimized area and income from different components of IFS (Mirzapur village, Nalanda)

Components	Optimized area	Total input cost	Optimized gross income	Optimized net income
Crop	1	26750	49860	23110
Horticulture	0.4	52470	96450	43980
Livestock	0.06	58860	98780	29920
Fish	0.54	54410	136970	82560
Total	**2.0**	**192490**	**382060**	**189570**

Objective function: maximize net income (ZNI)

Max: ZNI = 18220XAC +116200XAH + 498950XAL + 80464XAF

Area (acre) allocated: 1.2 (crop), 0.3 (horticulture), 0.08 (livestock), 0.42 (fish)

With an input cost of RS. 1,92,640 gross income was Rs. 3,48,165 and net income was found to be Rs. 1,55,525. When the allocated area was optimized changed, reallocated areas in acres were 1.0 (crop), 0.4 (horticulture), 0.06 (livestock), 0.54 (fish), optimized gross income was Rs. 3,82,060 and net income calculated from R programming model was Rs.1,89,570. Income was increased by Rs.34, 045 (22%) in the 2-acre IFS model after optimized reallocation of land among different components of IFS (Table 11.3 & 11.4).

Developing Precision Nutrient Management Protocols for Rice-Wheat and Rice-Maize systems in Indo-Gangetic Plains

Rice and maize are major consumers of nitrogen fertilizer and need optimization in terms of input use efficiency. Grain quality should also be emphasized for achieving nutritional security. Under this context, a field experiment was conducted with different doses of fertilizer N for rice and maize. Fertilizer N was applied at rates of 0, 40, 80, 120, 160, 200, and 240 kg/ha (N0–N240). An increase in grain yield in rice and maize was observed up to 160 kg/ha and beyond that, no gain in grain yield was noted (Fig.11.4). N content of grain increased with N rates and the highest rice grain N content of 1.49% was noted for N240 treatment which was at par with N200 (1.42%) but significantly higher than others by 13-32% (Fig. 11.4). With an increase of each kilogram of N, grain N content increased by 14 and 20 μg for rice and maize, respectively. The leaf N content registered a decreasing trend with the progress of crop growth for both rice and maize. The decrease in leaf N content between the first and last measurements was 33 and 20% for rice and maize, respectively. The agronomic efficiency (AE) of N initially increased with an increase in the rate of fertilizer N followed by a decrease with higher N doses (Table 11.5). Unlike the AE, the partial factor productivity (PFP) of N decreased gradually with an increase in the rate of fertilizer N. Maize noted a higher PFP than rice up to N80, and beyond that rice yielded higher than maize. The chlorophyll content of flag leaves also registered an increasing trend with an increasing rate of fertilizer N. The N240 resulted in 1.7, 1.7 and 1.9 times higher chlorophyll content than N0 at 39, 49 and 59 days after transplanting, respectively in rice whereas the same was 1.2, 1.3 and 2.8 times at 63, 73, and 82 days after sowing for maize.
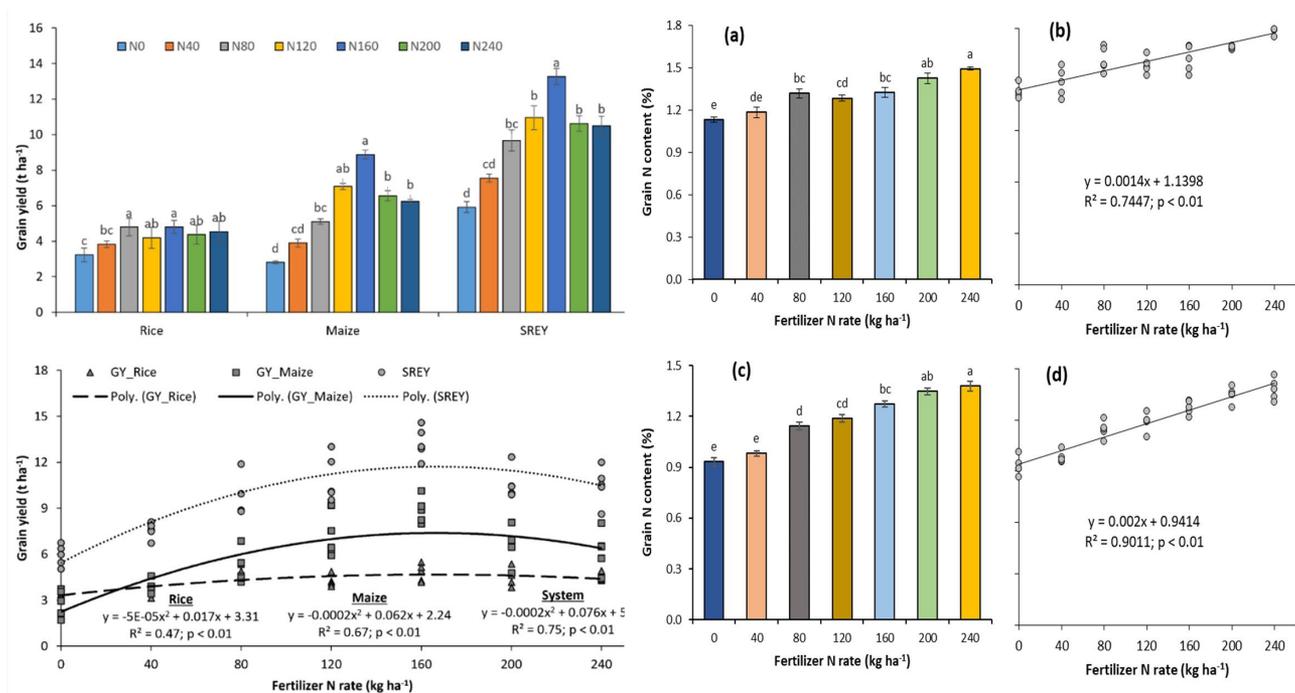
Fig. 11.4 Effect of different application doses of fertilizer N on yield of rice, maize and system, best fit regression to describe the interrelationship between yield and doses of fertilizer N. Grain N content of rice (a & b) and maize (c & d) as affected by different doses of fertilizer N.

Table 11.5 Agronomic use efficiency & partial factor productivity of N as affected by doses of N fertilizer

Treatments	Agronomic use efficiency (kg yield per kg N)			Partial factor productivity (kg yield per kg N)		
	Rice	Maize	System	Rice	Maize	System
N40	14.9ab	50.6a	40.8ab	97.5a	95.6a	188.7a
N80	19.6a	40.3ab	46.8a	63.8b	59.9b	120.8b
N120	8.0b	43.3ab	41.9ab	59.0c	35.0b	91.2c
N160	9.8ab	43.7a	45.9a	55.5cd	30.0b	82.9c
N200	5.7b	23.4bc	23.5b	32.8d	21.8c	53.1d
N240	5.5b	18.2c	19.1b	26.0d	18.9c	43.7d
Mean	10.6	36.6	36.4	55.8	43.5	96.7

Irrigation and Nitrogen Management of Diversified Rice Based Cropping System in Middle Indo Gangetic Plains

Crop diversification is considered as an important tool for acceleration of agricultural growth in India by promoting food and nutritional security, income and employment generation, poverty alleviation, judicious use of natural resources and ecological management. Diversification of rice-wheat cropping system may improve the productivity and sustainability of agricultural production in the Indo-Gangetic Plain region (IGPR), but the choice of alternative sequences to be used requires integrated assessment of various crop sequences. Based on the findings of the previous experiment on diversification of rice-wheat cropping system with vegetables; two most remunerative diversified cropping systems were chosen for study. An experiment was initiated during *Kharif* 2021 at the main farm of ICAR-RCER, Patna to optimize the nutrient sources especially nitrogen for different crops under diversified rice-based cropping systems

and to evaluate system productivity, water productivity and profitability of the proposed diversified rice-based production system. The field experiment was carried out in Split-split plot design with three replications. Short duration rice variety Swarna Shreya was cultivated as *Kharif* crop followed by vegetables and wheat as *rabi* crops, and greengram as summer crop. Treatments comprised of three cropping systems i.e. Rice-wheat-green gram, Rice-cauliflower- spinach- greengram and Rice-broccoli- leafy onion-greengram; two methods of irrigation i.e. surface irrigation and mini sprinkler irrigation with three methods of nitrogen application i.e. (i) Farmer's practice (100% Recommended dose of Nitrogen (RDN) through mineral fertilizer), (ii) 75% N through mineral fertilizer + 1 foliar spray through Nano urea and (iii) 50% N through mineral fertilizer + 2 foliar spray through Nano urea. Rice crop was grown with surface irrigation only.

Results revealed that yield of rice and greengram were not affected due to diversification of cropping systems but significant differences were found in yield of *rabi* crops (Table 11.6). As a result, cropping systems having vegetables as *rabi* crop produced significantly higher yield than rice-wheat-greengram system. The system productivity of rice-cauliflower-spinach- greengram system was significantly superior (39.38 t/ha) over other cropping systems and followed by rice-broccoli-leafy onion - greengram (29.60 t/ha). Rice-wheat-greengram resulted in least system productivity among the three cropping systems (12.91 t/ha).

In case of rice and greengram application of 50% recommended dose of nitrogen (RDN) through mineral fertilizer along with two spray of nano urea produced similar yield as that with 75% RDN with one spray of nano urea through mineral fertilizer and 100% recommended dose of nitrogen through mineral fertilizer. But in case of *rabi* crop, significantly higher yield was produced when 50% recommended dose of nitrogen was applied through mineral fertilizer along with two spray of nano urea than application of 100% mineral fertilizer (Fig. 11.5).

Effect of different methods of irrigation was not observed in *rabi* crop but in case of greengram significant differences were recorded (Table 11.6). Greengram crop grown with surface irrigation produced significantly higher yield than those irrigated through mini sprinkler. System productivity was also found significantly higher under surface irrigation system than mini sprinkler method of irrigation.
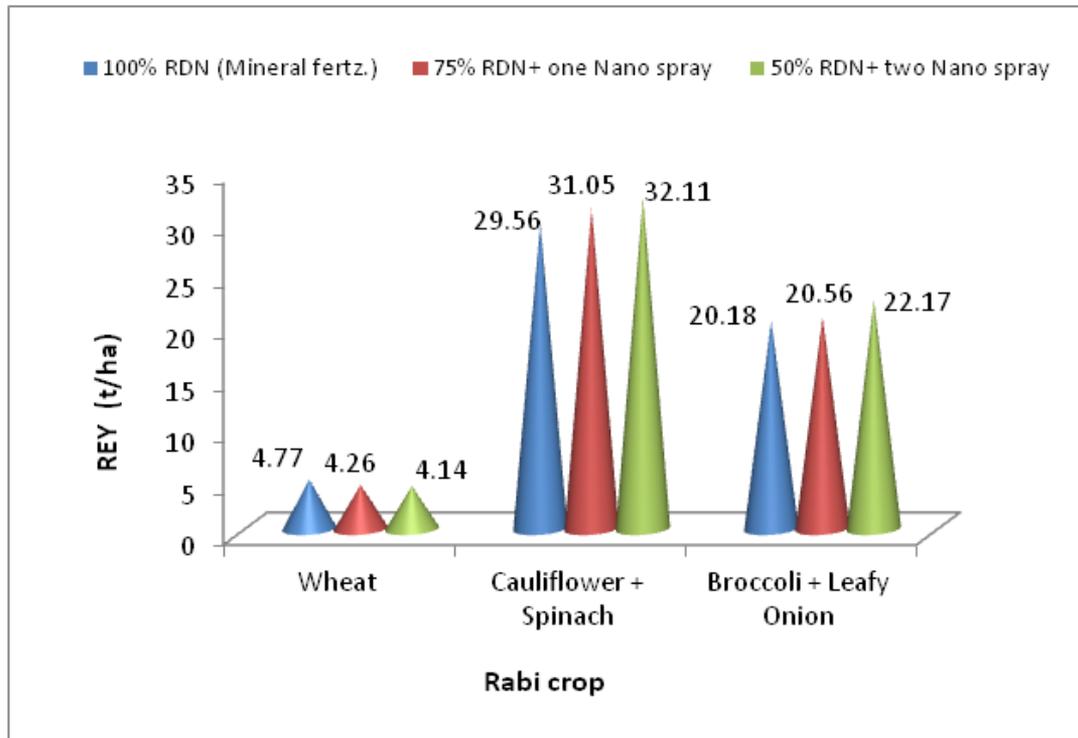

Fig. 11.5 Effect of methods of N application on REY (t/ha) of *rabi* crops

Table 11.6 Effect of different methods of irrigation and nitrogen application on yield and system productivity of diversified cropping system

Treatments	Rice yield (t/ha)	*rabi* yield (t/ha)	Greengram yield (t/ha)	REY of *rabi* crop (t/ha)	REY of greengram (t/ha)	System Productivity (t/ha)
Cropping system						
Rice-Wheat-Greengram	4.60	4.22	1.65	4.39	3.92	12.91
Rice-Cauliflower-Spinach-Greengram	4.63	29.98	1.62	30.91	3.84	39.38
Rice-Broccoli-Leafy onion-Greengram	4.79	18.45	1.62	20.97	3.83	29.60
CD 5%	NS	1.69	NS	1.73	NS	1.46
Irrigation method						
Surface irrigation	4.74	17.97	1.68	19.23	3.98	27.95
Mini Sprinkler irrigation	4.60	17.13	1.58	18.28	3.75	26.63
C.D (P=0.05)	NS	NS	0.08	NS	0.20	0.89
Nitrogen application						
100% RDN (Mineral Fertilizer)	4.85	17.05	1.68	18.17	3.99	27.01
75% RDN+ one Nano spray	4.63	17.44	1.60	18.62	3.79	27.05
50% RDN+ two Nano spray	4.55	18.16	1.61	19.47	3.80	27.83
C.D (P=0.05)	0.17	0.77	NS	0.86	NS	NS

Note: Rice crop was grown with surface irrigation only

12 Crop Diversification

Evaluation of Integrated Crop Managment in Rice-Fallows

A long-term field study to find out the most suitable rice-winter crop rotations; and appropriate crop establishment methods in rice-fallow for eastern India was initiated. After 7th year of the experiment, rice yields were higher in pulses-based system. Mean value of result, rice productivity was 39.9 & 20.7 % higher in TPR (4.57 t/ha) compared to ZTDSR (3.27 t/ha) & CTDSR (3.78 t/ha) (Table 12.1).

Table 12.1 Rice yield as influenced by different crop establishment-cum-residues management practices and succeeding crops (Mean data of 2022-23)

CERM	Rice yield	Winter crop yield (t/ha)					
		Chickpea	Lentil	Safflower	Linseed	Mustard	Toria
[ZTDSR-ZT] R-	3.19^F	2.02^{AB}	1.33^{AB}	0.95^{AB}	0.74^B	1.06^B	0.64^{ABC}
[ZTDSR-ZT] R+	3.34^E	2.13^A	1.49^A	1.16^A	0.86^A	1.27^A	0.71^A
[CTDSR-ZT] R-	3.69^D	1.66^{BC}	0.77^C	0.80^{BC}	0.5^{CD}	0.96^{BC}	0.63^{ABC}
[CTDSR-ZT] R+	3.88^C	1.85^{ABC}	1.03^{BC}	0.95^{AB}	0.59^C	1.12^{AB}	0.68^{AB}
[TPR-ZT] R-	4.41^B	1.53^C	0.19^D	0.51^D	0.40^D	0.82^C	0.52^C
[TPR-ZT] R+	4.73^A	1.74^{ABC}	0.10^D	0.67^{CD}	0.49^{CD}	0.92^{BC}	0.57^{BC}

R-: No residue retention, R+ : Residue retained

Standardization of the Agro-techniques in Nutri-cereals for enhancing Productivity in eastern India

A field experiment was initiated during *Kharif* 2020 with an objective of designing the most productive, profitable, and sustainable climate resilient cropping system for eastern India. Based on the local preferences of nutri-cereal in region, bajra, ragi and barnyard among minor nutri-cereals has been identified for further varietal testing.

Identification of the Best Cultivars of Pearl Millet/Bajra

Altogether 06 varieties of bajra (Dhan Shakti, HHB 67, MPMH 21, HHB 272, Proagro 9001, Proagro 9180) were evaluated during *Kharif* 2022. The maximum grain yield was recorded by bajra hybrid i.e., Proagro 9001 (2981 kg/ha)(Table 12.2).

Identification of Best Cultivars of Finger Millet/Ragi

07 varieties of ragi (VL 352, GPU 67, KMR 301, Birsa Madua, RAU 8, BL 379 and CFMV1) were evaluted (Fig. 12.1) and the maximum grain yield was recorded by ragi cv. RAU 8 (2100 kg/ha) (Table 12.2).

Fig. 12.1 Performance of nutri-cereals varieties (Bajra and Ragi) during *Kharif* 2021-22 at ICAR RCER Patna

Table 12.2 Crop yields of bajra and ragi under rainfed condtion (Mean data of *Kharif* 2022)

Bajra cultivars	Grain yield (kg/ha)	Ragi cultivars	Grain yield (kg/ha)
Dhan Shakti	2433[d]	VL 352	1648[bcd]
HHB 67	2544[c]	GPU 67	1426[def]
MPMH 21	2397[de]	KMR 301	1293[fg]
Proagro 9001	2981[a]	Birsa Mandua	1720[bc]
Proagro 9180	2939[ab]	RAU 8	2100[a]
HHB 272	2394[def]	BL 379	1462[de]
SEm±	37.7	CFMV 1	1796[b]
LSD (0.05)	110.2	LSD (0.05)	240

Evaluation of Cultivars and Nutrient Management in Barnyard Millet

Three varieties of barnyard (VL 207, DHMB 93-2 and DHMB 93-3) at 3 fertility levels (50, 75 and 100% RDF) were evaluated (Fig. 12.2) during *Kharif* 2022 to assess best cultivars in terms of production potential. Application of 100% recommended dose (60-40-25 kg NPK/ha) recorded the maximum crop yield in comparison to 50 and 75% recommended dose of fertilizer (Fig. 12.3). Maximum grain yield was recorded by barnyard cv. DHMB 93-3 (1704 kg/ha).

Fig. 12.2 Performance of nutri-cereals varieties (Barnyard/sanwa) during *Kharif* at ICAR RCER
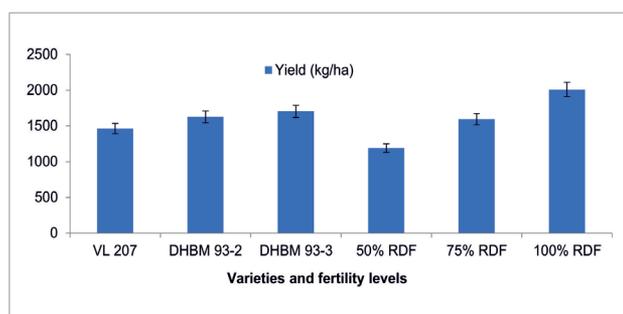

Fig. 12.3 Barnyard millet yields as influenced by different varieties and fertility levels under rainfed contion (Mean data of *Kharif* 2022)

BIODIVERSITY CONSERVATION

Network Project on Conservation of Lac Insect Genetic Resources

In continuation to survey for natural occurrence of lac insect and its host plants in Eastern UP and Bihar, survey was conducted in 2 districts of Eastern UP *viz.* Faizabad and Sultanpur. In Faizabad 6-blocks (Masodha, Pura Bazar, Bikapur, Faizabad, Milkipur and Amaniganj) were surveyed. Out of 3-blocks (Sultanpur Sadar block, Kurebhar and Kadipur) of district Sultanpur, good surviving lac insects were observed on Ficus religiosa and F. benghalensis in Sultanpur Sadar block (Fig. 12.4). In Patna out of 12 blocks, lac insects were found in 5-blocks (Danapur, Paliganj, Sampatchak, Bikram and Naubatpur) on *Ficus religiosa*, F. *benghalensis*. In Banka, out of 6 blocks,lac insects were observed in 2-blocks (Bounsi and Chandan) on Ficus sp and at one place on *Butea monosperma* (Fig. 12.5a, 12.5b). In Sitamarhi out of 4 blocks (Bajpatti, Parsauni, Bathnaha and Pupri) surveyed, lac insects were observed in a block namely Pupri on *Litchi chinensis* (Fig. 12.6).

Fig. 12.4 Naturally occurring lac insect on *Ficus religiosa*

Fig. 12.5a Naturally occurring lac insect on *Ficus benghalensis*

Fig. 12.5b Naturally occurring lac insect on
Butea monosperma

Fig. 12.6 Naturally occurring lac insect on
Litchi chinensis

FODDER CROPS

Response of Different Nitrogen and Zinc Management Practices in Fodder Oats

A field experiment was conducted to evaluate the efficacy of different nitrogen and zinc management practices in fodder oats. Three nitrogen management i.e., N1: whole recommended dose of nitrogen (RDN) through inorganic fertilizer (IN), N2:75% RDN (IN) + four foliar spray of Nano-N and N3: 50% RDN (IN) + five foliar spray of Nano-N were taken as main plot while three zinc management strategies *viz*., Zn0: control (No Zn), Zn1: Zinc @ 10 kg/ha (IN) and Zn2: 5 kg/ha Zinc (IN) as basal + four foliar spray of Nano-Zn were assessed in sub-plots with three replications. Application of N1+ Zn2 (18.94 t/ha) followed by N3+ Zn1 (17.57 t/ha) recorded higher green fodder yield (GFY) at first cut (Fig. 12.7). Whereas application of N3+ Zn1 (18.20 t/ha) remained at par with N2 + Zn1(16.60 t/ha) and N1 + Zn1(16.38 t/ha).
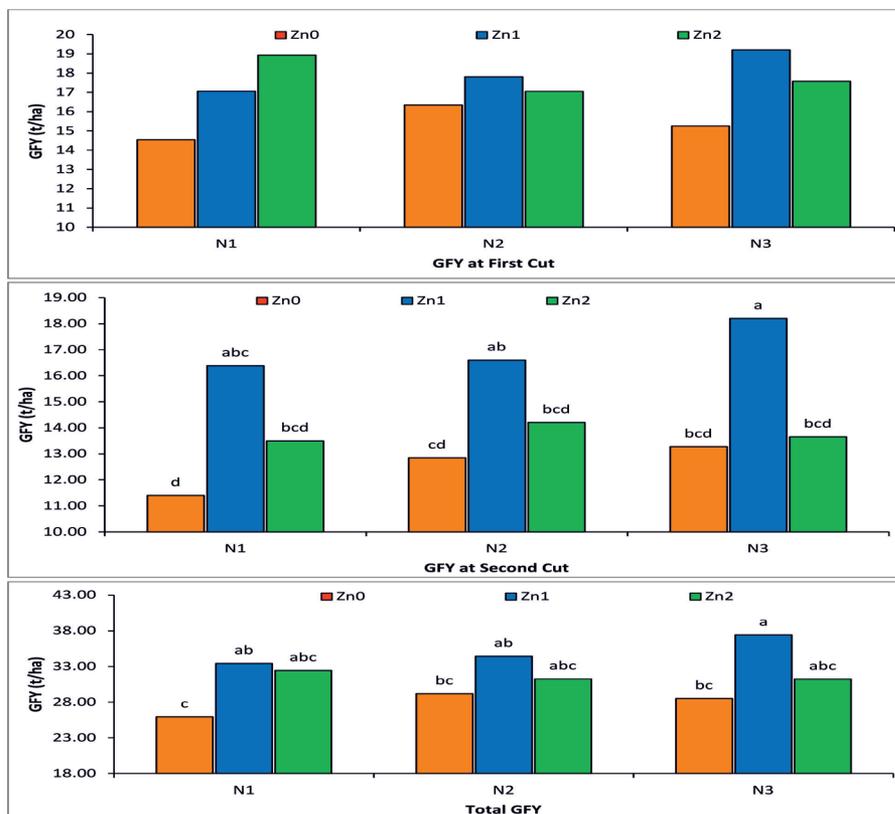

Fig. 12.7 Yield of fodder oats under different N & Zn management

13 Carbon Sequestration and Nutrient Dynamics

Leaching Loss of Nutrients under different Fertilizer Management Practices

The leaching loss of NPK nutrients below the root zone of brinjal and maize crops were studied using non weighting lysimeters. under four fertilizer management *viz.* control with no fertilizer application (T1), 100% inorganic (T2), 100% organic (T3) and integrated nutrient management 50% inorganic + 50% organic (T4). Recommended NPK dose of brinjal and maize was 120:26:50 and 120:60:50, respectively. Under organic treatment (T3) full dose of N, P and K for brinjal and full dose of N, P and 50% K in maize was applied through vermicompost.

It was observed that, the highest nitrogen leaching loss of 15.8% of applied fertilizer was recorded in T2, while INM treatment (T4) accounted N leaching loss of 8.6% of applied fertilizer (Table 13.1). The leaching loss of P was very low and varied from 0.2-0.28 kg/ha among the different treatments. Significantly highest K-leaching loss of 21.1 kg/ha was observed in T2 treatment. The organic treatment T3 registered the lowest K-leaching loss of 2.5% of applied fertilizer. The treatment T2 also recorded the highest leaching loss of calcium (28.2 kg/ha) and magnesium (13.1 kg/ha), while the lowest was observed in T3. In brinjal crop root zone higher negative N balance (-59.7 kg/ha) was observed in T1 and the least negative N balance (-3.1 kg/ha) was observed in T3. The uptake of N and P by the brinjal crop varied from 38.4-74.4 kg/ha and 13.0-26.6 kg/ha, respectively. The available P balance in soil showed positive balance in INM (T4) treatment having 5.2 kg/ha while available K balance showed highest negative value in all the treatments with highest of -63.8 kg/ha in T2 .

Table 13.1 Leaching loss of N, P and K in brinjal and maize under different nutrient management practices

Treatments	N-loss from soil and fertilizer (kg/ha)	N loss % applied fertilizer	P loss % applied fertilizer	K Loss from soil and fert (kg/ha)	K loss % applied fertilizer
Brinjal					
T1	12.4			9.5	
T2	31.3	15.8	0.31	21.1	23.2
T3	15.2	2.4	0.05	10.8	2.5
T4	22.7	8.6	0.18	15.5	11.9
LSD (p≤0.05)	5.94			5.93	
Maize					
T1	9.6			8.0	
T2	18.9	7.8	0.12	14.3	15.7
T3	11.9	1.9	0.02	8.8	1.9
T4	15.4	4.8	0.07	11.3	8.1
LSD (p≤0.05)	5.04			2.9	

The N-leaching loss in maize crop was highest in inorganic fertilizer treatment (T2). The P-leaching loss was very negligible and varied from 0.15 to 0.22 kg/ha. T3 registered K-leaching loss of just 1.9% of the applied fertilizer. The calcium leaching loss in maize was highest (23.6 kg/ha) in control, while it was lowest (20.9 kg/ha) under organic treatment. The magnesium leaching loss was not significant among the treatments and varied between 10.1 to 10.4 kg/ha.

The available N balance in maize varied from -9.2 to -35.9 kg/ha. The highest negative N balance of -35.9 kg/ha was recorded in T1. The N-uptake by maize was highest (78.4 kg/ha) in treatment T2. Balance sheet also indicated that the available P in maize varied from -1.8 to +4.8 kg/ha. Among the treatments, the P and K uptake

by maize varied from 10.8-34.2 kg/ha and 82.8-170.2 kg/ha, respectively. The available K balance sheet in maize showed negative value in all the treatments, being highest in T2 (-86.1 kg/ha).

The brinjal fruit yield under inorganic, organic and INM treatment were significantly higher over control. The highest brinjal fruit yield (17.5 t/ha) obtained in T2. Similarly, the water productivity varied from 1.67 to 3.13 kg/m³ among the treatments, being highest under T2. The brinjal root volume/plant was significantly highest of 13.24 cm³ in T2, while the root volume per plant was least (6.87 cm³) in T1. The maize cob yield varied from 2.38 to 11 t/ha among the treatments, being highest in T2. The water productivity in maize varied from 0.42 to 1.95 kg/m³ among the treatments, being highest in T2 treatment. Similarly, the root volume/ plant was highest of 76.1 cm³ in inorganic treatment, T2, while it was lowest (35 cm³) in control.

Organic Amendments for Phosphorus Mobilization in Acidic Soils

A field experiment on phosphorus mobilization through organic amendments in acidic soils was conducted at ICAR-RCER, FSRCHPR Ranchi during 2021-22. The experiment was designed in RBD with nine treatments and three replications. The treatments included: T1 = Control (RDF), T2 = RDF + lime (3 q/ha), T3 = PSB (3 kg/ha), T4 = PSB (5 kg/ha), T5 = PSB (7 kg/ha), T6 = Vermicompost (3 t/ha), T7 = Vermicompost (5 t/ha), T8 = Vermicompost (7 t/ha) and T9 = Green manuring (dhaincha). The nitrogen (N) and potassium (K) were applied as per the RDF in all treatments while phosphorus (P) application was omitted from treatments T3 to T9. The application of phosphorus solubilising bacteria (PSB) was done by mixing with fine powder of FYM at the rate of 30, 50, 70 kg/ha in treatment T3, T4 and T5 respectively.

It was observed that different treatments of organic phosphorous sources significantly affected the concentrations of soil phosphorus fractions in the post-harvest soil after one cropping cycle of maize and french bean. The saloid-P, which represents the labile pool of

phosphorus in soil, increased over its respective initial concentrations and control treatment. The saloid-P varied from 41.67 to 77.50 mg/kg and it contributed to about 5-10% percent of the total P. The Fe-P fraction was a major form of inorganic P fraction present in soil followed by Al-P. The different forms of inorganic P in general decreased in the order of Fe-P>Al-P>Saloid-P>Reductant Soluble-P>Ca-P>Occluded-P.

The total, organic and inorganic phosphorus ranged from 544 to 761.67 mg/kg (Fig. 13.1). The highest amount of total P was found in inorganic fertilizers treatments while total P content decreased over initial P content in treatments wherein application of P was omitted. The inorganic P content in different treatments was 54-72% of total phosphorus present in soil while organic P content was 28-46% of total phosphorus content in the soil (Fig. 1). Among all the treatments T8 i.e. vermicompost application at the rate of 7 t/ha and T5 i.e. PSB application at the rate of 7 kg/ha were adjudged as more efficient treatments for P solubilization in soils.
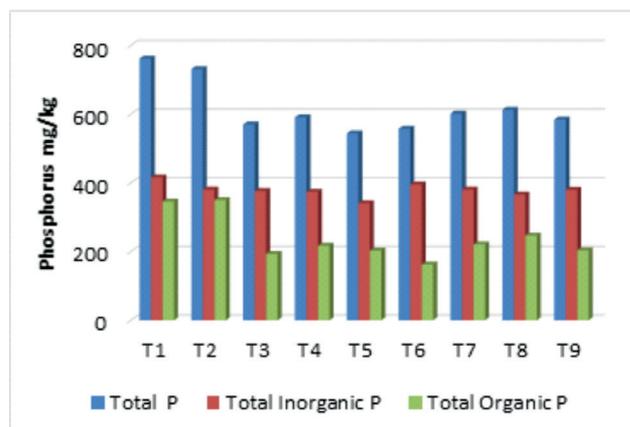

Fig. 13.1 Effect of organic amendments on different forms of phosphorus in soil

14 Water Quality and Productivity

Determining Optimum Decision Variables for Furrow Irrigated System

Okra jeevan F1 hybrid variety was sown on 11th July 2022 in furrow irrigated system in 0.20, 0.40, and 0.60% bed slope at a plant spacing of 0.50m x 0.10m (Fig. 14.1). The furrow length of the field was 20m. The cut-off ratio of irrigation applied as 0.85, 0.80, and 0.75 in the plot having slopes of 0.20, 0.40, and 0.60%, respectively. The moisture content was taken using moisture meter at a 15 days interval during the crop season. The plot with a slope of 0.2% and a cutoff ratio of 0.85 had the highest yield (8.28 t/ha). However, no significant yield increase was observed over the other two combinations of 0.2% bed slope and 0.80 cut off ratio (yield 8.13 t/ha) and 0.6% bed slope and 0.75 cut off ratio (8.04 t/ha).

Fig. 14.1 The okra jeevan F1 Hybrid variety grown at 0.2% bed slope during *Kharif* season

Delineation of Flood Hazard Zones of Assam

The extent of flood in the state was mapped as well as the zoning of the flood-prone areas was carried out as per its flood frequency using Remote Sensing and Geographical Information Techniques (RS & GIS) technique. Zoning of the flood-prone areas will help to identify and implement suitable techniques according to the flood zone which will help to enhance the land and water productivity of those areas. Annual Flood Layers of 1998-2010 (13 years) of Assam used for this study. Results showed that about 23470 km² area (29.9% of the geographical area) of Assam is flood-prone (Fig. 14.2).

Lakhimpur, Nagaon, Dibrugarh, Dhemaji, Kamrup, etc. are some of the most flood-prone districts in the state. Zoning of the flood hazard area as per its vulnerability to flooding revealed that about 1154 km² area of the state comes under very high risk (flooded 11-13 times out of 13 times), 2432 km² under high risk (flooded 8-10 times out of 13 times), 4589 km² under moderate risk (flooded 5-7 times out of 13 times), 4975 km² under low risk (flooded 3-4 times out of 13 times) and 10650 km² under very low risk zone (flooded 1-2 times out of 13 times). It was also observed that most of the area under very high, high, and moderate risk flood hazard regions is located in Mangaon, Lakhimpur, Sibsagar, Kamrup, Dibrugarh, and Berpeta districts of the state (Fig. 14.3).
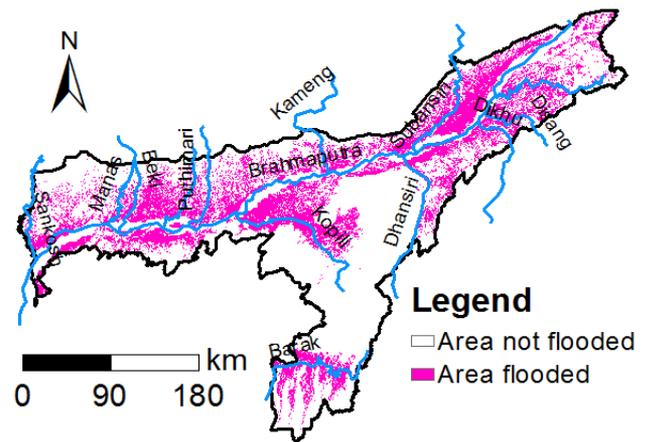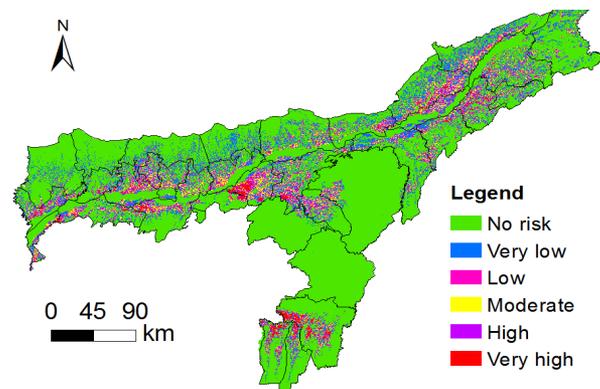

Fig. 14.2 Flood-prone areas of Assam

Fig. 14.3 Flood hazard zones in Assam

Integrated Modelling Approach for Developing Drought Management Strategies in the Sakri River Basin

This study was conducted in the Sakri River Basin of India. This river basin is situated in two states of India, wherein agriculture and allied activities are main source of livelihood. It extend between 24° 23' 34" and 25° 21' 5" N latitude and 85° 16' 23" and 86° 13' 6" E longitude. River Sakri originates from Giridih district (elevation 365 m amsl) of Jharkhand and flows through Jharkhand and Bihar, drains into the Harohar river in Patna district (elevation 42 m amsl) of Bihar (Fig. 14.4a). Length of river Sakri is approx. 100 km with its basin area of 3781.64 km^2, which covers 5 districts (Giridih, Koderma, Nawada, Sheikhpura and Nalanda) of both the states of India. It was observed that the river basin is dominated with Hydrologic soil group C (moderately high runoff potential, less than 50% sand and 20-40% clay content) and D (high runoff potential, less than 50% sand and more than 40% clay content). The data from five agro-meteorological weather stations for the period of 30 years (1991-2020) were used. The SPI (Standardized Precipitation Index), EDI (Effective drought index) and SPEI (Standardized Precipitation Evapotranspiration Index) indices were described. Drought severity and magnitude were found according to these indices. Among these drought indices, EDI is a time step independent drought index and other is multi-time scale indices were defined at 1-, 3-, 6-month scales. Analysis of the results indicated that the 6-month scale is appropriate for comparing drought indices in the study area.
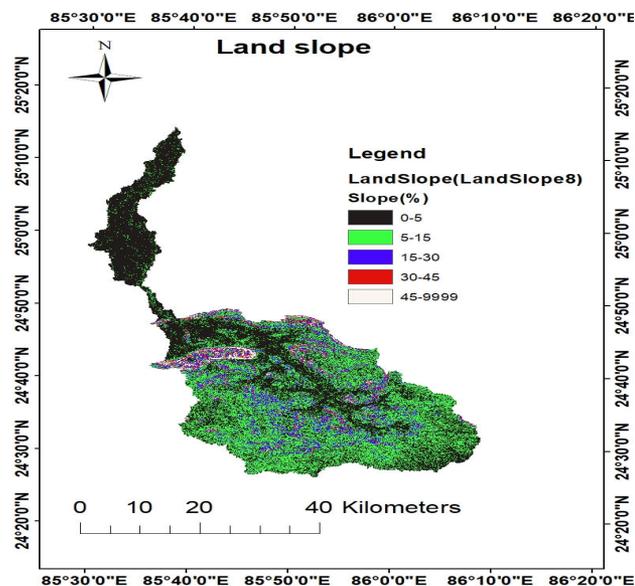

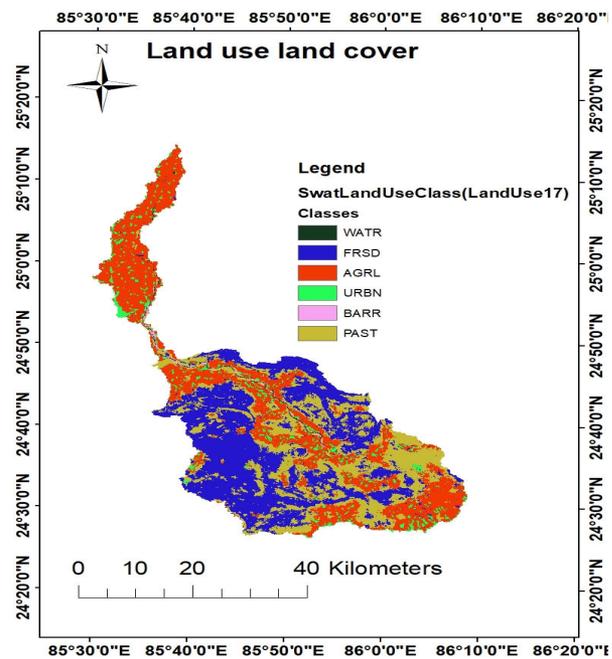**Fig. 14.4a Topography map of river basin**

Fig. 14.4b Land use land cover map of river basin

Prioritization of Watersheds for Soil and Water Conservation Measures in Nalanda, Bihar

In Nalanda, Bihar, detailed studies of several morphological parameters, including linear, relief, and areal at the scale of watersheds have been conducted using remote sensing, GIS, as well as the weighted sum approach technique. Overall results revealed that the majority of the watersheds are 5th order, elongated in shape, and follow the dendritic to subdendritic drainage pattern. However, the majority of the sub-basin area, except the mountainous portions around the lower boundary (>35 percent), falls under the flat to moderate slope with HSG D, which has a very high runoff potential. Overall analysis revealed that about 56.3 per cent area (like Laranpur, Parwalpur, Rajgir, Silao, etc.) comes under very high priority followed by 30.5 per cent as high, 4.2 per cent as medium whereas 2.22 to 6.78 per cent area comes under very low to low priority for execution of water harvesting planning by accounting the variation of morphometry, slope, HSG, geomorphology, and lithology under consideration (Fig. 14.5). Such type of findings is more beneficial in prioritization of vulnerable watersheds and the prompt attention of water harvesting planning by policy makers/ decision makers.
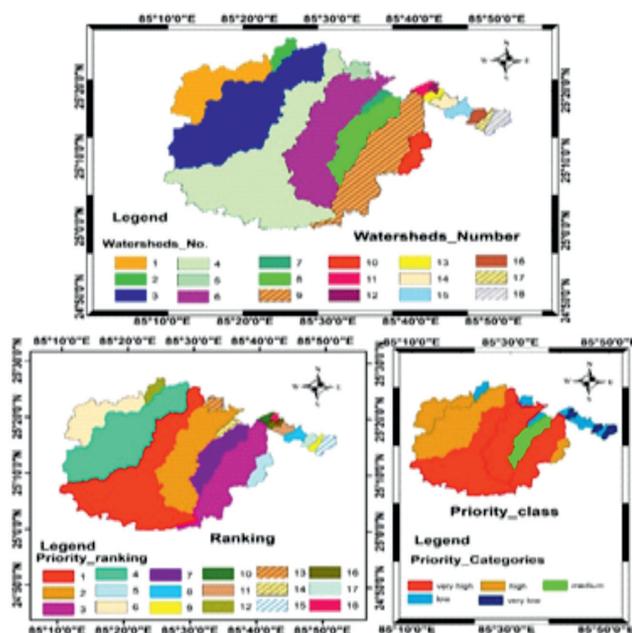
Fig. 14.5 Overall ranking and final priority map of various watersheds

Evaluation of Water Budgeting Parameters in Paddy

The water balance components of paddy (Swarna Shreya) were examined during second year field experiment in the *Kharif* season, using the drum culture technique (Fig. 14.6). In this experiment, identical conditions were maintained in the field and the drums, and rainfall, irrigation depth, crop evapotranspiration (ETc), percolation beyond the root zone of the crop, and surface runoff during the crop growth period were all taken into account in the water budgeting process by routinely monitoring the water lost from each drum on a daily basis (Table 14.1).

Fig. 14.6 Experimental field with paddy

Table 14.1 Water balance components of paddy

Crop	Rainfall	Irrigation	ETc	DP	Runoff	±ΔS
	In mm					
Paddy Swarn Shreya	554.3	300	439.5	220.2	0	194.6

Results revealed that the percolation beyond the root zone of the crop and water losses through evapotranspiration was 220.2 mm and 439.5 mm, respectively under the conventional puddled rice method which was about 25.78% and 51.45% of total water applied during 2022 and the rest amount of water (22.77%) stored within the root zone of the crop. The actual crop evapotranspiration (ETc_Actual) and crop coefficient (**Kc)** stage-wise variations over the cropping season were shown in Table 14.2.

Table 14.2 Stage-wise variation of crop evapotranspiration throughout cropping season.

Crop growth stages	ETc_Actual (mm)	Kc Values
Initial	4.78±1.01	1.14±0.16
Crop development	5.42±1.46	1.25±0.08
Mid-season	4.29±1.09	1.26±0.18
End-season	3.04±0.48	0.96±0.11
Overall	4.48±1.38	1.19±0.18

Optimization of Cropping Pattern to Maximize Water Productivity

In order to assess present water productivity and explore possible ways to maximize water productivity by optimally reallocating crops in different parcels of land, a

study was conducted in 20 ha cultivable area of Sahebbari village under Nadia district in West Bengal as shown in Fig. 14.7.
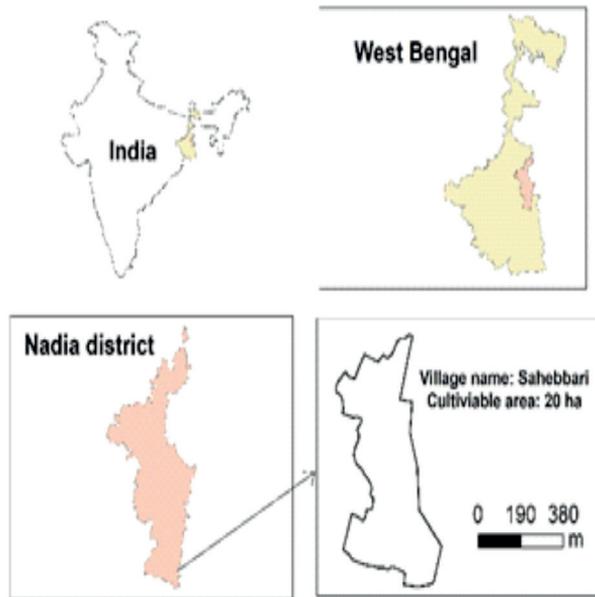

Fig.14.7 Location of study area

Data about inputs applied (like seeds, fertilizer, insecticides/ pesticides, land preparation, farm implements, water and labour) outputs produced (like main product and by-product) along with cost were collected from farmers through a developed questionnaire. Water productivity maximization problem was formulated and constraints were decided after interaction with farmers. The objective function i.e. Maximization of Water Productivity (ZWP) was defined as

$$Max\ Z_{WP} = \left[\sum_{i=1}^{2} \sum_{j=1}^{9} \frac{1}{IA_{ij}} \left[A_{ij} \left(Y_{ij} P_{ij} + YB_{ij} PB_{ij} - CP_{ij} \right) - PGW \times NH \right] \right]$$

Where ZWP is Net annual return from all the crops of command per unit of irrigation water applied (Rs.-ha/m3); i = index for crop season (i = 1 for monsoon or *Kharif* season, 2 for non-monsoon or *rabi* season) ; j = index for crop name; Ai j = area to be allocated (ha) in season i for crop j; IAi j = irrigation applied in season i for crop j (m3); Yi j = yield of crop j grown in season i (kg/

ha); Pi j = current market price of crop j in season i (Rs./kg); YBi j = yield of by-product of crop j grown in season i (kg/ha); PBi j = current market price of by-product of crop j in season i (Rs./kg); CPij = cost of production (excluding irrigation water price) of crop j grown in season i (Rs./ha); PGW = price paid for ground water applied (Rs./hr); NH = number of hours of operation in providing irrigation.

Constraints for project are site at Nadia district

Crop area constraints

1. $A_{AR} + A_{PG} + A_{PU} + A_{TR} + A_{CH} \le 20$ ha

2. $A_{BR} + A_{L} + A_{MU} + A_{TO} + A_{TR} + A_{CH} \le 20$ ha

3. $A_{AR} \ge 10$ ha

4. $A_{BR} \ge 4$ ha

5. $A_{TR} \ge 1$ ha

6. $A_{CH} \ge 1$ ha

Ground water availability constraints

7. $0.144A_{AR} + 0.288A_{PG} + 0.0414_{APU} + 0.54_{ATR} + 0.422A_{CH} + 0.288\ A_{BR} + 0.081_{AL} + 0.081\ A_{MU} + 0.2160\ A_{TO} \le 3.6$ ha-m

Man-days requirement constraints

8. $120\ A_{AR} + 475\ A_{PG} + 100\ A_{PU} + 1010\ A_{TR} + 1208\ A_{CH} + 160\ A_{BR} + 50_{AL} + 55A_{MU}$

    $+ 100\ A_{TO} \le 73000$ man-days

Here $A_{AR}, A_{PG}, A_{PU}, A_{TR}, A_{CH}, A_{BR}, A_{L}, A_{MU}, A_{TO}$ are the areas to be allocated under Aman rice, pointed gourd, pumpkin, Tuber rose, chilli, boro rice, lentil, mustard and tomato crops, respectively.

The value of water productivity considering existing area under different crops and revised water productivity values under different scenarios considering area reallocation under different crops and addition or removal of various constraints, employing simplex linear programming technique are given below in Table 14.3.

Table 14.3 Existing and optimum water productivity computed at Sahebbari village under Nadia district in West Bengal

Sl. No	Crop	Existing Area (ha)	Optimum area allocation (ha) when constraints 1 to 6 considered	Optimum area allocation (ha) when constraints 1 to 4 considered	Optimum area allocation (ha) when constraints 1 to 3 considered and ABR ≥ 3 ha	Optimum area allocation (ha) when constraints 1 & 2 as well as AAR ≥ 5 ha, ABR ≥ 5 ha are considered
1	Aman Rice	10	10	10	10	5
2	Pointed gourd	4	0	0	0	0
3	Pumpkin	4	1.11	10	10	15
4	Tuber rose	1	1	0	0	0
5	Chilli	1	1	0	0	0
6	Boro rice	6	4	4	3	5
7	Lentil	2	0	7.33	10.89	10.11
8	Mustard	8	0	0	0	0
9	Tomato	2	0	0	0	0
	Total area	38	17.11	31.33	33.89	35.11
	Water Productivity (Rs/m³)	301.03/38 = 7.921	71.475/17.11 = 4.177	291.635/31.33 = 9.308	337.558/33.89 = 9.961	392.517/35.11 = 11.179

It is concluded from above that the existing water productivity value of 7.921 Rs/m³ reduced to 4.177 Rs/m³ when all constraints were applied and area under Tuber rose and chilli crops was atleast 1 ha. Though these crops are remunerative, but occupy field both during *Kharif* and *rabi* seasons and consume lot of water as well as labour, so it is not advisable to cultivate these crops. Once constraint of allocating atleast 1 ha area under Tuber rose and chilli was removed, water productivity increased to 9.308 Rs/m³. Again when area under Boro rice was limited to 3 ha, water productivity further increased to 9.961 Rs/m³. Aman rice and Boro rice consume lot of water. If area under these crops is greater than equal to 5 ha and area under Tuber rose and chilli is zero, water productivity is maximum i.e. 11.179 Rs/m³.

Studies on Irrigation Water Pricing and Influencing Factors

In order to collect required data/ information about agricultural inputs used and their costs, labour cost involved in agricultural operations, value of land, implements, infrastructure, output (main as well as bi-product) produced along with their sell price, a structured questionnaire was developed and farmers from Sahebbari village under Nadia district in West Bengal, shown above, were interviewed and questionnaires were filled up.

Irrigation water price was assessed by considering ground water applied by farmers. Residual Value Method, which basically calculates the incremental contribution of each input in the production process, if all the inputs except water are assigned appropriate prices was employed. The residual obtained by subtracting the non-water input costs equals the gross margin and can be interpreted as the maximum amount paid by farmer for water after covering the cost of production. Results of the study are given below in Table 14.4.

It may be observed from Table 14.4. that Irrigation water price considering irrigation through ground water in Sahebbari village under Nadia district in West Bengal varied from maximum 89.66 Rs/m³ for lentil; 88.43 Rs/m³ for tomato; 74.20 Rs/m³ for pumpkin; 64.0 Rs/m³ for mustard; 43.42 Rs/m³ for tuber rose; 27.26 Rs/m³ for chilli; 15.28 Rs/m³ for pointed gourd; 13.33 Rs/m³ for Aman rice and minimum 12.26 Rs/m³ for Boro rice. It clearly indicates that in lentil and tomato crops ground water is efficiently utilized, so irrigation water price is high, whereas to produce Boro rice and Aman rice more water is required, so irrigation water price for Boro rice and Aman rice is less.

Table 14.4 Data of farmers from Sahebbari village under Nadia district in West Bengal

Crop	Aman Rice	Pionted gourd	Pump Kin	Tuber Rose	Chilli	Boro Rice	Lentil	Mus tard	Tomato
Input cost (including seed, organic matter, fertilizer, insecticed, pesticide etc., excluding water & Labour) (Rs.)	24300	152250	23700	35550	51390	17100	9375	11625	20250
Labour cost involved in ploughing/rotavator/ tilling/harrowing/ sowing/dibbling/ planting/transplanting/ weeding/harvesting/ threshing etc. (Rs.)	30000	118750	25000	255000	301200	40000	12500	13750	25000
Fixed cost including rental value of land, depreciation cost of farm building and implements and interest on fixed cost (Rs.)	31500	135000	33750	225000	202500	39600	40500	40500	101250
Total cost of cultivation (Rs.)	85800	406000	82450	515550	555090	96700	62375	65875	146500
Yield (T)	5.25	45.00	22.50	15.00	22.50	6.60	2.25	2.25	45.00
Sale price (Rs./T)	20000	10000	5000	50000	30000	20000	60000	60000	7500
Total output (Rs.)	105000	450000	112500	750000	675000	132000	135000	135000	337500
Output - Input (Rs.)	19200	44000	30050	234450	119910	35300	72625	69125	191000
Total irrigation applied through Ground water (m3)	1440	2880	405	5400	4320	2880	810	1080	2160
Irrigation water price (Rs/m³)	**13.33**	**15.28**	**74.20**	**43.42**	**27.76**	**12.26**	**89.66**	**64.00**	**88.43**

15 Conservation Agriculture

A long-term field experiment have been undertaken under the CSISA project since 2009 (*rabi*) on CA in rice-based cropping systems at the ICAR Patna (Fig. 15.1). After 7th year, ZTDSR in CA-based rice-mustard-maize system faced a severe problem of rice mealy bug, and hence, crop field was divided into 4 -equal plots (ZTDSR, CTDSR, PTR, UPTR). After two years of conventional tillage (CT), these plots were again converted into ZTDSR. After 13th year, maximum rice yield (5.59 t/ha) was recorded with machine tranplated rice (MTR) at par with TPR (5.24 t/ha) (Table 15.1).

Table 15.1 Rice yields as influenced by different tillage-cum-crop-establishment methods under long-term CA-based system (Mean data of *Kharif* 2022)

Crop scenario	Crop establishment	Grain yield (t/ha)	Straw yield (t/ha)	Residues load (t/ha)	Root biomass (t/ha)
TPR-CTW-Fallow (S1)	Broadcasted	5.24[bc]	4.45[b]	0.00[d]	0.90[b]
MTR-ZTW-ZTMU (S2)	MTR	5.59[a]	3.96[c]	2.52[b]	0.85[bc]
ZTDSR-ZTW-ZTM (S3)	ZT	5.15[cd]	3.29[d]	2.99[a]	1.08[a]
ZTDSR-ZTM-ZTM (S4)	ZT	4.51[ab]	5.25[a]	1.89[c]	0.72[d]

CTR: conventional-till rice, MTR: machine transplanted rice, CTW: conventional-till wheat, ZTMU: zero-till mungbean, ZTDSR: zero-till direct seeded rice, ZTM: zero-till mustard, S; Scenario

Fig. 15.1 Performance of rice in diverse tillage-cum-crop establishment methods

Table 15.2 Rice yield as influenced by different tillage-cum-crop establishment methods in long-term CA-based system (Mean data of *Kharif* 2022)

Tillage-cum-crop establishment methods	Grain yield (t/ha)	Straw yield (t/ha)	Residue load (t/ha)	Root biomass (t/ha)	Total biomass (t/ha)
RPTR-CTW-CTM	4.99[ae]	5.54[bcde]	3.16[bcdef]	1.15[fg]	14.8[def]
PLTR-CTW-CTM	5.46[ab]	5.71[bc]	3.31[abc]	1.43[d]	15.91[abc]
CTMTR-ZTW-ZTM	5.16b[cd]	5.66[bcd]	3.38[ab]	1.25[f]	15.45[cd]
ZTMTR-ZTW-ZTM	4.80[ef]	5.45[cdef]	2.99[fg]	1.38[de]	14.62[defg]
SRI-SWI-ZTM	5.75[a]	6.11[a]	3.48[a]	1.61[ab]	16.95[a]
CTDSR-ZTW-ZTM	5.30[bc]	5.82[ab]	3.25[bcde]	1.55[bc]	15.92[ab]
ZTDSR-ZTW-ZTM	4.76[efg]	5.31[defg]	3.30[abcd]	1.66[a]	15.03[cde]

RPTR: Random puddle transplanted rice, CTW: conventional-till wheat, CTM: conventional-till mungbean, PLTR: puddle line transplanted rice, CTMTR: conventional-till machine transplanted rice, ZTMTR: zero-till machine transplanted rice, SRI: system of rice intensification, SWI, system of wheat intensification, CTDSR: conventional-till direct seeded rice, ZTDSR: zero-till direct seeded rice (Table 15.2).

Soil organic carbon and crop productivity as influenced by tillage operations in India

Global meta- and mixed model analyses were done to evaluate the effect of no-till (NT) on SOC concentration (SOCc, g C kg^{-1} soil) and stock (SOCs, Mg C ha^{-1} land) across climate, soil texture, cropping systems, and no-till duration to appraise priority-setting. Compared to conventional tillage (CT), NT favoured a significant rise (SOCc) of 38% in the 0-5 cm soil layer and a much lesser 6% increase in the 5-10 cm layer and no change beyond 10 cm (Fig. 15.2). The microbial biomass C was most abundant C pool, with 61% and 23% increases in NT in 0-5 and 5-10 cm layers.
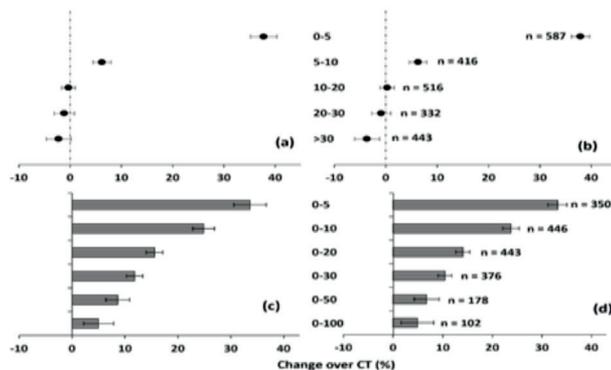

Fig. 15.2 Impact of no-till on SOC concentration and stock in different soil layers in (a) & c) meta-analysis and (b) & (d) mixed model analysis.

Water conservation in different irrigation and tillage management in rice-based systems

Irrespective of soil layers, zero-tillage always resulted in higher soil moisture content than conventional tillage throughout the growing season during winter. Trends of soil moisture content for 10-20, 20-30 and 30-40 cm soil layers were almost same as 0-10 cm soil layer (Fig. 15.3).
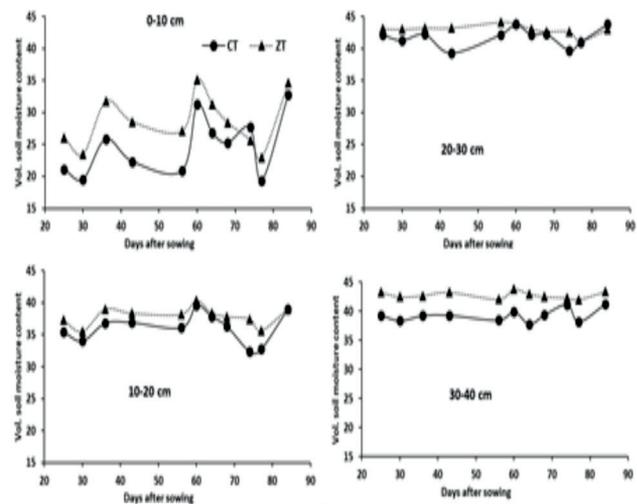

Fig. 15.3 Volumetric soil moisture content (%) as affected by different establishment methods in soil profile.

Irrespective of irrigation methods, yield was at par under CT and ZT (Table 15.3). However, numerically yield of wheat was higher under ZT than CT. Soil moisture-based irrigation recorded the highest yield (4.87 t/ha) followed by farmers' practice (4.39 t/ha) and the lowest yield was noted for deficit irrigation (3.96 t/ha) for wheat. In maize, soil moisture-based irrigation and farmers' practice recorded a similar yield and were significantly higher than deficit irrigation. Irrespective of tillage and irrigation methods, the average wheat and maize yield was 4.40 and 6.96 t/ha, respectively. In the case of rice, unpuddled transplanted rice recorded highest yield (4.98 t/ha) which was 3% higher than PTR (4.85 t/ha)

Table 15.3 Yield (t/ha) of wheat & maize affected by different establishment and irrigation methods

Tillage	Farmers' practice	Soil moisture-based irrigation	Deficit irrigation	Main Plot means
Wheat				
CT	4.22	4.84	3.84	4.30
ZT	4.56	4.89	4.08	4.51
Sub-Plot Mean	4.39^B	4.87^A	3.96^C	
Maize				
CT	6.56	6.51	6.33	6.47
ZT	7.50	7.68	7.20	7.46
Sub-Plot Mean	7.03^A	7.09^A	6.76^B	

Impact of different biomass proportion and irrigation on crop yield in rice-fallow system: An experiment was initiated during 2021-22 to study the impact of different proportions of *rabi* biomass incorporation on rice yield. Variety, total biomass of 10.1 t/ha was incorporated in rice field in five proportions (0%-T1 ,25-T2,50-T3,75-T4 and 100%-T5 of biomass) ,10 days prior to rice transplanting. Result showed that the biomass yield and grain yield was higher under T5 (Fig. 15.4 & 15.5).
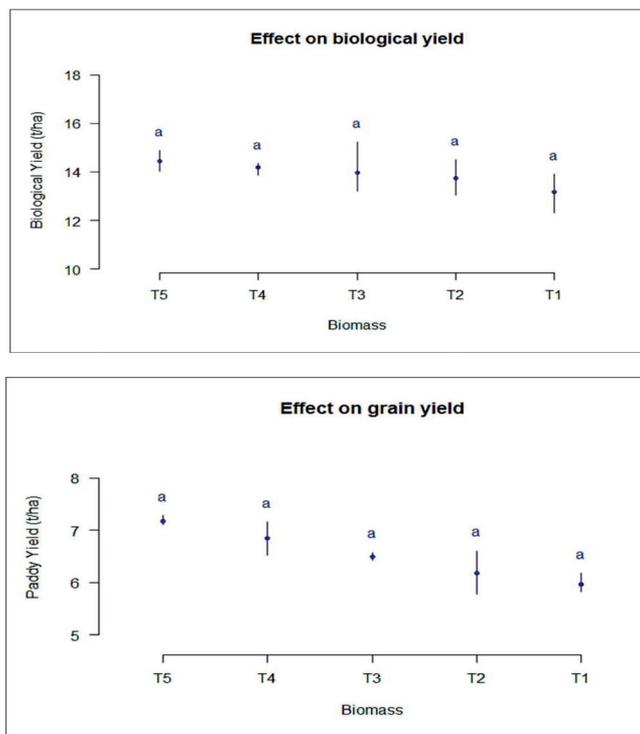

Fig. 15.4 Impact of different proportion of biomass incorporation on rice biomass and grain yield.

During *rabi*,three crops *viz.* mustard, lentil and chickpea were taken under four irrigation system i.e. control (no irrigation), surface, drip and micro sprinkler system. Fig. 15.5 a, b, c shows that in all the crops drip and sprinkler performed better compared to surface irrigation
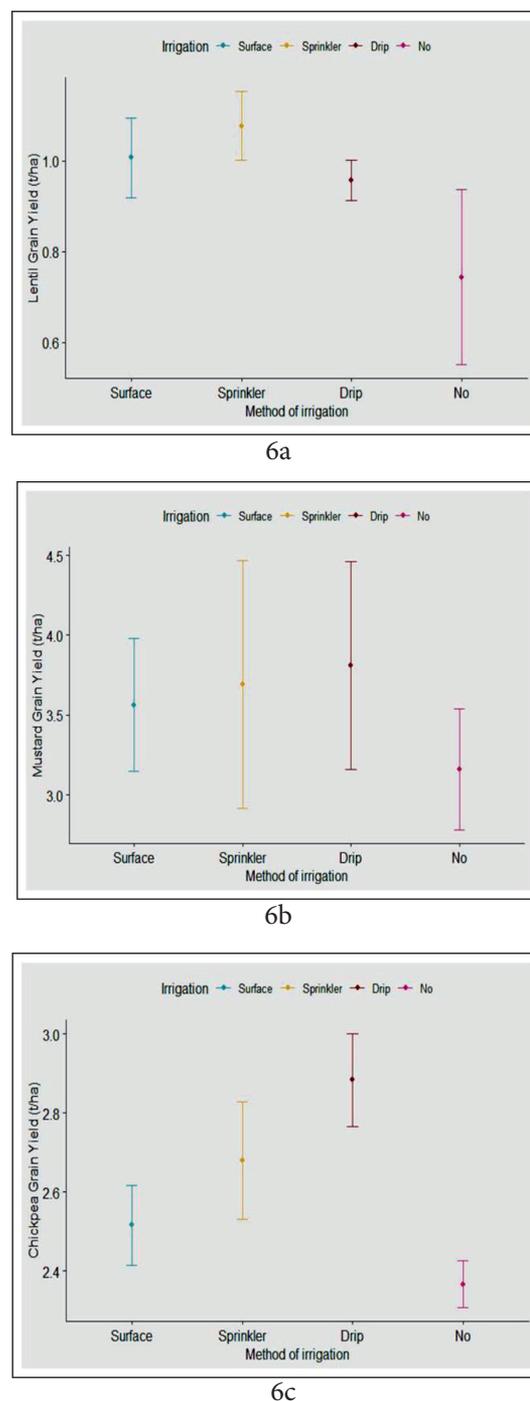

6a

6b

6c

Fig. 15.5 Impact of different proportion of biomass incorporation on rice biomass and grain yield.

Basin Enrichment in Bearing Orchards of Bael, Mango and Guava

The experiment is being conducted since 2020 to study the effect of mulching with Tephrosia biomass on yield and fruit quality of bael, mango and guava (Fig. 15.6). In case of guava, biomass mulching @ 3 kg dry biomass/m2 resulted in the maximum plant height and trunk diameter that of control

Fig. 15.6 Mulching of guava orchard with Tephrosia biomass

All treatments with biomass mulching resulted in significant increase in soil EC, available phosphorus over that of control in guava orchard (Table 15.4). Among the different fractions of soil organic carbon in guava orchard, all the treatments with biomass mulching were at par and resulted in significant increase in the content of very labile and labile carbon fractions over that of control (Table 15.5). The highest content of total organic carbon was observed with biomass mulch applied @ 3 kg dry biomass per m².

Table 15.4 Effect of mulching on soil chemical properties in guava

Treatments	pH	EC (µS/cm)	Available nitrogen (kg/ha)	Available phosphorus (kg/ha)	Exchangeable Potassium (kg/ha)
T1	4.76± 0.11	152.71[b]± 7.50	226.33[ab] ±10.38	24.640[b] ±1.30	224.24[a] ±14.87
T2	4.96± 0.11	163.51[b]± 10.26	226.59[ab] ±9.78	27.052[b] ±1.439	156.87[b] ± 24.88
T3	4.86± 0.12	259.70[a]± 16.68	246.96[a] ±3.53	33.856[a] ±1.77	160.08[b] ± 14.13
Control	4.81± 0.06	102.24[c]± 5.58	200.74[b] ±13.23	17.569[c] ±2.08	182.78[b] ± 8.86

T1= 1.0 kg dry biomass per m², T2= 2.0kg dry biomass per m², T3= 3.0 kg dry biomass per m², Control= No mulching

Table 15.5 Effect of biomass mulching in soil organic carbon fractions in soil in guava orchard

Treatments	Soil organic carbon fractions (Mg/ha)				
	Very labile	Labile	Less labile	Non labile	Total OC
T1	7.31[a]± 0.47	4.82[a]± 0.15	3.35± 0.43	3.74± 0.37	19.23[bc]± 0.36
T2	7.48[a]± 0.24	5.19[a]± 0.20	3.00± 0.38	4.26± 0.38	19.94[b]± 0.19
T3	8.06[a]± 0.24	5.57[a]± 0.23	2.94± 0.12	5.15± 0.51	21.73[a]± 0.51
Control	6.29[b]± 0.33	3.98[b]± 0.29	3.34± 0.40	4.30± 0.82	17.91[c]± 0.45

T1= 1.0 kg dry biomass per m², T2= 2.0 kg dry biomass per m², T3= 3.0 kg dry biomass per m², Control= No mulching

All the treatments with biomass mulching resulted in higher values of soil dehydrogenase activity and fluoroscein diacetate than control during November 2021 to March 2022 (Fig. 15.7 & 15.8).
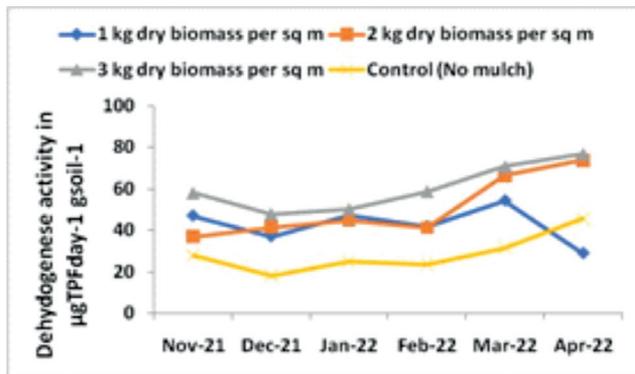
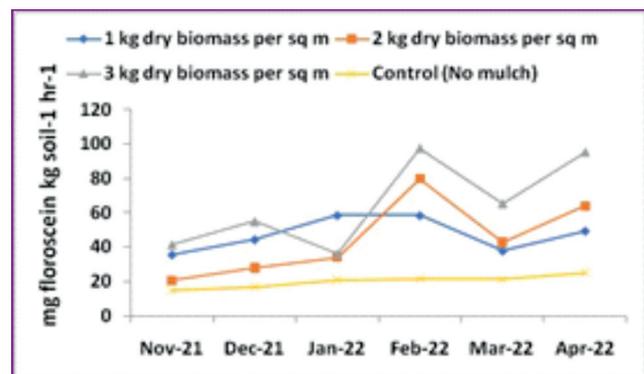**Fig. 15.7 Effect of mulching on soil Dehydrogenase activity in guava**

Fig. 15.8 Effect of mulching on Fluorescein Diacetate enzyme activity in soil of guava orchard

Evaluation of Natural Farming module in Eastern Plateau and Hill Region (EPHR)

A comparative evaluation of Conventional Farming (CF) and Natural Farming (NF) modules in different cropping systems for EPHR was undertaken at Ranchi (Fig. 15.9). Experiment was laid out in split plot with NF and CF as main-plot and crops in sub-plot. Paddy-lentil, black gram-niger, finger millet-mustard and cow pea-chick pea system were evaluated. Principles of NF i.e., seed treatment by Beejamrita, Ghan jeevamrita, Jeevamrita as source of nutrients, paddy straw as mulch to suppress weeds & Whaapasa for moisture conservation were applied. Plant protection measures included application of Neemastra, Agniastra and Brahmastra. Soils from natural farming plots had higher microbial count as compared to CF (Table 15.6). In NF, initial trend showed a slight improvement in soil pH while the available nitrogen and potassium were higher in soils of CF plots (Table 15.7).

Table 15.6 Microbial count in soils of NF and CF plots

Sample	Bacterial colony (cfu/g of soil) ×106	Actinomycetes colony (cfu/g of soil) ×106	Fungal colony (cfu/g of soil) × 104
Natural farming (NF)	88.50	80.50	5.00
Conventional farming (CF)	36.50	27.50	2.75

Table 15.7 Soil chemical properties under natural and conventional farming (after 2-cropping)

| Treatments	pH	Organic Carbon (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	EC
Conventional Farming						
Niger	4.99	0.57	213.23	23.68	286.16	89.28
Lentil	4.84	0.49	219.47	19.57	228.48	86.28
Chickpea	4.90	0.62	228.88	20.37	227.36	109.25
Mustard	4.88	0.53	210.06	14.69	232.68	80.84
Natural Farming						
Niger	5.06	0.53	243.68	12.05	373.75	81.02
Lentil	5.28	0.59	244.55	12.43	309.40	67.82
Chick pea	5.31	0.57	262.03	23.93	312.65	113.43
Mustard	4.99	0.48	233.93	26.18	211.25	83.64
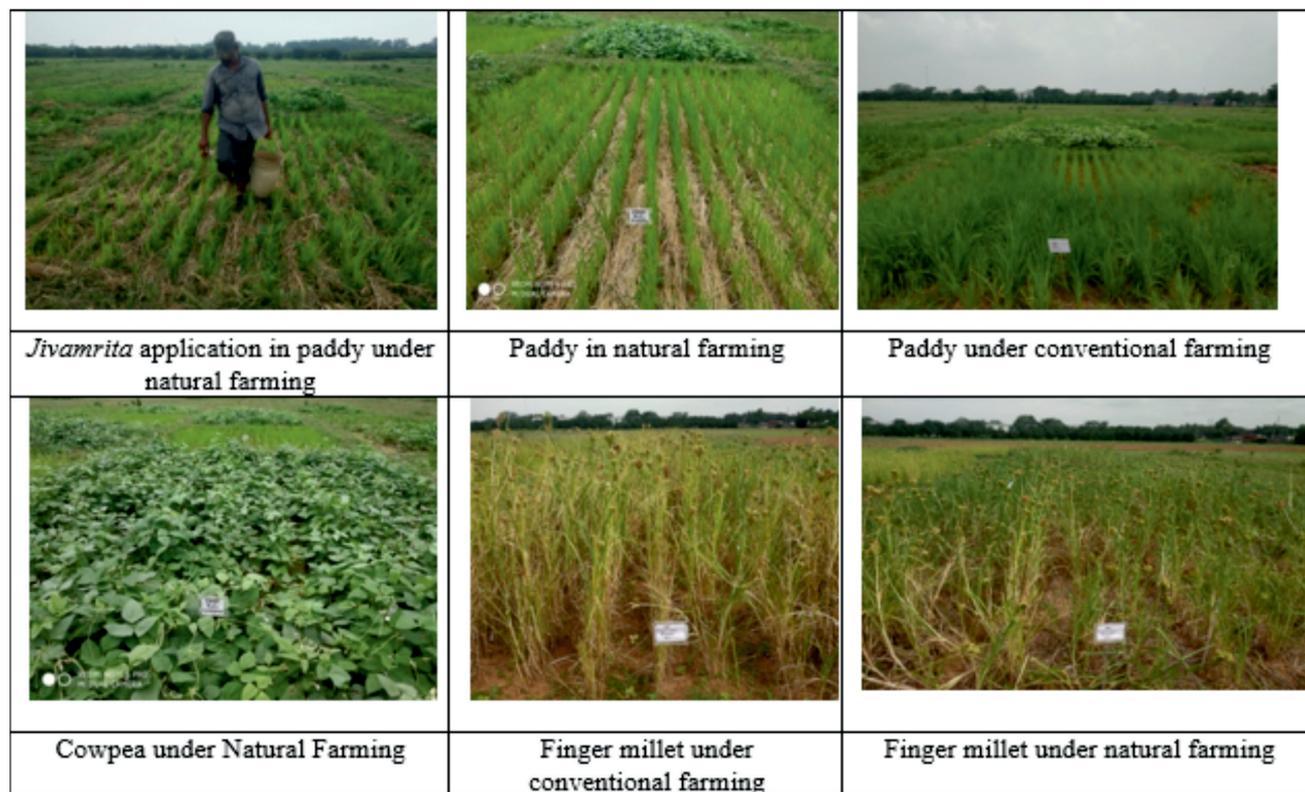
Fig. 15.9 Field view of the crops under conventional and natural farming practices

At 90 DAS, plant height was significantly higher under NF for lentil (25.55 cm), chick pea (36.00 cm) and Niger (48.35 cm), whereas conventional farming the plant height of mustard (125.90 cm) was statistically at par with NF (Table 15.8). Root length of lentil (4.43 cm) and chickpea (7.05 cm) were markedly higher under NF in comparison to CF, however niger and mustard had higher root length in CF. Except niger, test weight of lentil (2.02 g), mustard (0.37 g) and chickpea (18.17 g) was higher in NF. The NF resulted in higher seed yield per plant for lentil (1.13), niger (2.58) and chick pea (5.00) mustard showed higher seed yield of 2.76 g in CF.

Table 15.8 Growth and yield attributes of crops under natural and conventional farming practices

Treatments	Plant Height (cm)	Root length (cm)	No. of Branches/ plant	No. of Pods/ plant	Test weight (g)	Grain yield/ plant (g)	Straw yield/plant (g)
Treatment means (Main x Sub)							
NF x Lentil	25.55	4.43	8.46	30.95	2.02	1.128	4.04
NF x Niger	48.35	8.32	8.05	24.40	0.36	2.578	3.53
NF x Mustard	109.1	10.11	5.95	69.35	0.37	1.73	4.44
NF x Chickpea	36.0	7.05	18.90	33.25	18.17	5.00	6.93
CF x Lentil	25.10	3.54	8.65	28.15	1.95	0.83	2.90
CF x Niger	47.48	8.88	7.32	18.06	0.38	1.35	2.50
CF x Mustard	125.90	11.00	12.05	77.90	0.33	2.76	4.97
CF x Chickpea	29.35	6.15	17.95	23.00	17.72	2.685	6.85
CD 5%	8.78	2.06	6.65	21.21	0.39	1.434	3.27

At plot scale, NF treatment resulted in significantly higher seed yield (6.10 q/ha), straw yield (20.66 q/ha), biological yield (25.63 q/ha), harvest index (25.0%) and rice equivalent yield (17.62 q/ha) of chickpea (Table 15.9). However, yield attributes of mustard like seed yield (5.25 q/ha), straw yield (19.19 q/ha), biological yield (24.44 q/ha), harvest index (19.0%), rice equivalent yield (12.87 q/ha) were significantly higher in CF as compared to NF. Cowpea, chickpea, finger millet & lentil of NF had higher crop productivity in comparison to CF. Among four cropping systems, rice equivalent yield of cowpea-chickpea system was significantly higher (140.40 q/ha) under NF.

Table 15.9 Performance of *rabi* crops under natural and conventional famring practiecs

Treatments	Seed yield (q/ha)	Straw yield (q/ha)	Biological yield (q/ha)	Harvest index (%)	Rice equivalent yield (q/ha)	System productivity (REY, q/ha)
Treatment means (Main x Sub)						
		12.33	17.21	31.3	13.02	29.68
NF x Niger	1.52	11.38	12.99	12.3	5.81	42.80
NF x Mustard	2.50	13.81	16.31	15.8	6.13	13.86
NF x Chickpea	6.10	20.66	25.63	25.0	17.62	140.40
CF x Lentil	3.09	10.42	13.50	23.5	8.24	33.24
CF x Niger	1.01	12.38	12.73	13.0	6.18	45.79
CF x Mustard	5.25	19.19	24.44	19.0	12.87	19.74
CF x Chickpea	3.13	16.51	19.64	16.8	9.06	119.65
CD 5%	1.22	5.88	6.85	0.072	4.01	13.35

Weed Seed Bank Dynamics and Resource-use Efficiency under diverse Tillage Production Systems in Eastern Indo-Gangetic Plains

A field study was initiated during *Kharif* season of 2021 to identify an effective weed management strategy as well as a climate resilient tillage and crop establishment method for sustainable intensification of rice-fallows in Eastern India. The experiment was conducted in a split plot design with 3 main plots and 4 sub plots and with 3 replications (Fig. 15.10). The treatments comprised of different tillage and crop establishment practices as main plot treatments and weed management practices as subplot treatments. The experiment was conducted in a rice-wheat-greengram system. Results of the study revealed that among weed management practices, pre-emergence application of pyrazosulfuron-ethyl (25 g/ha) fb post-emergence application of cyhalofop-butyl + penoxulam (100 + 25) g/ha (tank-mix) led to significant reduction of weed density as well as biomass in rice. Post-emergence application of clodinafop-propargyl + metsulfuron-methyl (60+5) g/ha (tank-mix) at 30 days after sowing in wheat significantly reduced the weed density as well as biomass, whereas in case of greengram, application of pendimethalin (1000 g/ha) as pre-emergence fb post-emergence application of imazethapyr (100 g/ha) at 25 DAS significantly suppressed weed seedling emergence (Fig. 15.11). It was observed that conventional-tilled direct seeded rice (CTDSR) fb zero tilled wheat (ZTW) fb zero tilled greengram (ZTG) led to significant improvement in crop productivity and profitability in rice, wheat and greengram. This treatment also led to significant improvement in resource use efficiency. The treatment CTDSR led to 23.1% higher water productivity (WP) than LPTPR in rice, whereas CTDSR-ZTW resulted in 6.7% higher water productivity than LPTPR-CTW in wheat. The results of the study indicated that integration of improved crop establishment practice along with efficient weed management practices could lead to sustainable crop intensification
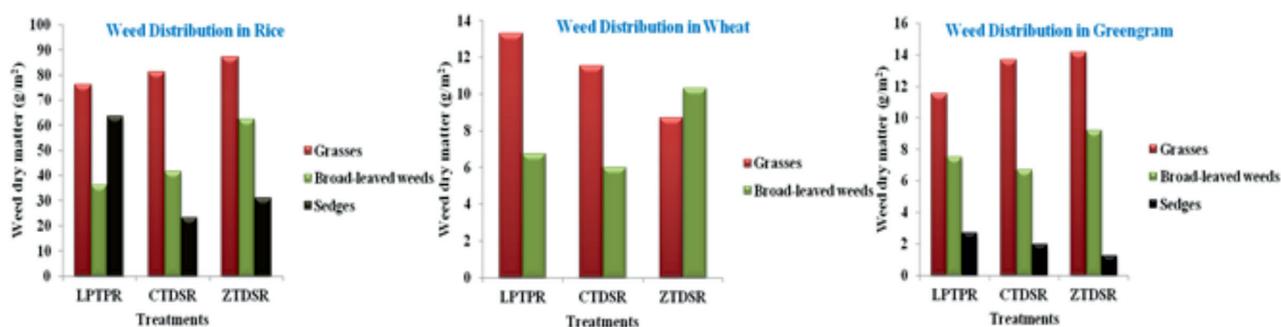
Fig. 15.10 View of Experimental Plot

Fig. 15.11 Weed distribution in crops

Solar Energy Application

16

Irrigation Command Area of Small Capacity Solar Pumps in Eastern Region of India

Quantified groundwater abstraction capacity of existing small capacity solar pumps of 1hp-0.9 kWp, 1hp-1.2 kWp, 2hp-1.8 kWp and 3hp-3.0 kWp DC solar submersible pumps on mean monthly averaged daily basis for different months under the prevailing solar radiation condition and the groundwater depth regime (≤ 10 m) in Eastern region of India. In Eastern region most of the farmers have operational holding size ≤ 2.0 ha; therefore, small capacity solar pumps are suitable. In most part of the region the groundwater depth regime round the year remains ≤ 10 m bgl. On a bright day and in low insolation period, i.e., December & January solar irradiance ranged from 200-600 W/m² while in remaining months it was 200-930 W/m². The mean monthly averaged daily solar radiation for this region ranged from 3.6 to 6.4 kWh/m²/day. The power availability from solar array to the pump depends on the operating month and also on operating time over a day. During low insolation months, pumps can be run between 8.30-15.30 hrs; whereas, in other months it was 7.30-16.30 hrs under tracked solar array. Investigation revealed that between 9.30 - 14.00 hrs time band the tracked and fixed solar array produce almost equal power and therefore discharge under

two arrangements are found same (Fig. 16.1). Over this duration discharge of solar pump settles near the peak value; therefore, drip and micro-sprinklers can be operated with 2HP-1.8kWp and 3.0HP-3.0 kWp solar systems under direct coupling arrangement. The volume of water abstracted under fixed solar array arrangement was 19-23 percent less compared to 3 times tracked array done at 7.30 hrs, 10.00 hrs and 14.30 hrs over a day. The mean monthly averaged daily discharges of different capacity solar pumps were measured to compute water availability for irrigation on daily basis round the year.
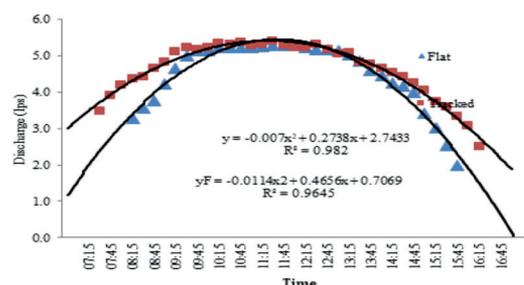

Fig. 16.1 Discharges under 3 times tracked and a fixed solar array 3 HP solar pumping system for maximum solar radiation month (April)

The cost of the solar water system is still high; therefore, it should be used for its potential benefits. For various reasons farmers are unable to tap the potential benefits of their solar pumping system. To tap potential benefit of solar pumping system farmers must grow some

profitable crops such as vegetables and fruit crops, the promising crops for this region, under efficient mode. The command areas of 1HP-0.9 kWp, 1HP-1.2 kWp, 2HP-1.8 kWp and 3HP-3.0 kWp DC solar submersible pumps were estimated for these crops (Table 16.1).

Table 16.1 Irrigation command area of different capacity pumps for groundwater depth level ≤10m, bgl

Crop	Sow. Time	Har. Time	Crop Dura. (Day)	ETo (mm)	Kc	Etc (mm)	Eff. Rain (mm)	Irri. Req. (mm)	Irrigation command area (ha)			
Vegetable									1 hp-0.9	1 hp-1.2	2 hp-1.8	3 hp-3.0
Bottle gourd	Jan	May	120	438.6	1.1	482.4	74.5	407.9	0.64	0.98	1.44	2.52
Brinjal	Sept.	Feb	120	409.7	1.1	450.6	153.1	297.5	0.88	1.34	1.98	3.46
Potato	Oct.	Feb.	90	344.3	1	327.0	88.3	238.8	0.82	1.25	1.85	3.23
Ladyfinger	Feb.	June	100	691.3	1.3	891.8	121.9	769.9	0.28	0.43	0.64	1.11
Onion	Oct.	Feb.	110	344.3	0.9	309.8	88.3	221.6	1.08	1.65	2.43	4.26
Tomato	Sept.	Feb.	120	448.6	1	448.6	157.5	291.1	0.90	1.36	2.01	3.53
Chilly	May	Oct.	120	787.6	1.1	866.4	552.7	313.7	0.83	1.27	1.87	3.28
Ridge gourd	Feb.	May	90	525.8	1.1	578.4	74.5	503.9	0.39	0.95	1.41	2.46

Crop	Sow. Time	Har. Time	Crop Dura. (Day)	ETo (mm)	Kc	Etc (mm)	Eff. Rain (mm)	Irri. Req. (mm)	Irrigation command area (ha)			
									1 hp- 0.9	1 hp- 1.2	2 hp- 1.8	3 hp- 3.0
Cabbage	Sept.	Jan	90	377.9	1	377.9	153.1	224.8	0.80	1.22	1.80	3.15
Cauliflower	Sept.	Jan.	90	377.9	1	377.9	153.1	224.8	0.80	1.22	1.80	3.15
Fruits												
Papaya	Jan.	Dec.	360	1317	1.1	1449	592.3	856.5	0.92	1.40	2.06	3.61
Banana	Jan.	Dec.	360	1317	1.1	1449	592.3	856.5	0.92	1.40	2.06	3.61

Development of Solar Irrigation Pump Sizing Tool

Selection of optimally sized solar pumping systems that matches the bio-physical situations of the concerned farmers is a challenging task particularly in large schemes like, PM-KUSUM, wherein the Government of India's is planning to invest ₹34,035 crores to support the installation of 3.5 million solar irrigation pumps. An innovative Solar Irrigation Pump Sizing (SIPS) Tool has been developed to assist in selection of 'right size' of solar irrigation pump (Fig. 16.2). The tool has universal applicability in the sense that it uses nationwide datasets on climate, soils and crops, wherein users can fetch the required data for the location of their interest.
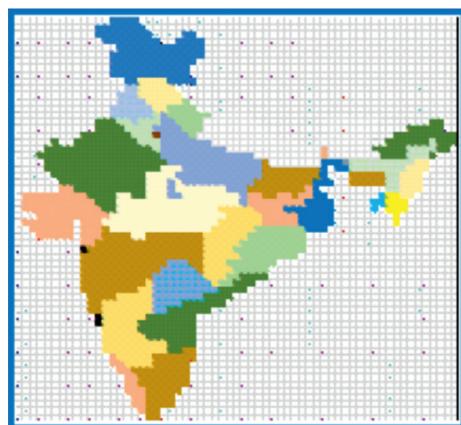

Fig. 16.2 Screenshot of the start screen and 'select location' page

The general architecture of the tool is shown in Fig.16.3. The tool has four modules *viz.* crop water requirement module, discharge estimation module, head loss estimation module and the pump selection module that selects the best matching pump from the models specified by Ministry of New and Renewable Energy (MNRE). This SIPS Tool is designed to precisely estimates the irrigation demand, calculate the peak discharge and head requirements to arrive at optimal size of SIP. The tool has been adopted by the MNRE and the ministry is advocating use of this tool by all the implementing agencies of the PM-KUSUM. The tool is also useful farmers, researchers and technical persons involved in adoption and promotion of solar pumping systems across India.
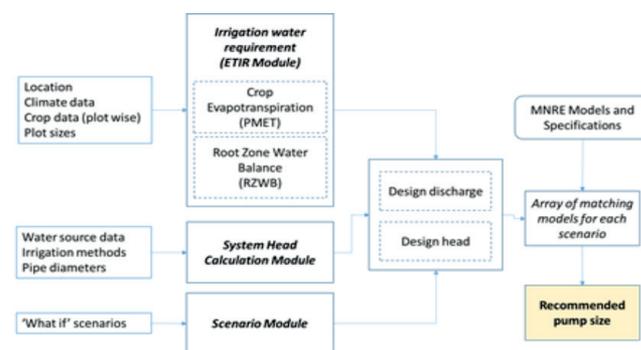

Fig.16.3 General architecture of the beta version of SIPS tool

The SIPS tool has Evapotranspiration based Irrigation Requirement (ETIR) module which uses the climatological approach to estimate the reference evapotranspiration (ETo), crop evapotranspiration (ETc), effective rainfall (Pe) and irrigation water requirement (Ir) of each crop within the selected cropping sequences. The ETIR module estimates these parameters for the period of 10 years (2009-2018) at daily time step. The 10-year average irrigation water requirement of each month is then converted to monthly water requirements in volumetric units. The pump selection module is programmed to select the smallest capacity model from the array of pump models specified the Ministry of New and Renewable Energy (MNRE) of Government of India.

Farm Machinery

17

Design and Development of Motorized Cole Crop Harvester

A prototype of manual cole crop harvester was designed. Before designing the prototype, data of cauliflower stem diameter and its maximum canopy cover was noted. The average canopy cover was 54±4.23 cm and average stem diameter was 3.2±0.31 cm. The variety of cauliflower was Madhuri which was sown on 18th October 2022. The biometric data was recorded at the time of harvesting on 16th February 2022. Based on the stem diameter and canopy area, a manual prototype for cutting the stem of the cauliflower was designed. It was tested for its cutting performance in the cauliflower field. However, after harvesting a few cauliflowers, it became apparent that the prototype had a few flaws: the cutting blade's width was insufficient to remove the entire stem, the handle's length was too short, and the cutting action by hand was cumbersome and involved drudgery. The alteration is being done in the workshop of the institute.

Modification of Manual Octagonal Maize Sheller

The existing octagonal maize sheller (OMS) was modified and provided with a rotating handle and a clamp so that it can easily be clamped with table, wooden rack etc. (Fig. 17.1). This will free one hand which will continuously rotate the maize sheller and other hand will be used to feed the maize cob. The OMS was welded with three-pronged rod each of length 120 mm (9 mm dia) and the end was welded to a washer (44 mm dia). The washer was connected to the hub (cycle) with the help of nut and a long bolt (9 mm dia) with grooves both ends. One end of the bolt is attached with the L shaped handle. As the handle rotates, it rotates the OMS also. A square MS pipe (25×5 mm) was welded with the hub. At the end of the square pipe a clamping system is provided which can accommodate maximum thickness size of 40 mm. Tubular maize Sheller with handle is a small kind of machine for threshing maize, features on simple structure, high rate of threshing and easy to use and maintenance. It is reliable and safe because it is not controlled by the power so; it is more convenient in using. It is much suitable for the needs of small farmer's maize thresher.
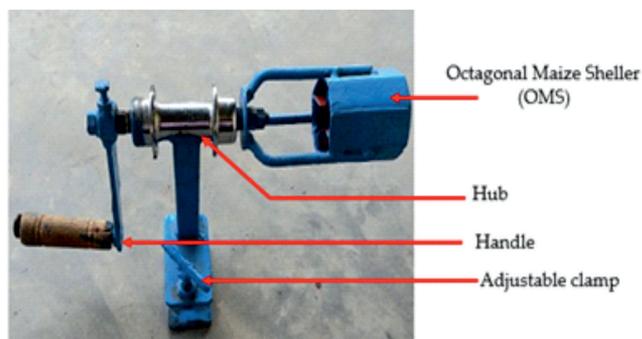

Fig. 17.1 Modified octagonal Maize Sheller

Ergonomic evaluation of maize shelling by OMS and modified OMS was carried out with farm women at ICAR RCER, Patna during 7-15 July 2022 (Fig. 17.2 & 17.3). The maize cobs used for the study were harvested from institute farm. The cobs were allowed to dry for few days and at the time of experimentation the moisture content of the cobs was 12.65 per cent. There was an increase in the average heart rate (86.60 to 87.60), energy expenditure as well as oxygen consumption while shelling with the modified OMS, however, there was also an increase of output capacity by 32 per cent. The average output capacity of modified OMS was 18 kg/h as compared to 13.9 kg/h (Table 17. 1) with the existing octagonal maize sheller

Fig. 17.2 Shelling by OMS

Fig. 17.3 Shelling by modified OMS

Table 17.1 Comparison of different parameters during maize shelling (N=5)

Particulars	Octagonal Maize Sheller (OMS)	Modified OMS
Overall dimensions		
(LxWxH), mm	72×65	360x85x230
Shape	Octagonal	Tubular maize Sheller with handle
Weight (kg)	0.23	1.73
Unit cost (Rs)	100	500
Time spent to shell 10 cobs (min)	4.06±1.77	3.18±0.43
Average heart rate during rest (beats/min)	86.60±4.67	87.60±3.58
Average working heart rate (beats/min)	94.35±3.55	101.60±8.12
Average recovery heart rate (beats/min)	89±2.91	91.79±3.99
ΔHR (beats/min)	8.35±3.55	14.00±8.90
Output (kg/hr)	13.92±0.12	18.35±0.11
ΔHRKG (beats/kg)	35.97	45.78
Average OCR (l/min)	0.395	0.478
TCCW	48.89	65.46
Average Energy expenditure rate, KJ/Min	8.28	10.00

Refinement of Indigenous Plough and Weeding Rake in Eastern Hill and Plateau Region

A prototype of an indigenous plough was developed based on Ergonomic parameters to minimize drudgery (Fig. 17.4). The plough was developed after carefully studying different types of indigenous plough of Chhattisgarh, Jharkhand, and Odisha state. Hence, it is an amalgamation of different ploughs. The performance evaluation of developed animal-drawn indigenous plough was carried out at Ramgarh, Jharkhand. The soil of experimental plot was sandy clay loam (sand: 53.76%, silt: 18% and clay: 28.24%). Soil moisture content was 6.74% at 0-15 cm and 13.77% at 15-30 cm soil depth respectively. Ambient air temperature during the experiment varied from 20°C -31°C and relative humidity varied between 64 % and 94% during the experiment. The speed of ploughing was 3.85 and 2.95 km/hr for developed and local plough, respectively. Energy expenditure was estimated 10.53 kJ/min for developed plough whereas for local plough, it was 11.30 kJ/min. An increase of 18.07 % in working efficiency and drudgery reduction of 6.81 % was observed with developed plough.

The draft force was measured for pulling it by a pair of bullocks and recorded 58.64 kgf for developed plough and 63.765 kgf for the local plough (Fig. 17.4). After evaluation in the field, few modifications have been suggested by farmers which are being incorporated in the plough.

Fig.17.4 Evaluation of developed prototype plough in field

18 Livestock and Fisheries

Livestock

Characterization of Lesser-known Germplasm of Farm Animals

A study was undertaken in 11 districts of Bihar to characterize the lesser-known animal germplasm. Based on the examination of the phenotypic and morphological characteristics, Tirhut goats and Champaran pigs have been identified for a further detailed study.

Tirhut goats (Fig. 18.1) found in the Agro-climatic Zone-I had different coat colour varying from white, brown and black. These animals were taller, but slimmer in size with drooping ears. Around 16.23 percent of these goats were found polled in both genders. Body weights

of these goats were found to be 6.28±0.33 kg, 10.11±0.29 kg, 13.24±0.46 kg and 16.73±0.55 kg, respectively at 3, 6, 9 and 12 months of age.

The tribal farmers of Zone 1 are rearing Champaran pigs (Fig. 18.2). They resembled to some extent with Ghungroo pigs, but also possessed the characteristics of wild pigs. One unique trait these pigs possess is higher fecundity with 12 to 18 piglets in a single parturition. Good mothering ability is these pigs' additional character, which is vital for piglet survivability and lowered mortality. Body weights of these piglets were found to be 22.41±0.45 kg, 43.18±0.36 kg, 60.71±0.52 kg and 78.35±0.57 kg, respectively at 3, 6, 9 and 12 months of age

Fig. 18.1 Tirhut goat

Fig. 18.2 Champaran pig

Network Project on Buffalo Improvement

Network Project on Buffalo Improvement is operational in Patna since 2014. The current herd strength is 105 animals, of which 61 are breedable. Due care was paid to reduce the mortality in the herd, as the project lost only 03 animals, with the herd mortality of 2.85 percent. Semen of 20th set of bulls from CIRB were used for inseminating. The conception rate was 50.69%. Twenty nine buffaloes calved with the male to female calf ratio of 1.07:1. The average lactation milk yield was 2486.33±48.45 kg with the range from 1678 to 2786 kg. Herd strength, calves born, animals in milk, calf mortality and average total lactation milk yield over the years (Fig 18.3).
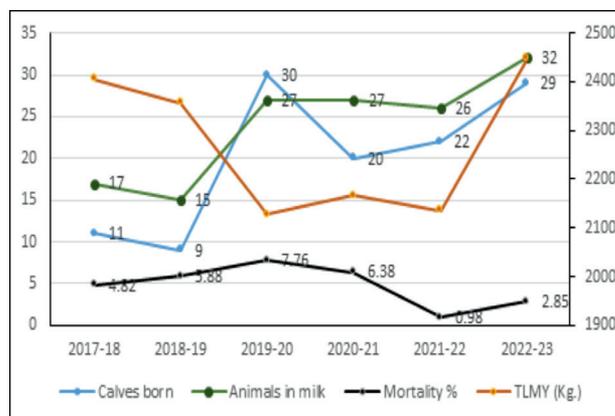

Fig.18.3 Performance of Murrah buffaloes under network project

To avoid letdown in the reproductive traits, MS-Excel-based animal reproduction monitoring program called buffalo reproductiondaytoday.xls was created in which all reproductive data including artificial insemination, pregnancy verification and calving particulars were recorded everyday for future prediction. The system also helped to identify the expected animals for artificial insemination and pregnancy verification on a particular day.

Development of Egg and Meat Strains of Ducks Suitable for Backyard Farming

Ducks are one of the vital species providing livelihood support to many farmers in the Eastern India. Though these ducks are less productive, they are very hardy and less susceptible to diseases. Hence, idea was to develop an egg and a meat strain of ducks by making suitable crossbreeding and selective breeding programme. Initially 100 ducklings each from Khaki Campbell and White Pekin were purchased from Vivekanand Ashram, Jharkhand. At 3 months of age, the ducklings (5% of population) were selected based on their body weight and phenotypic parameters. Selected drakes were allowed to mate with the selected non-descript ducks from Bihar

The F1 generation ducklings were reared and selective breeding was done to choose the birds with higher body weight. The average body weights of Pekin x Bihar desi were 31.58% superior to their dams (Table 18.1). Drakes from F1 population were selected based on body weight and inter se mating was carried out. Eggs collected from F1 ducks were again incubated and F2 generation is being reared and studied for their phenotypic characteristics (Fig 18.4)

Fig. 18.4 Cross-bred ducks in F2 generation

Table 18.1 Body weight of selected duck population and average body weight in F1 generation

Age in months	Body weight (kg) in the selected population				Average body weight (kg) in entire population			
	White Pekin		Bihar Desi		Crossbred ducks (F1)		Crossbred ducks (F1)	
	Duck	Drake	Duck	Drake	Duck	Drake	Duck	Drake
1	0.50±0.01	0.54±0.01	0.32±0.03	0.37±0.05	0.45±0.12	0.47±0.12	0.43±0.13	0.40±0.14
2	0.75±0.07	0.88±0.08	0.55±0.12	0.62±0.14	0.69±0.17	0.80±0.18	0.68±0.17	0.77±0.19
3	0.95±0.01	1.09±0.01	0.64±0.02	0.65±0.03	0.88±0.17	1.05±0.19	0.86±0.19	1.03±0.19

Assessing Genetic Variability in Ducks of Eastern States

Mitochondrial DNA sequencing followed by genome assembly and annotation was attempted for ducks from Chhattisgarh. Mitochondrial genome NC_009684.1 was used as a reference assembly to guide the assembly. Attempts were also made to characterize microbiota along the oviduct mucosa in native (Maithili) and exotic (White Pekin and Khaki Campbell) duck breeds. For this, three birds of each breed were euthanized by cervical dislocation followed by decapitation as per the IAEC approval. The mucosal surface of each compartment of the oviduct, was scraped in sterile tubes. The DNA was extracted from these scrapings and submitted for shotgun metagenome sequencing. The raw sequence data was uploaded in MG-RAST server.

Effect of Genetic & Non-genetic Factors on Prolificacy of Bengal Goat

The present study evaluated the effect of photoperiod on secretory patterns and presence of a sexually active male buck upon the onset of reproductive activity and oestrous cycle in Black Bengal goats (Fig. 18.5) exposed to 3 months of long days (16 hour of light/day). Long day light (300 lux) was provided by extra light beyond natural day length light. The design of the experiment is given in (Fig. 18.5 & 18.6).

During seasonal anoestrus, 34 does age 10 (n=16) or 15 (n=18) months were subjected to the male effect (Table 18.2). After the end of the photoperiod treatment, the males, were introduced to the does and maintained with them for the following 30 days to induce the male effect. All four experimental groups were located in open barns completely isolated from the other ones. Oestrous activity was recorded daily by direct visual observation over the 32 days following the bringing of the sexes together (introduction).

Fig. 18.5 Black Bengal Buck

Fig. 18.6 Experimental design of effect of photoperiod on reproductive activity and oestrous cycle in Black Bengal goats

The photo-stimulated bucks (PHOTO) undertook more (%) genital sniffs (88.19), nudges (76.39) licking (58.33), sneezing sounds (82.94), attempts (88.19) and mounting (100) than the unstimulated bucks (CONTROL) (p < 0.01). The interval from male introduction to first oestrous behaviour at 10 and 15 months of age was shorter in dams exposed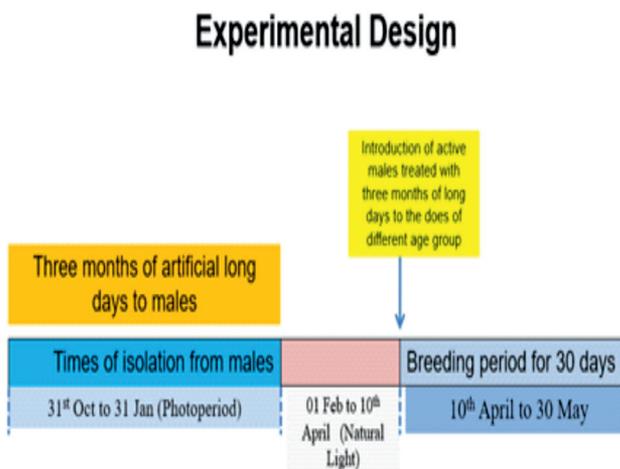 to the PHOTO males (7.5 and 4.44 days) than among those exposed to the CONTROL males (10.6 and 10.83 days). The percentage of fecundity and fertility was significantly higher in the females submitted to the male effect using photo-stimulated bucks in both age groups.

Table 18.2 Reproductive response of Does expose to photo-stimulated bucks (PHOTO) and unstimulated bucks (CONTROL)

Age of does	10-Month-old does		15-Month-old does	
Traits	CONTROL (n=8)	PHOTO (n=8)	CONTROL (n=9)	PHOTO (n=9)
Fecundity (%) (% of pregnant does mounted by bucks)	62.5	87.5	66.67	100
Fertility (%) (% of goats kidding per doe serviced)	50	75	55.56	88.89
Prolificacy (Kids born by female kidding)	1.25±0.25	1.17±0.17	1.11±0.15	1.33±0.17

From day 8 after introduction, the percentage of does showing elevated progesterone (Fig.18.7) was higher among the 15-month-old than the 10-month-old female, independent of the type of male to which they were exposed (P<0.05). However, the percentage of does showing elevated progesterone was higher among those exposed to the PHOTO males than those exposed to the CONTROL males (P<0.05).
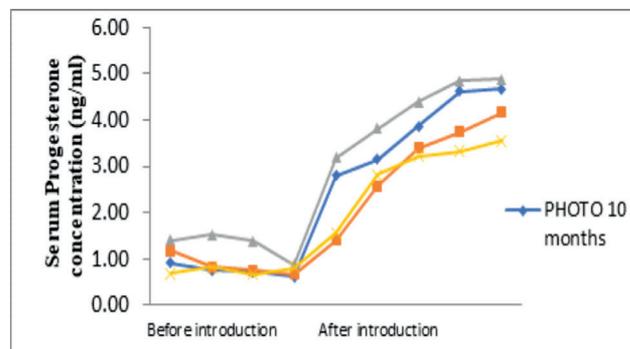

Fig. 18.7 Serum Progesterone concentration (ng/ml) in Black Bengal does

Low Cost Backyard Poultry Production System

The present investigation aimed to evaluate the effect of earthworm and groundnut fodder on Kadaknath chickens' growth in backyard rearing while keeping deep litter system as control (Fig. 18.8 & 18.9). One-month-old kadaknath chickens (n=300) were assigned to 2 treatments with 5 pens per treatment and 10 Kadaknath chickens per pen in a completely randomized design. The experiment was conducted for 28 weeks to evaluate the performance of Kadaknath chickens fed on natural feed *viz.* earthworm, maggot, groundnut fodder with broken rice (Table 18.3). Nutrient contents of the feeds offered to Kadaknath chicken were analyzed. The two treatments used in this experiment were: T1: commercial ration without natural feeding and maintained on deep litter system, T2: natural feeding (without commercial ration) and maintained under backyard system. The outcomes of the study depicted the greater overall feed intake value in Kadaknath chicken fed the commercial ration (grower mesh) than those fed the diets containing natural feed. The average weight gain for the chickens was almost equal in both groups (Table 18.4).

Table 18.3 Feed Intake of Kadaknath chicken

Age in weeks	Grower mesh (g/ bird)	Broken rice (g/ bird)	Moringa olifera leaves (g/ bird)	Earthworm (g/ bird)
5th to 7th	35	35	15	10
8th to 15th	40	40	15	10
16th to 20th	80	50	15	10
20th onwards	110	60	15	10

Table 18.4 Effect of production system on the performance of Kadaknath chicken

Parameters	Production systems					
	Commercial ration			Natural feeding		
	Male	Female	Avg.	Male	Female	Avg.
Initial weight (g)	440.5 ±2.54	362.42 ±8.84	378.03 ±9.13	449.5 ±3.39	354.00 ±12.38	373.10 ±12.16
Final weight (g)	1768.33 ±55.22	1506.88 ±13.19	1559.17 ±24.35	1646.67 ±82.64	1298.96 ±31.63	1368.50 ±39.21
Weight gain (g/bird/day)	7.90 ±0.37	6.81 ±0.12	7.03 ±0.13	7.13 ±0.54	5.62 ±0.21	5.93 ±0.22

Fig.18.8 Deep litter system of rearing

Fig.18.9 Backyard system of rearing

Characterization and Evaluation of Chicken Germplasm of Eastern Region

Characterization of indigenous chickens and their production systems in five districts of Jharkhand *viz.* Ranchi, Khunti, Simdega, Gadhwa and Latehar were carried out based on structured field surveys of 251 households. Native chickens were prominent (82%) compared to Naked Neck (5%) and Aseel (13%) among the three types of indigenous chickens. The management and upkeep of chicken is largely (75%) carried out by women family members. The market price depends on chickens' phenotype, age, sex and by season of year. The average flock size was 24.29±0.63 with a hen to cock ratio close to 6.0:1.7. The majority of farmers (50.9%) recognized that high mortality was on account of fatal disease, locally called as Jhukni (Newcastle disease). The farmers (>95%) were unaware about vaccination and deworming of birds. Chickens were being housed in separate houses or under bamboo baskets at night and mating was natural.

In males, black and golden yellowish plumage was dominant in Ranchi while in Khunti, Simdega, Gadhwa and Latehar districts, red & black mix plumage was dominant (Fig. 18.10). However, female chickens (Fig.18.11) were characterized by reddish brown, black and white brown plumage. The predominant shank colour was yellow. The colour of ear lobe and comb were red, and skin was white in all the birds. The predominant comb type was single followed by pea and rose. The production constraints mentioned need urgent mitigation measures to sustain the utilization of indigenous chicken. The present study has developed the baseline data of indigenous chickens for recognition as a distinct breed in the future.

Fig. 18.10 Chicken germplasm (Male) from Jharkhand with different plumage colour

Fig. 18.11 Chicken germplasm (Female) from Jharkhand with different plumage colour

Evaluation of Traditionally used Growth Promoters in Pig

A feeding trial was conducted to assess the supplementation of spent mahua flower in the regular diet of growing pigs (Fig. 18.12). Four treatment rations were prepared. All the group fed with commercial ration with different level of supplementation of spent mahua. The feeding trial of 90 days was conducted on growing T&D pigs divided in four equal groups. The growth of pigs was measured by body weight gain and linear body measurement of each pig in the groups. The pigs in the treatment group, with 10 % and 15 % spent mahua supplementation, had a daily weight gain of 397 g and 402 g respectively during the experimental period compared to pigs at 5% and the control group (391 g and 389 g). Linear body measurement of the pigs followed the same

trend as observed in the other response parameters.

Fig. 18.12 Spent mahua and its feeding to piglets

Table 18.5 Effect of feeding spent Mahua on average dry matter (DM) consumption and average body weight of piglets

P eriod	Experimental groups							
Treatments	T1 (control)		T2 (5% spent Mahua)		T3 (10% spent Mahua)		T4 (15% spent Mahua)	
Timeline	DM consumption (kg)	Average body weight (kg)	DM consumption (kg)	Average body weight (kg)	DM consumption (kg)	Average body weight (kg)	DM consumption (kg)	Average body weight (kg)
Initial	-	9.69 ±0.47	-	9.70 ±0.58	-	9.45 ±0.38	-	9.72 ±0.89
1st fortnight	91.92 ±0.28	14.25 ±0.67	92.12 ±0.35	14.88 ±0.61	92.88 ±0.74	15.12 ±0.45	93.98 ±0.77	15.87 ±1.05
2nd fortnight	119.65 ±0.39	19.48 ±0.55	120.12 ±0.55	19.65 ±0.65	121.14 ±0.58	20.89 ±0.45	122.21 ±0.87	21.98 ±0.57
3rd fortnight	131.97 ±0.49	25.68 ±0.87	132.11 ±0.45	25.70 ±0.75	133.21 ±0.55	26.88 ±0.58	133.88 ±0.65	27.05 ±1.21
4th fortnight	137.35 ±0.51	31.66 ±0.89	137.45 ±0.35	31.87 ±0.56	138.44 ±0.89	32.54 ±0.41	140.12 ±0.55	32.98 ±0.54
5th fortnight	167.55 ±0.68	37.89 ±1.07	167.98 ±0.78	37.88 ±1.01	168.22 ±0.91	38.75 ±1.18	168.35 ±1.01	39.02 ±1.20
6th fortnight	176.11 ±0.89	44.68 ±1.12	177.11 ±0.90	44.89 ±1.28	178.21 ±1.08	45.24 ±1.58	179.22 ±0.89	45.95 ±1.25

Exploring Genetic Basis of Mastitis Resistance in Livestock

Milk from 278 animals (157 cow and 121 buffalo) from the institute farm and farmer's field were collected and screened for subclinical mastitis by the California mastitis test (CMT) 98 animals (46 cow and 42 buffalo)

were found positive for clinical/subclinical mastitis. Out of 49 animals screened from our institute farm 11 animals (7 buffalo and 4 cow) were positive for subclinical mastitis. Positive milk samples were processed for bacterial isolation under aerobic culture. Based on colony characteristics, staining, morphology, and growth

characteristics on selective media, bacterial isolates have been identified. The bacterial isolates identified comprised *Staphylococcus aureus, Staphylococcus spp., Streptococci spp., Escherichia coli, Bacillus spp., Corynebacterium spp., Diplococci*, *Micrococci* and others unidentified. *S. aureus* isolates were confirmed on Mannitol salt agar (MSA) medium and by *thermonuclease gene* PCR. Antibiotic sensitivity test was performed to know the efficacy of antibiotics commonly used for treatment of mastitis. 50 % of the *Staphylococci species* isolated were resistant to ampicillin, penicillin-G, polymyxin-B and cefixime, chlortetracycline and tetracycline. About 33% staphylococci showed resistance to enrofloxacin, amoxyclav, ofloxacin, norfloxacin, amoxycillin and ciprofloxacin. However, isolated *Staphyloccocci species* were 100% susceptible to bacitracin, chloramphenicol, ceftriaxone, imipenem, doxycycline, gentamicin, amikacin and vancomycin.

Milk samples were collected from healthy animals suffering from clinical/subclinical mastitis (n= 75). Genomic DNA was isolated. A 211 bp fragment (Fig. 18.13) comprising exon 13 of lactoferrin gene was analyzed for detection of polymorphism expected to be present at this locus. The primers reported by Kathiravan et al. (2010) was used for amplification of lactoferrin gene. Primers used for amplification were forward, 5' AGAGCTGGCTCCCCATGTTTCTT 3' and reverse 5' AGGGCCCTGTCCTGATGAAGC 3'. PCR cycling conditions were standardized with different concentrations of $MgCl_2$, Taq polymerase, dNTPs and primers. PCR reaction is performed in in a total volume of 25 μl with 100 ng of genomic DNA, 10 pmoles of each primer, 2 mM of $MgCl_2$, 100 μM of each dNTP, 1X PCR reaction buffer and 1 U of taq DNA polymerase. PCR programme followed for amplification of gene fragment was initial denaturation for 95ºc for 2 min than 35 cycles of denaturation at 95ºc for 30 sec, annealing at 58ºc for 30 sec, extension at 72ºc for 30 sec and then final extension of 72ºc at 5 min.
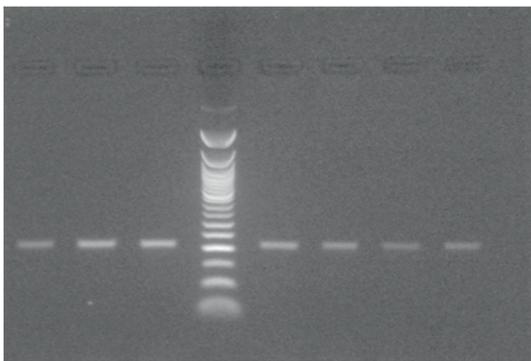

Fig. 18.13 PCR amplification of 211 bp fragment of lactoferrin gene

Restriction fragment length polymorphism (RFLP) were used for identification of allelic variants of amplified Lactoferrin gene fragment. HPPY188I restriction enzyme is used for RE digestion of PCR product. Optimum digestion was obtained at 37ºC for overnight incubation in a BOD incubator. The restriction fragment of different length was separated in 3% agarose gel run at 80 V for 1 hr. The length of each fragment generated by Hpy188I restriction digestion was compared with 50 bp marker. Our finding revealed that Hpy188I has no recognition site in 211 bp fragment of lactoferrin gene.

Molecular Epidemiology and Therapeutic Management of Bovine Theileriosis

The project concluded with the current year's work, including 256 blood samples collected and screened. GSBS (Giemsa stained blood smears) were performed for microscopic confirmation of *Theleria spp*. The work focused on the subtyping of *Theileria orientalis* which caused Oriental Theileriosis. The DNA was isolated from *Theleria spp*. positive samples and amplified by polymerase chain reaction using genus-specific primers (18S smaller subunit rRNA gene of the V4 region). The presence of amplified DNA of *Theileria spp*. was confirmed in agarose gel. The samples were further confirmed of *T. orientalis* using species-specific primers that amplify the major piroplasm surface proteins (MPSP gene) (Fig. 18.14). The positive samples of *T. orientalis* were further identified for the three reported subtypes from India i.e Chitose, Ikeda and Buffeli using SSU rRNA gene primers (Ts Ikida (826bp), Ts Chitose-831bp, Ts. Buffeli -825 bp) (Fig. 18.15). The subtyping of *Theileria orientalis* showed that 100% of the *T. orientalis* were positive for Chitose subtype while 7.69% samples contain both Chitose and Buffeli subtypes which indicate that majority of *T. orientalis* infection with clinical manifestation is due to *T. orientalis* subtype chitose. It was further confirmed by sequencing of PCR amplified products and blasting on NCBI server (Figure 18.16). The sequence was submitted to NCBI BankIt for getting GenBank accession numbers: -

(1) BankIt 2662970MKT2_Bihar_Thieleria OQ241436, Tripathi et al., 2023

(2) BankIt2662998MKT09_Bihar OQ241437, Tripathi et al., 2023

(3) BankIt2661508 1222_731_013_PCR_MKT_7_ Thieileria, OQ207675

(4) BankIt2662010 1222_731_005_PCR_3_THO1_ Bihar_MKT03.ab1 OQ207676, Tripathi et al., 2023

(5) BankIt2662020 MKT_05_Bihar OQ207677, Tripathi et al., 2023

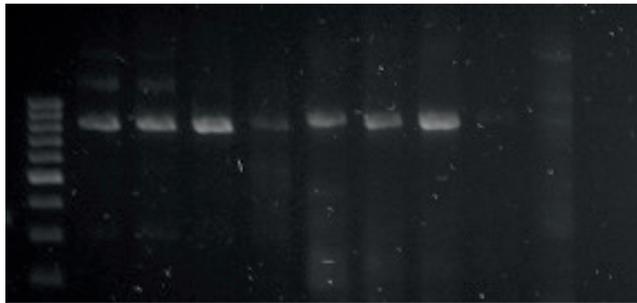(6) BankIt2662029 Thieleria OQ207678, Tripathi et al., 2023

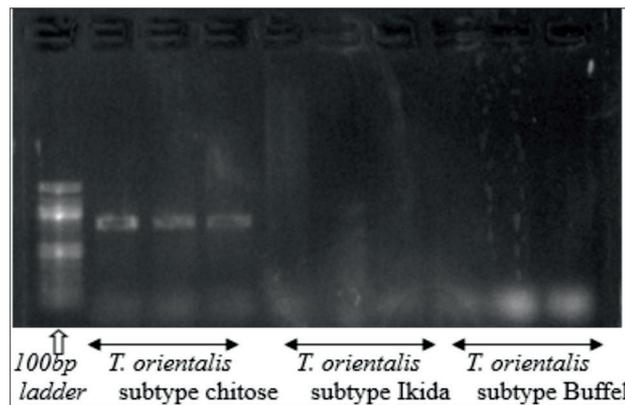**Fig. 18.14 Samples identified as *T. orientalis* (MPSP gene)**

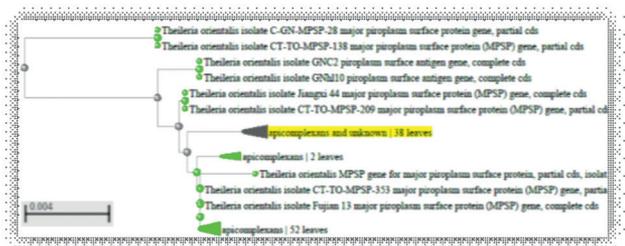**Fig. 18.15 Subtyping of *T. orientalis* positive samples.**

Fig. 18.16 Blast tree View: Rectangle Cladogram of Sequence No OQ207676, indicating similarity (>99%) with *Theileria orientalis* isolate chitose (MZ852008.1 and MZ852009.1)

Effect of Environmental Exposure of Arsenic in Animals of Bihar

Samples collected from Nurichak, Udaypur and Kachhariadih village (Nawada district), Ekauna (Bhojpur district) and Sabalpur (Saran district) of Bihar were evaluated for arsenic content in drinking water, animal blood and urine. The level of arsenic in water, blood and urine samples from Nawada was found to be below the detection level (control). The mean level of arsenic (μg/liter) in the water samples from Bhojpur and Saran districts were 27.73±5.63 and 46.48±9.34, respectively, and were higher than the maximum permissible limit of 10 μg/liter. The rectal temperature, respiration rate per minute, rumen motility, hemoglobin and TEC of cattle from Bhojpur were non-significantly different from those of the Nawada district. The mean level of arsenic (μg/liter) 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 which were higher than control animals.

Study of Genetic Polymorphism of Candidate Genes Associated with Production Traits in Goats of Eastern Region

The present study explored genetic polymorphism in targeted regions of PLAG1, STAT3, β-LG and NGF genes in Black Bengal goat. Genomic DNA was isolated from whole blood samples of Black Bengal goat by QIAGEN Dneasy Blood & Tissue Kit. To amplify the targeted regions, two sets of forward and reverse region-specific oligonucleotide primers for STAT3 gene and one set for each PLAG1, β-LG and NGF genes were designed using Primer3 software. The targeted regions of each primer set were genotyped using PCR-RFLP technique to detect SNPs. All the primer sets in the study were polymorphic except primer set 2 (Exon 7 & 8 regions) of STAT3 gene was monomorphic in Black Bengal goat. Total five nucleotide changes (g.58706363D>I, g.42111147A>C, g. 42111756 T>A, g.4601A>G, g.705A>G) of PLAG1, STAT3, β-LG and NGF genes were observed in the tested breed. PCR-RFLP analysis with Hae III enzyme revealed SNP at locus g.58706363D>I in 3' flanking sequence (616 bp) (Fig.18.17) of PLAG1 gene, resolved into DD (453 and 163 bp) and ID (616, 453 and 163 bp) genotypes in the tested population (Fig.18.18). PCR-RFLP analysis with Msp1 restriction enzyme revealed SNPs at STAT3 locus g.42111147A>C revealed AA and AC genotypes, whereas, at STAT3 locus g.42111756 T>A showed monomorphic pattern of AA genotype in the studied population. PCR product (427 bp; Fig.18.19) harboring SNP at locus g.4601A>G in Exon 7 of β-LG gene was digested with Sac II enzyme, revealed AA, AB and BB genotypes (Fig.18.20). In addition, SNP at locus g.705A>G in exon 1 (319 bp) (Fig.18.21) of NGF gene was digested with Mbo II enzyme showed GG and AG genotypes in the tested breed (Fig.18.22).

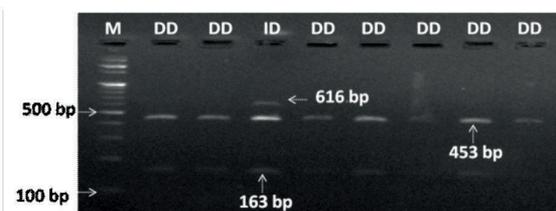**Fig. 18.17 Resolution of PCR product of PLAG1 gene (Lanes 1-14: 616 bp; Lane M: 100 bp DNA ladder)**

Fig. 18.18 PCR-RFLP of SNP locus [g.58706363D>I] in PLAG1 gene

Fig. 18.19 Resolution of PCR product of β-LG gene (Lanes 1-14: 427 bp; Lane M: 100 bp DNA ladder)
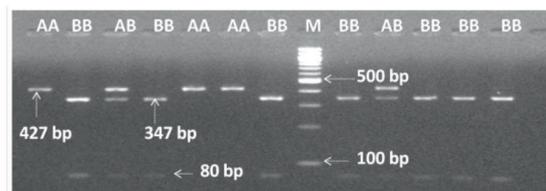

Fig. 18. 20 PCR-RFLP of SNP locus [g.4601A>G] in β-LG gene
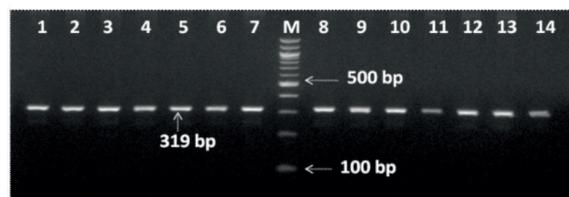
Fig. 18.21 Resolution of PCR product of NGF gene (Lanes 1-14: 319 bp; Lane M: 100 bp DNA ladder)
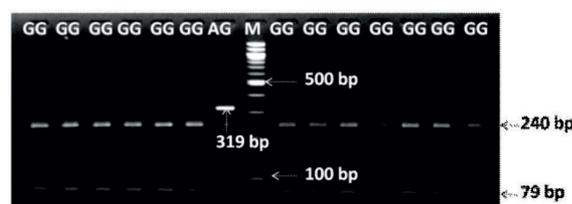
Fig. 18.22 PCR-RFLP of SNP locus [g.705A>G] in NGF gene

All India Coordinated Research Project (AICRP) on Goat Improvement

The project aims to improve Black Bengal goats' production and reproduction performance under village conditions by selective breeding through genetically superior bucks. The center possesses a nucleus herd in Patna and five clusters in different agro-climatic subzones of Bihar, namely Samastipur, East Champaran, Araria, Katihar and Jamui districts. Superior bucks were selected based on growth rate and distributed yearly to the clusters from the nucleus herd or from other village herds.

So far, the number of goats registered (tagged) under this project is more than 4000, of which 1194 are breedable female goats. A total of 339 males and 374 females have been added to the project during the year by new births (Table 18.6)

Table 18.6 Flock dynamics of goats in order of type of birth and parity

Clusters	No. of Does	No of does with type of birth				No. of does by order of parity				No. of male added		No. of female added	
	Does	Singlet	Twins	Triplet	Quad	1	2	3	4	0-1 M	1-3 M	0-1 M	1-3 M
Araria	239	116	76	42	5	106	83	31	19	69	85	72	152
Jamui	202	92	63	42	5	87	67	34	14	56	130	51	127
Katihar	247	119	79	43	6	113	63	48	23	61	154	64	151
Motihari	258	134	84	36	4	122	83	38	15	66	147	72	141
Samastipur	248	112	76	56	5	95	76	55	22	87	145	115	114
Total =	**1194**	**573**	**378**	**219**	**25**	**523**	**372**	**206**	**93**	**339**	**661**	**374**	**685**

The mean body weights of Black Bengal goats recorded at 12 months of age were 11.76±0.39 kg for males and 10.21± 0.31 kg for females which are 12.21% and 19.14% higher than the traits recorded in the base population.

Study on milk production characteristics indicated that Black Bengal goats' mean lactation yield and length were 23.31±0.86 litre and 108.93±0.63 days, respectively (Table 18.7).

Table18.7 Lactation performance of Black Bengal goat

Factors	30 d yield (kg)		60 d yield (kg)		90 d yield (kg)		120 d yield (kg)		Lactation yield (kg)		Lactation length (Days)	
	(l)		(l)		(l)		(l)		(l)		(d)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Overall Mean	10.38	0.24	18.25	0.36	21.70	0.59	23.31	0.82	23.31	0.82	108.93	0.64
Season of Kidding												
Mar - Apr	10.80	0.68	17.84	0.77	21.25	0.98	22.82	0.84	22.82	0.84	114.66	0.95
Oct- Nov	11.45	0.62	18.36	0.84	21.73	1.06	23.54	1.03	23.54	1.03	113.46	1.08
Type of Kidding												
Single	10.32	0.34	17.85	0.72	21.16	1.03	22.28	1.01	22.28	1.01	119.56	1.68
Twin	10.94	0.29	18.54	0.61	21.47	0.85	22.85	0.89	22.85	0.89	116.97	1.85
Triplet	11.42	0.44	19.35	0.77	23.91	0.98	25.21	0.92	25.21	0.92	117.61	0.92
Lactation Order												
1	7.62	0.11	12.72	0.17	15.92	0.82	17.16	0.84	17.16	0.84	111.69	0.96
2	9.57	0.15	17.08	0.28	21.68	1.07	22.65	0.99	22.65	0.99	113.15	1.05
3	11.81	0.18	19.97	0.22	23.88	1.11	25.60	1.02	25.60	1.02	115.80	0.83
4	14.60	0.15	24.73	0.19	28.56	0.98	31.33	0.93	31.33	0.93	112.45	1.12

As outreach activities, 5 health camps were conducted during the period in which more than 900 animals were dewormed and more than 200 animals were provided treatments for various illnesses.

Identification and Characterization of Common Zoonotic Pathogens in Domestic Animals

A total of 104 poultry & cattle faecal samples/rectal swabs were collected from an organised farm in Patna and different locations in Madhepura and Madhubani districts from farmer's animals in Bihar. The duck faecal samples were collected from local non-descript breeds as well as from established breeds in flocks that had a recent history of diarrhea. Cross-bred cattle and Sahiwal cattle maintained in an organized farm with a recent history of diarrhea were used for sampling. The samples were used for isolation and identification of *E. coli*. The isolated and confirmed *E. coli* were processed for DNA extraction and PCR to study the prevalance of pathogenic *E. coli* collected from local poultry and cattle population. A total of 98 *E.coli* isolates were identified. *E. coli* were screened for species confirmation by USPA F & R primers, and

the virulence factors were determined by PCR with primers for VTcom, VT1, VT2 and eae genes. From the 48 isolates collected from ducks, 2 had shiga toxin production potential, and both were shiga toxin 2 (STX2) positive. Of 50 isolates collected from Cattle, 30 were Positive for the shiga toxin gene with VTcom primer. Of the 50 isolates collected from Cattle, 23 were shiga toxin 1(STX1) positive and 10 were STX 2 positive (Fig. 18.23). Whereas, 2 isolates were STX1 and STX2 positive. From the 48 isolates collected from ducks, 5 were positive for eae gene. Out of 50 isolates collected from Cattle, 18 were were positive for eae gene (Fig. 18.24). Considering the potential of STEC to cross species barrier, it is imperative to take steps to prevent zoonotic infections with shiga toxin producing *E. coli*. Therefore, monitoring and surveillance must occur in the animal production system, particularly at individual animal production points and occur in the animal production system, particularly at individual animal production points and herd/flock level, to minimise zoonotic infections and economic loss to farmers.
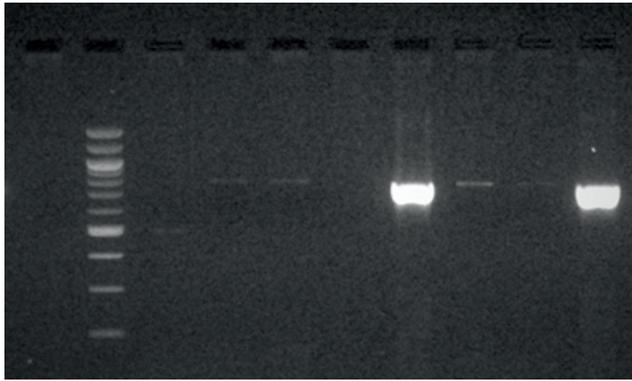
Fig. 18.23 Agarose gel electrophoresis showing amplification of VT2 gene of *E. coli*
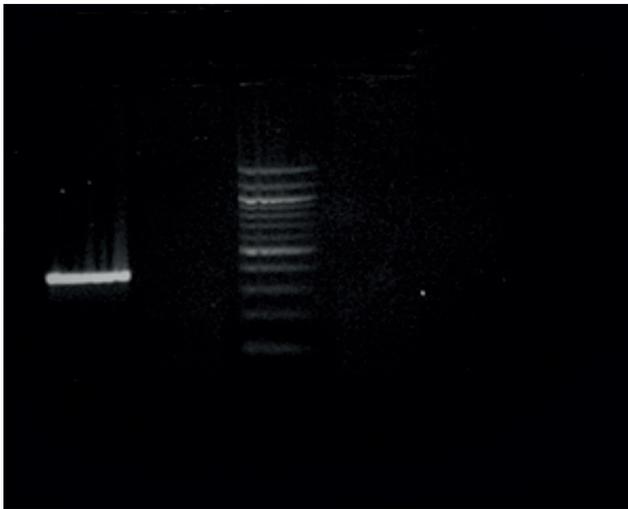

Fig. 18.24 Agarose gel electrophoresis showing amplification with eaeAF and eaeAR primers

Assessment of Antimicrobial Drug Resistance in Bacteria of Animal Origin

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 (Fig. 18.25). Simillarly, 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 (Fig. 18.26). The *S. aureus* was coagulase positive as visualized by amplicon of ≈700 coa gene on PCR (Fig. 18.27).

In AST of *S. aureus* isolates, all the tested *S. aureus* 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. Better sensitivity was observed for Bacitracin, Imipenem, Cefepime, Ceftriaxone, Amikacin and Vancomycin.

The AST profile of confirmed *E. coli* isolates showed >50 % resistance to penicillins, cephalosporins, carbapenems, aminoglycosides, fluoroquinolones and tetracyclines; whereas resistance to penicillin and fluoroquinolones was recorded at the highest rate (>60%). All the *E. coli* isolates were subjected to initial screening and confirmation for ESBL production. Out of 70 tested, 27 (32.8%) *E. coli* were phenotypically confirmed ESBL (Extended Spectrum β-lactamases) producer strains (Fig. 18.28). In the molecular studies on ESBL phenotypes of *E. coli* 92.5% were TEM positive (Fig. 18.29), 25.9% CTX positive (Fig. 18.30), 18.5% positive for both TEM and CTX and none were SHV positive by gene-specific PCR. All *E. coli* and *S. aureus* bacterial isolates have been cryopreserved for future use.
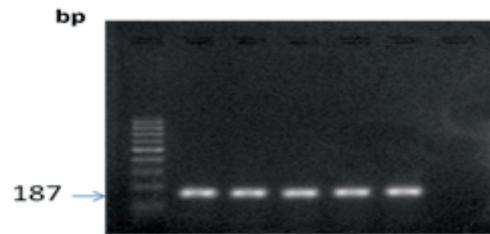

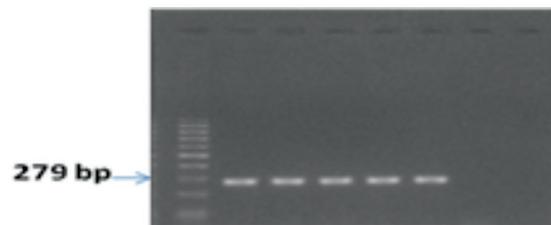**Fig. 18.25 Molecular confirmation of *E. coli* by uidA gene PCR**

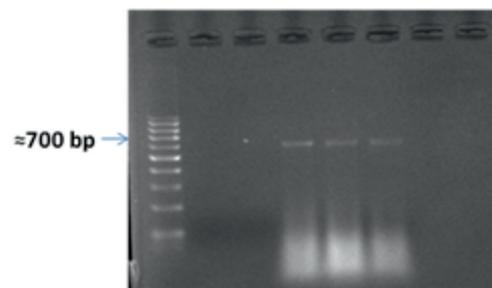**Fig. 18.26 *S. aureus* specific PCR showing 279 bp amplicon of nuc gene**

Fig. 18.27 *S. aureus* virulence typing: coagulase gene PCR
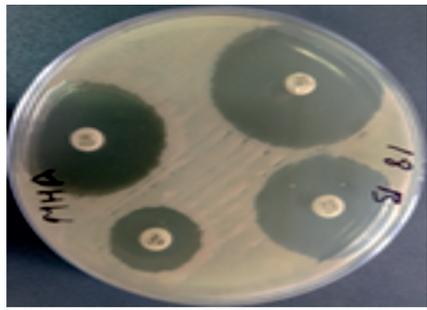
Fig. 18.28 Confirmation of ESBL *E. coli* strain by combination disc method
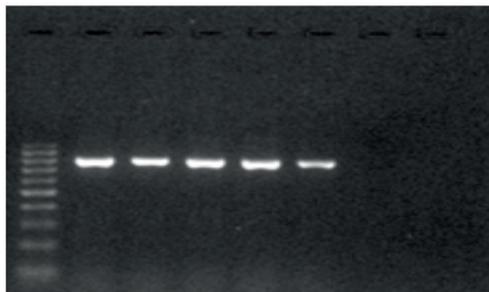
Fig. 18.29 PCR amplicons for TEM gene (800 bp) from *E. coli.*
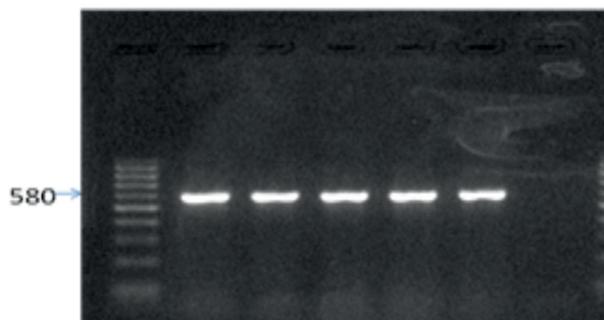
Fig. 18.30 PCR amplicons for CTX (580 bp) from *E. coli.*

FISHERIES

Performance of Different Manures on Fish Productivity

India has large livestock population, and many farmers have more than one livestock in their backyard for various reasons. In our earlier studies, we have seen the impact of livestock manure in fish ponds and in that study, we found that the performance of cattle dung was the best. In the present study, three treatments were planned, T1: Cattle & goat-cum-fish, T2: Cattle & duck-cum-fish and T3: Feed (3% body weight). Three species (Catla, rohu and mrigal carp) were used for the study and stocking densities of 7000/ha).

All the water quality parameters like water temperature, pH, dissolved oxygen, alkalinity (190.25-231.75 mg l^{-1}) and hardness (150.38-161.75 mg l^{-1}) are within the acceptable limit in all the treatments (Table 18.8). The pH of pond water in all the integrations ranged between 7.67-7.80 and dissolved oxygen was within 7.13-8.65 mg l^{-1} and was better for fish production purpose. Similarly, Total ammonium concentration ranges between 0.08 to 0.41 .mg l^{-1}, nitrite ranges between 0.09-0.09 mg l^{-1} and phosphate ranges between 0.08-0.12 mg l^{-1}. and Net primary productivity were estimated. Maximum Gross primary productivity (GPP) was recorded in T1 (Cattle & goat combination) (0.27 g C m^{-3} h^{-1}) followed by the T3 (0.15 g C m^{-3} h^{-1}) and T2 (0.12 g C m^{-3} h^{-1}). It can be assumed that mixed application integration has not significantly deteriorated water quality parameters when used in prescribed quantity and with judiciary use. Soil organic carbon content in all the ponds ranging between 0.56 to 1.16%. Soil phosphorous content was also reasonably good ranging between 0.17-0.26 ppm. Similarly, Potassium and nitrogen in different fish ponds ranging between 0.08-0.18 mg g^{-1} and 0.07 – 0.19 mg g^{-1}. The most abundant and frequently recorded planktonic organisms were Rotifers (*Branchionus falcatus* and *Keratela tropica*), Cladocerans (*Moina brachiata, Leydigia spp.*), *Navicula spp. Diatoma spp. Scenedesmus spp.* Filamentous algae etc. A swamp of zooplankton is generally associated with the application of organic manure.
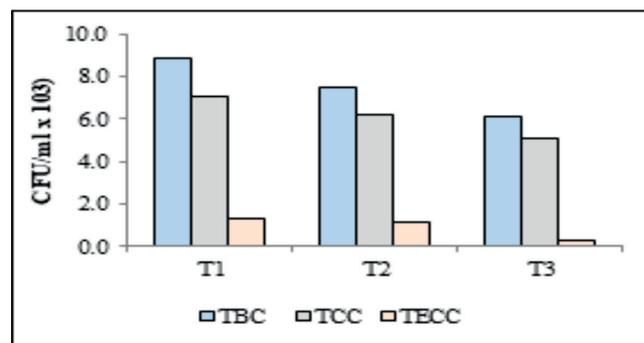
Fig.18.31 Microbial load in the fish pond

Microbiological analysis like Total bacterial count (TBC), Total coliform count on MA (TCC) and Total *E. coli* count on EMB (TECC) of the fish pond under different treatments were estimated (Fig. 18.31). From the study it was found that bacterial load in cattle + goat integration is relatively higher followed by cattle + duck integration and least was observed in feed supplemented fish ponds. Haematological parameters in Indian major carps were also analysed and there was no noticible variations among the species as well as among different

Table 18.8 Water quality parameters under different treatments

Parameters	T1	T2	T3
Water			
Alkalinity(mg l^{-1})	190.25±19.30	188.25±14.75	231.75±19.25
Hardness (mg l^{-1})	161.75±11.18	150.00±14.98	150.38±15.80
D.O (mg l^{-1})	8.65±0.62	8.42±0.70	7.13±0.45
Temp (ºC)	24.80±2.85	28.39±1.78	28.16±1.80
pH	7.75±0.14	7.80±0.15	7.68±0.09
Ammonium (mg l^{-1})	0.41±0.27	0.08±0.11	0.21±0.02
Phosphate (mg l^{-1})	0.08±0.02	0.12±0.03	0.12±0.03
Nitrite(mg l^{-1})	0.09±0.02	0.10±0.01	0.09±0.01
Water Primary Productivity (g C m^{-3} h^{-1})			
Gross Primary Productivity	0.27±0.04	0.14±0.03	0.09±0.02
Net Primary Productivity	0.12±0.03	0.07±0.01	0.05±0.01
Respiratory quotient	0.15±0.04	0.07±0.02	0.04±0.01
Soil parameters			
OC(%)	1.155	1.156	0.656
N (mg/g)	0.192	0.14	0.07
K (mg/g)	0.14	0.18	0.08
P (ppm)	0.263	0.18	0.168
PH	7.85	7.74	7.96
EC (mS/m)	140.8	63.78	106

Weight gain of different fish species under different integration was recorded throughout the culture period. The present study found that production from bottom dweller, mrigal was better followed by rohu. The percentage weight gain of fish was maximum in the feed-based pond and was lowest in the cattle and goat combination (T1). Grass carp showed maximum species-wise survival rate. Overall survival rate in case of feed-based treatment (T3) was maximum (81.1%) followed-by cattle & duck combination (T2) and lowest survival (69.7%) was recorded in case of cattle and goat combination (T1). A similar trend was also recorded in case of overall production. Three treatments were studied and compared and found that feed-based treatment showed the maximum fish production (3441.7 kg/ha) followed by cattle and duck combination (2026.70 kg/ ha) (Fig.18.32). From the present study, it has been recorded that the mrigal has achieved overall best growth. Regarding overall production, cattle + duck

combination fertilization facilitates the very good fish production. No doubt that fish rearing with concentrated feed can increase fish production but resource poor farmers of the region could also adopt combined use of fertilizer for getting higher fish production
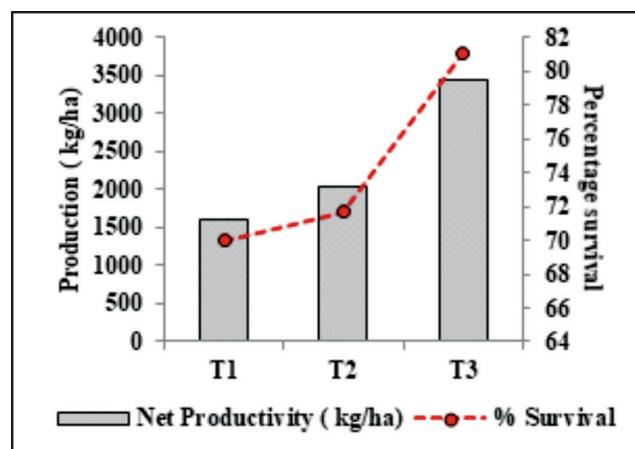
Fig.18.32 Fish production and overall survival from different treatments

Economic Feasibility of Integrated Prawn-cum-Fish Farming in Polyculture System in Eastern Region

The experiment was conducted at the the institute fish farm in an earthen pond of 1000 m² area. 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 (5 kg), agrimine (100 g) and DAP (0.5 kg) etc. The plankton develop after 4-5 days of manuring. Stocking was done in the month of April @ 5000 nos./ha of fish Catla & Rohu (135 g) and 20,000 nos./ha (0.005 g) of prawn seeds, respectively. Feeding was done with Starter 1 feed @ 100% body weight of prawn till they attain the body weight 1.0 g and floating feed @ 4% of the body weight was used to feed catla and rohu. Monthly length-weight data were collected for growth analysis and health management of prawn and fish. Water quality parameters like DO, pH, alkalinity, hardness, ammonia, nitrite and phosphate were within the acceptable limit. During the 150 days of culture period, catla attained a size of 1053 gm while Rohu attained 760.75gm. It was observed that growth rate of Catla was faster than to Rohu. The prawn attained 49.66 gm during the culture period indicating better growth in 150 days (Fig.18.33). At the end of culture catla, rohu and prawn gave production of 1580 kg/ha, 1160 kg/ha and 638 kg/ha, respectively (Fig.18.34).
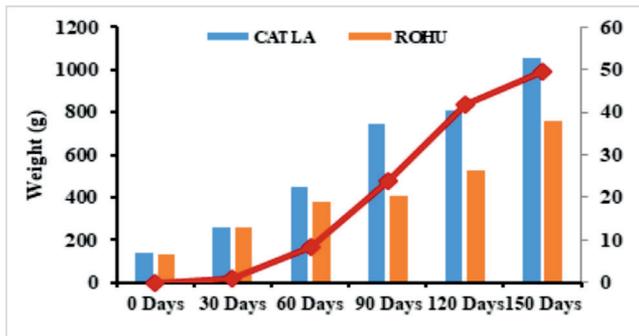
Fig. 18.33 Growth performance of Catla, Rohu and Prawn under polyculture system
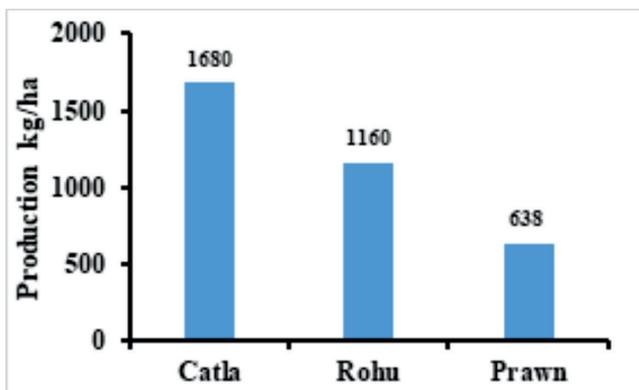
Fig. 18.34 Production of Catla, Rohu and Prawn under Polyculture System

Culture Potential of Selected Indian Minor Carps

Labeo gonius is medium-sized carp commonly known as 'Kuria Labeo (Fig. 18.35). Present study was conducted to establish baseline data on morphometry, stage-wise LWRs, and stage-wise growth rates of Labeo gonius from fry to adult under captive conditions as well as breeding performance of this captive species.

Morphometric measurements and meristic counts

Measurements of various morphometric characters including their range, mean, median, standard error, standard deviation and coefficients of correlation revealed maximum value (31.70%) for eye diameter while minimum (16.14%) for snout length of *L gonius* (Table 18.9). Regression of total length against standard length, pre-dorsal length, dorsal fin length, dorsal fin height, body depth, pre-pectoral length, pre-ventral length, pre-anal length, caudal fin length and caudal peduncle depth were also established. Total length showed maximum degree of correlation with standard length (0.991) while minimum with caudal fin length (0.912). The regression of head length against snout length, post-orbital length, eye diameter and inter-orbital length was observed that head length showed maximum degree of correlation with inter-orbital length while minimum with snout length.

Fig. 18.35 Harvested *L. gonius* from fish pond

Table 18.9 Descriptive statistics of various morpho-meristic characters of *Labeo gonius*

Morphometric characters	Min	Max	Median	Mean±SE	SD	CV%
Total length	64.68	264.30	160.18	157.25±3.10	31.92	20.30
Standard length	50.63	207.70	124.64	123.07±2.42	24.96	20.28
Pre-pectoral length	14.57	49.40	30.62	30.03±0.56	5.72	19.05
Pre-pelvic length	27.11	104.80	64.04	63.14±1.25	12.89	20.41
Pre-anal length	41.38	156.70	95.41	94.69±1.86	19.13	20.20
Pre-dorsal fin length	24.35	88.60	52.62	52.82±1.05	10.82	20.48
Dorsal fin length	12.12	56.20	31.09	30.80±0.66	6.81	22.11
Dorsal fin height	10.53	49.40	28.72	28.74±0.60	6.16	21.44
Caudal fin length	5.61	24.80	14.09	13.97±0.30	3.13	22.36
Caudal fin length	14.04	56.60	34.77	34.18±0.76	7.87	23.01
Body depth	13.23	58.60	33.94	33.12±0.72	7.39	22.31
Head length	14.18	50.10	31.08	30.55±0.56	5.80	18.99
Snout length	5.87	14.81	11.40	11.19±0.18	1.81	16.14
Eye diameter	2.12	12.20	5.84	5.73±0.18	1.82	31.70
Post-orbital length	8.31	25.20	13.93	14.12±0.26	2.69	19.05
Inter-orbital length	7.69	23.90	16.63	16.34±0.28	2.90	17.74
Meristic characters						
Dorsal fin rays	15	17	16	15.73±0.07	0.69	4.40
Pectoral fin rays	13	17	14	14.29±0.07	0.68	4.78
Pelvic fin rays	08	09	09	8.99±0.01	0.10	1.10
Caudal fin rays	18	24	20	20.59±0.13	1.31	6.35
Anal fin rays	06	08	07	7.08±0.03	0.30	4.30
Scale on transverse line	14	17	15	14.83±0.07	0.75	5.03
Scale on caudal depth	24	32	28	28.73±0.18	1.80	6.28
Scale on lateral lines	76	84	78	79.60±0.35	3.65	4.58
Number of gill rakers	41	71	56	55.87±0.46	4.76	8.51

The species possessed 15-17, 13-17, 8-9, 18-24, and 6-8 rays on dorsal, pectoral, pelvic, caudal, and anal fins, respectively. The number of scales on transverse line, caudal depth and lateral lines varies from 14-17, 24-32 and 76-84, respectively. Moreover, the number of gill rakes on the lower limp of first gill arches varies from the 41 to 71. Based on the meristic counts the fin formula can be written for the species as D15-17P13-17V8-9A6-8C18-24Gr41-71Str14-17Sll76-84Scd24-32.

Table 18.10 Length-weight relationship and condition parameters of *L. gonius*.

Life stage	Mean length	Mean weight	Parameters of the LWR				Growth type
	(cm)	(g)	n	a	b ~3	r²	-ve/+ve
Fry	3.81 ±0.12	0.68 ±0.04	79	0.00005725	2.127	0.75	-ve
Fingerlings	7.72 ±0.04	5.81 ±0.08	221	0.00001756	2.865	0.87	-ve
Juveniles	11.75 ±0.12	18.06 ±0.60	354	0.00006654	3.094	0.94	+ve
Adult	21.09 ±0.11	176.56 ±1.76	747	0.00002409	3.172	0.95	+ve

Length-Weight Relationship

The regression analysis of the LWRs parameters is illustrated in Table 18.10 and logarithmic length-weight relationship in Fig. 18.36. The LWRs parameters were explained through an equation as $W = 0.00005725*L2.217$ $(r^2 = 0.75)$ for fry, $W = 0.00001756*L2.865$ $(r^2 = 0.87)$ for fingerlings, $W = 0.00006654*L3.094$ $(r^2 = 0.94)$ for juveniles and $W = 0.00002409*L3.172$ $(r^2 = 0.95)$ for adults' individuals. The highest degree of correlation of determinants and exponents value was recorded for adults, whereas the lowest was for the fry stage. A positive allometric growth pattern was noted for the juveniles and adult specimens whereas negative allometric growth patterns were for fry and fingerlings. All the data was pooled and overall length–weight relationship was derived and presented in Fig. 18.37.
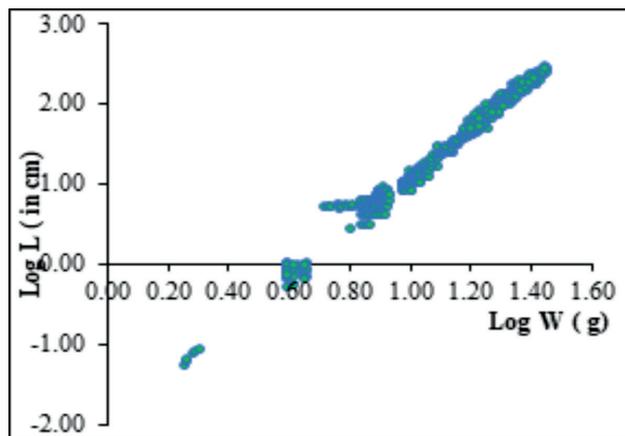
Fig. 18.36 Logarithmic length-weight relationship of different life stages of *Labeo gonius*

Growth and Survival

The annual increments in length and weight of fry, fingerlings, and juveniles, *L. gonius* was estimated. Fingerlings reached the total size and weight increments of 6.82 cm and 8.95 g after three months of culture, juveniles reached 9.35 cm and 31.51 g after four months of culture, and adults reached 18.93 cm and 270.49 g after a year of culture. The fry, fingerlings, juveniles, and adults had mean lengths of 3.81, 7.72, 11.75, and 21.09 cm and mean weights of 0.68, 5.81, 18.06, and 176.56 g, respectively. Specific growth rate (SGR) is inversely related to the development stage, with the highest SGR recorded at the fry stage (3.28%) and the lowest at the adult stage (0.41%). The survival percentages of fry, fingerlings, juveniles, and adults were 90.67, 91.67, 95.38, and 96.31% (Fig. 18.38).
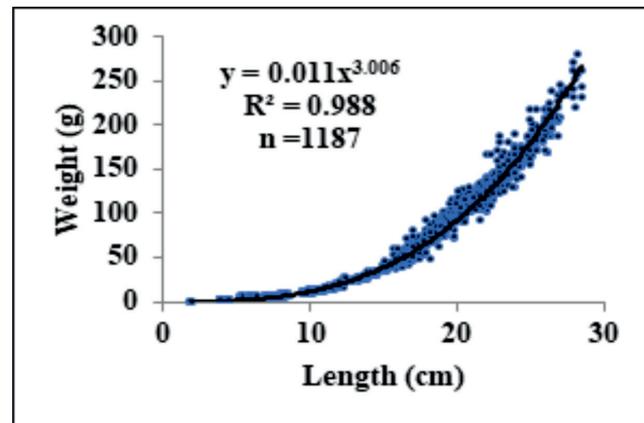
Fig.18.37 Overall Length-weigh relationship of *Labeo gonius*
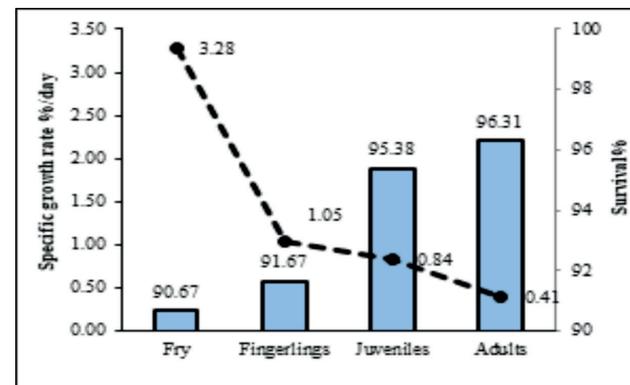
Fig.18.38 SGR and survival percentage of different life stages of *Labeo gonius* under cemented tanks system

Broodstock Development and Breeding

Brood fisher was maintained separately for nearly two years and weight gain against period of rearing has been recorded. At the end of 640 days of culture average brood weight was 341.57± 6.61. Few breeding trials were conducted of *L. gonius* at the institute portable hatchery unit. A total of 9 sets (one female with one or two males) were used, out of which 5 females responded perfectly. The average size of brooders in terms of length, weight, and the breeding trail's detail is enclosed in Table 18.11. Hormone used for breeding purposes was Wova-FH. Different stages of development of this species are presented below (Fig. 18.39 a-f). From the study, it can be assumed that these species respond well in the induced breeding programme when brooders are reared in a confined environment. Responses of this species are also relatively satisfactory (55%), and fertilization and hatching of this species in the present study were 71.5% (69.5-73.4%) and 74.5%, respectively. This important minor carp is in high demand in many eastern states and hence can be included in the mono-culture or poly-culture system for a higher return.

Table 18.11 Summary of the breeding trial conducted for *L. gonius*

Breeding details	Male	Female
Injected brooders	14	9
Average brooder weight	297.63g (213-362)	392.8 g (319-569)
Hormone used (Wova-FH®)	0.4-0.6 ml/kg	0.7-0.8ml/kg
Response of brooder	42.86%	55.56%
Spawning observed	10-12 hrs (After injection)	
Fecundity	48.92 nos./gm of body weight	
Fertilization %	71.5% (69.5-73.4%)	
Hatching %	74.5% of fertilized egg	
Egg diameter (mm)	2.54±0.3	
Hatchling size length (mm) & weight (mg)	5.52±0.32 mm & 1.5-2.0 mg	

Mature Male & female Brooder   Injecting hormone   Brooders released into spawning tank   Fertilized eggs

Fingerlings to adult gonius   Seed for transportation   Newly hatched larvae   Embryonic development
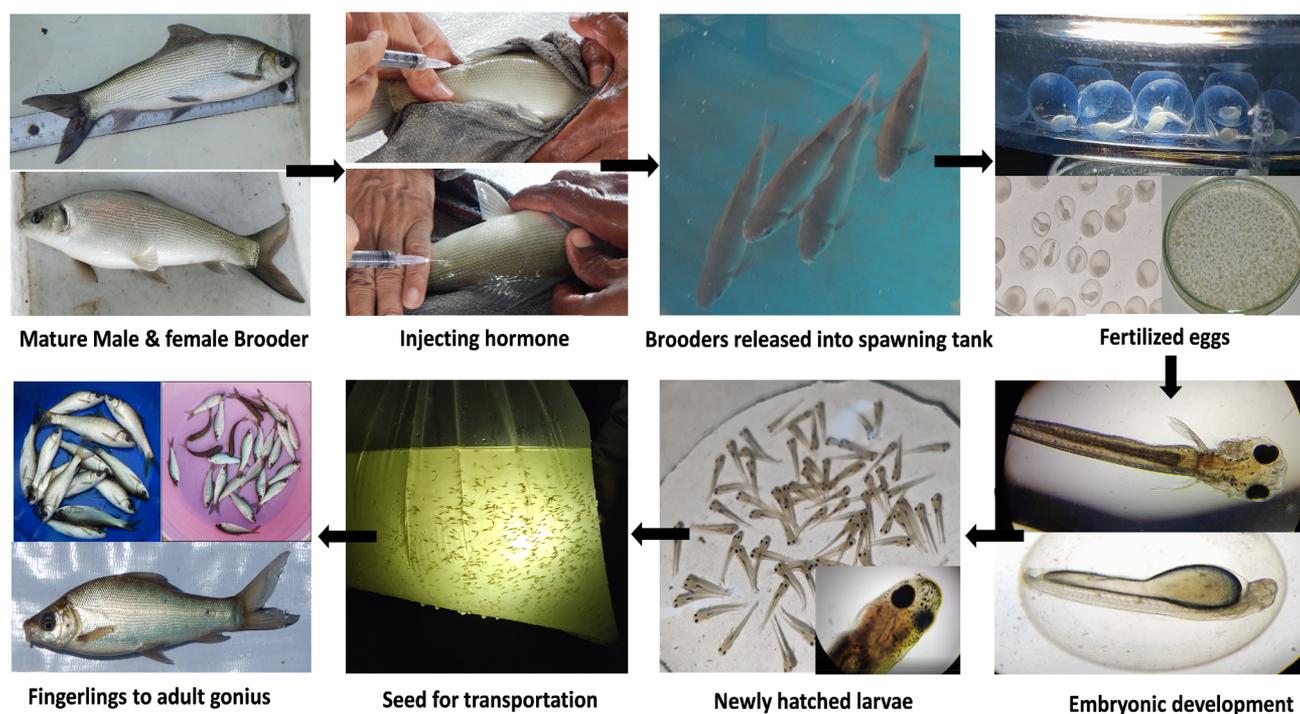
Fig.18.39 Induce breeding trail of *Labeo gonius*

Fish Production Performances in Biofloc Technology

In a Biofloc system, the growth performances of minor carp *Cirrhinus reba* (Reba) at high stocking density and low feeding were studied (Fig. 18.40). Prior to beginning the experiment, every Biofloc tank were washed and disinfected with KMnO₄. The average biomass gain and FCR were significantly greater for the first treatment (T1), where high stocking (30/m²) and low feeding (@ 2% of total fish biomass) was maintained (Fig. 18.41). However, the specific growth rate (1.13%) and survival rate (95.22%) were substantially higher in T3 (stocking @ 15/m²) than in treatments T1 and T2 (stocking @ 20/m²) (Table 18.12). All water quality parameters were confirmed to be within acceptable levels for fish culture. The floc concentration was maintained by consistently adding a carbon source (Jaggery). Haematological parameters varied non-significantly between the control and Biofloc systems. This biofloc study suggests that minor carp's moderate to high stocking densities are more productive and economically lucrative than low stocking densities (Table 18.12).

Table 18.12 Overall production performances of *C. reba* in Biofloc system

Treatments	Mean initial wt (g)	Mean final wt (g)	SGR (% per day)	Survival (%)	Production (t/ha)	Total input cost (₹ in lakh)	Total Gross income (₹ in lakh)	Net profit (₹ in lakh)	B:C ratio
T1	3.07 ±0.43	13.71 ±0.59	1.00 ±0.55	93.11	3.83	6.15	9.56	3.42	1.55
T2	3.25 ±0.29	14.69 ±0.73	1.01 ±0.64	94.75	2.78	5.38	6.95	1.57	1.29
T3	3.10 ±0.34	16.97 ±0.76	1.13 ±1.03	95.22	2.42	4.98	6.05	1.07	1.21
Control	3.65 ±0.10	9.96 ±0.90	0.67 ±0.33	92.33	1.37	2.91	3.43	0.52	1.17

Fig. 18.40 *Cirrhinus reba* culture practices in Biofloc
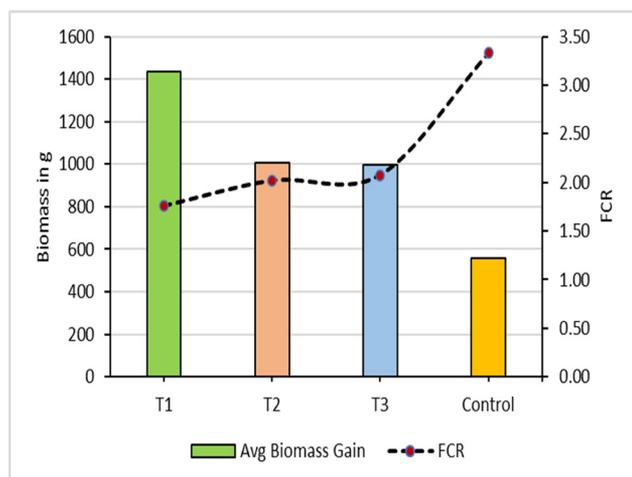
Fig. 18.41 Biomass gain and FCR of *C. reba* under Biofloc culture system

Biodiversity Status of Kasaraiya Dhar Maun

Total 42 species belongs to 15 family of finfishes, prawn and mollusc were recorded in the Kasaraiya Dhar Maun during 2022. Total 6 species of freshwater spiny eel belonging to a family Mastacembalidae of order Perciformes were recorded during study period (Fig. 18.42). In consideration of macrophytes, total 6 species of macrophytes such as *Ceratophyllum demersum, Hydrilla verticilla, Najas minor, Azolla pinnata, Lemna minor* and *Eichhornia crassipes* were found throughout year in the Maun. Since *Eichhornia crassipes* is known as a floating plant, which covers more than half of the water spread area in Kasaraiya Dhar Maun. This Maun is also the habitat of a large number of phytoplankton and zooplankton. As phytoplankton, *Spirogyra, Chlamydomonas, Ulithrix, Rhaphiodionema, Chhlorella vulgaris, Sriogonuim, kutzing, Rhizocloniumkutzing* and *Microspora amoena* were recorded during the study period. Further, Paramecium, Daphina, Moina and Copepodes were found as zooplankton in the water of Kasaraiya Dhar Maun.

Fig. 18.42 Identified fish species of Mastacembalidae family from Kasaraiya Dhar Maun

To know biological condition of fishes at Kasaraiya Dhar, *Nandus nandus, Macrognathus pancalus, Mastacembalus armatus, M. deyi, Mystus tengara* were selected for the study (Fig. 18.43). The details on the mean length and weight, feeding habit, gut content, maturity stage, gastro-somatic index and gonado-somatic index were studied for five species. The feeding habit of all fives species was carnivorous in nature. Bi-lobed ovary was found in *Nandus nandus* (Fig. 18.44), *Macrognathus pancalus* and *Mastacembalus armatus*. The fully matured ovaries in both *Nandus nandus* and *Mastacembalus armatus* were found during May month.

Fig. 18.43 Biological examination of fish

Fig. 18.44 Ovary of *Nandus nandus*

reba Hamilton, *Chanda nama* Hamilton, *Mystus bleekeri* Day, and *Clupisoma garua* Hamilton), from the River Ganga in Bihar, India (Fig. 18.45). A total of 557 fish specimen were collected seasonally from September 2021 to August 2022 using a monofilament drift gill net and a conical trap net Khairel jal. In morphometric analysis, the highest degree of correlation was observed between all species' total and standard lengths (except *C. garua*). The estimated exponent value b varies from 2.920 to 3.214, where the slopes of regression lines among the species have significant differences. The growth coefficient (b) value indicated that three species (*B. barila, C. nama*, and *C. garua*) follow positive allometric growth, whereas *M. bleekeri* shows isometric growth and *C. reba* exhibits negative allometric growth. The condition factor value for these fishes ranged from 0.67 to 0.98, which indicated that the population of *C. reba* was robust compared to all other species. A new maximum length (146.8 mm) was obtained for *B. barila* from India. The present study gives baseline biological information on five commercially important indigenous fish species found in the River Ganga, Bihar. As the population of these species has been dwindling in recent times, these data will be important for the conservation and sustainable utilization of these important species in the long run.
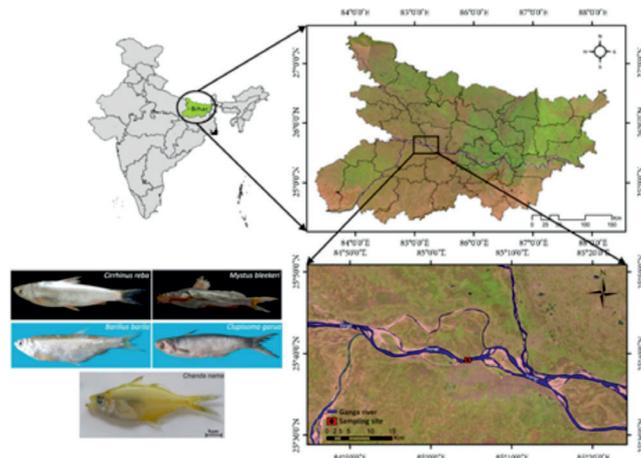
Fig. 18.45 Sampling site of different fish species collected from the Ganga River

Morphometric Characteristics, Length-Weight Relationships, and Condition Factors of Five Indigenous Fish Species from the River Ganga, Bihar

Morphometric characteristics, length-weight relationships (LWRs), and condition factors (K) were studied for five indigenous fish species belonging to five different families (*Barilius barila* Hamilton, *Cirrhinus*

Studies on the Biological Parameters of Indigenous Fish Species of Ganga river

Length-weight relationship, condition factors, and hepatosomatic index for six indigenous fish species under six genera and six families, namely, *Eutropiichthys vacha, Sperata seenghala, Xenentodon cancila, Puntius sophore, Glossogobius giuris* and *Mastacembelus armatus*

were studied from the river Ganga in Bihar, India. Fish specimens were collected monthly using a monofilament drift gill net (100-200 m long, 2 m high, and mesh size 10-30 mm,), and a conical trap net/Khairel jal (8 m long, 10 m mouth width, 1 m cod-end width, and cod-end mesh size 5-10 mm) between September 2021 to August 2022. The estimated exponent b value for these fishes varies from 2.748 to 3.952, where the slopes of regression lines among the species have significant differences (F = 57.13, Dfd = 271, P<0.0001). Four fish species reveals positive allometric growth patterns whereas negative for *M. armatus* and *S. seenghala*, respectively (b< 3). *Puntius sophore* has the highest condition factor values in all species, while *G. giuris* has the highest hepatosomatic index.

The Otolith Studies of *Puntius sophore* collected from the Ganga and Punpun Rivers of Bihar

This study analysed the morphometric correlations between fish and otoliths of the commercially and nutritionally important 'Pool barb,' *Puntius sophore* collected from the Ganga and Punpun rivers in Bihar (Fig. 18.46). There was a positive correlation between fish and otolith's many observed morphometric characteristics, such as LWRs, length frequency distributions, condition factors, and otolith aspect ratios (Fig. 18.47). The condition factors for this species showed that the circumstances in both rivers were ideal for their existence. All of these connections are important for the management of fisheries and may be used in time series studies of diet, stock structure, environmental shifts, and conservation efforts in the future.
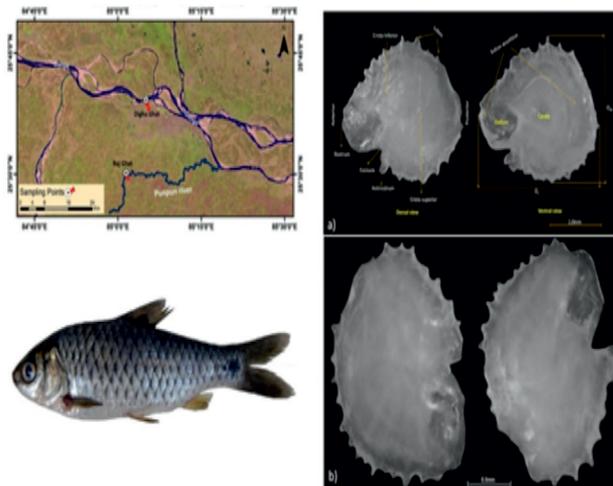
Fig. 18.46 Otolith morphology and sample collection site of *Puntius sophore*
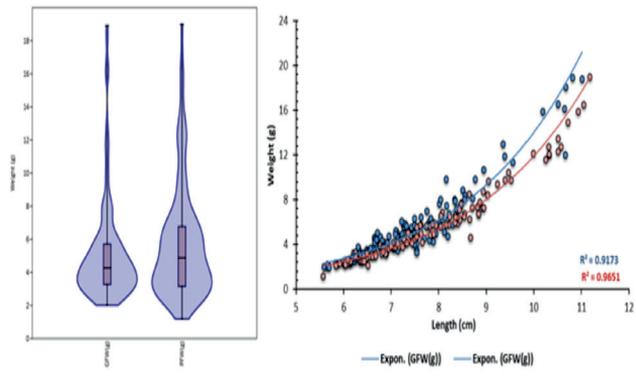
Fig. 18.47 Weight frequency and LFR relationship of *Puntius sophore*

Socio-economic Studies and Transfer of Technology

19

Transfer and Adoption of Improved Agricultural Technologies

The studies were conducted in 9 districts of Bihar and 3 districts of Jharkhand. Primary data was collected from 350 farmers and 123 extension functionaries using a well-structured questionnaire and personal interviews/observations. This project concluded in August, 2022.

Improved varieties adopted by the farmers

More than half (52%) of the farmers surveyed had marginal land holdings of less than 1 hectare, while small and medium landholders were 26% and 22%, respectively. Improved crop varieties were recognized as important by most farmers. In rice, 81% of farmers are using improved varieties or hybrids, while in Wheat, although HD 2967 is popular, adoption of other varieties are increasing but still its adoption is less than 50%. Farmers mostly use hybrids in maize. In pulses such as Arhar and Bengal gram, less than 50% of farmers have adopted improved varieties, while in moongbean, around 75% of farmers have adopted improved varieties. (Table 19.1).

Table 19.1. Adoption of improved crop varieties

Crops	Improved Varieties	Adoption of improved / recommended varieties (%)
Rice	Shankar Dhan, Rajendra mansuri,, Pioneer hybrid	81
Wheat	HD 2967, PBW-343, HD 2733, HD 2285	40
Maize	Pioneer, Shaktiman, Syngenta hybrids	96
Moong	Pusa Vishal, SML 668	75
Sarson	Rajendra Sarson, Swarna	22
Rai /Mustard	Pusa Bold	10
Arhar	Pusa Bahar, Narendra Arhar	47
Bengal gram / Chana	Rajendra Chana, Pusa 256	43
Mango	Amrapali , Langra	53
Vegetables	Hybrids of Tomato	40

Improved Technology Adoption

Vermicompost and FYM is used by 43% of surveyed farmers. Zero tillage (ZT) wheat, one of the cost saving technologies was adopted by nearly 42% farmers. Vaccination in animals is practiced by 28% farmers. Adoption of seed treatment is hardly practiced by 16% farmers and hence more efforts are needed for adoption of seed treatment in different crops. Although, system of rice intensification (SRI) was practiced by limited percentage of farmers but later it was discontinued due to more labour requirement and weed management problems. The economic gain due to adoption of ZT in wheat was assessed. On an average, ZT sown wheat gained 1.5 t/ha grain yield than conventional till wheat, besides saving on seed by 10 kg/ha, saving of first irrigation cost and reduction in cost of crop establishment by Rs. 2500/ha. The ZT wheat sowing is one of the fast-growing technologies in the Bihar state. The technology has been adopted in more than 2.5 lakh hectare area during the last 5 years.

Technology Transfer Mechanisms and Constraints Faced by Extension Functionaries

To study the technology transfer mechanism and constraints faced by extension functionaries, data were collected from 123 extension personnels of Bihar and Jharkhand through Google form and interview schedule. Among extension personnel, 52% were Agricultural Coordinators followed by Assistant Technology Manager (ATM) (25%) who are in direct contact with the farmers in the villages. Supply of quality inputs is one of the major thrust areas of the agriculture department for dissemination of new technology. In the majority of cases these are not available on time to the extension personnel as well as to the farmers. The unavailability of inputs on time is the major constraints revealed by the extension personnel (Fig. 19.1).
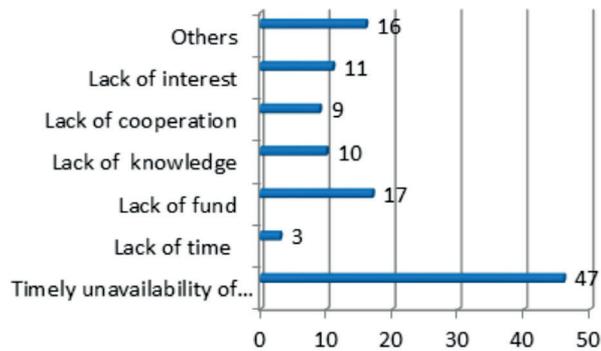
Fig. 19.1 Constraints faced by officials in technology transfer

Among technology transfer methods used, personal contacts was found to be most preferred method of technology dissemination adopted by 72.60% extension personnel. Training, demonstrations, Kisan mela and exposure visits were another sources of effective transfer of technologies reported by majority of officials (Fig. 19.2).
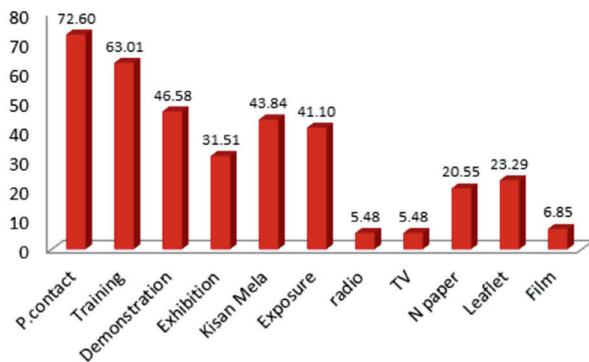
Fig. 19.2 TOT methods adopted by extension officials

Status of Utilization of Digital Tools in Agriculture Sector in Eastern India

Extent of use and Constraints in Digital Tools Utilization in Agriculture

The application and utility of digital tools among extension functionaries and farmers were studied through online questionnaire schedules survey in four states i.e., Uttar Pradesh, Jharkhand, Bihar and West Bengal during 2022. Data were collected from a total of 773 individuals of which 368 were extension functionaries and 405 were farmers from different places in Bihar, Jharkhand, UP and WB and their responses were recorded through online Google Forms.

The study collected data on the usage of digital tools (mobile phones, smart phones, computers, laptops, and tabs) and internet among farmers and extension functionaries in five different age groups (up to twenty, thirty, forty, fifty and sixty years) and educational categories (illiterate, matriculate, higher secondary, graduate and post graduate). Its benefits and constraints were measured in Likerts five point continuum scale. Results showed that younger farmers up to the age of 40 years are using more digital tools than older farmers, except for non-smart phones. Illiterate individuals were found to be poor users of digital tools, except for mobile phones and Smart TVs. Overall, more than 80% of farmers had a positive view towards the use of digital tools.

Higher cost (88%), technical complexity (55%) and poor internet connectivity (67%) are the major limitations faced by more than half of the farmers under study (Fig. 19.3). Among extension functionaries, results showed that 73% were using smart phone, digital tools were used by 75% of the middle-aged extension functionaries, and more than 85% of extension functionaries were of positive view toward use of digital tools. Higher cost (84%), technical complexity (47%) and poor internet connectivity (84%) are the major limitations faced by 80% of extension functionaries. The study indicate need for targeted interventions to improve digital literacy, reduce technical barriers, and improve internet connectivity for effective adoption of digital tools in agriculture.
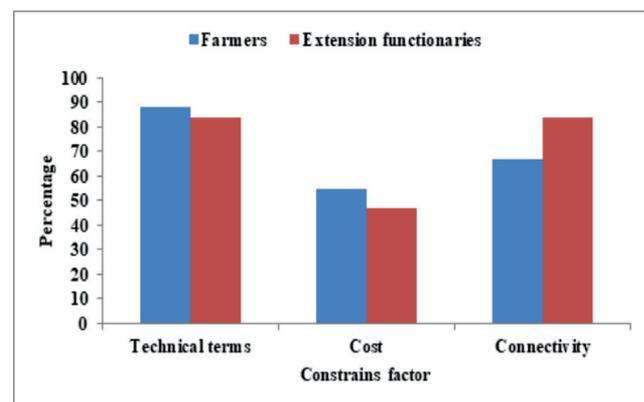
Fig. 19.3 Constraints faced by the extension functionaries and farmers in using digital tools in Bihar, Jharkhand, and West Bengal

Impact of e-NAM on Improving Marketing of Agricultural Produce in Eastern India

Small and marginal farmers (comprises 80-90% of total farmers) in eastern India face challenges in marketing their agricultural produce at a remunerative price. Despite high marketed surplus ratios, only 30% of the production is sold in APMC Mandis (Market). Government of India launched electronic National Agriculture Market (e-NAM) in April, 2016 to create a unified National Agricultural Market by providing online trading platforms to farmers, buyers, traders and other stakeholders. A need was felt to study the impact of e-NAM on agricultural marketing and therefore, a new project entitled "Impact of e-NAM on Improving Marketing of Agricultural Produce in Eastern India" was initiated from December 2021.

Current Status of e-NAM in Eastern India

Currently, e-NAM covers 1260 APMC Mandis in 22 states and 3 union territories across the country. There are 1.73 crore farmers, 2.25 lakhs traders, 1.04 lakhs commission agents and 2179 FPOs are registered on e-NAM platform in India. Among the eastern states, it is operational in Uttar Pradesh, Chhattisgarh, Jharkhand, West Bengal and Odisha. An account of total Mandi and proportion of e-NAM Mandi is given in table 19.2.

Table 19.2 Share of regulated APMC markets on e-NAM platform in Eastern states

States	No. of Regulated APMC Markets	No. of APMC markets on e-NAM Platform	% share in Total
Chhattisgarh	187	14	7.5
Jharkhand	190	19	10.0
Uttar Pradesh	623	125	20.1
West Bengal	475	18	3.8
Odisha	436	54	12.4
All India	6610	1260	19.06

Among the stakeholders registered on e-NAM, again Uttar Pradesh leads the way with 33 lakh farmers registered on e-NAM followed by Odisha, Jharkhand and Chhattisgarh (Table 19.3). In West Bengal the lowest number of farmers are registered. Among traders, similar pattern was observed. It can be seen that number of FPOs getting registered on e-NAM is increasing which is a good sign for effective agricultural marketing.

Table 19.3 Stakeholders registered on e-NAM platform in Eastern Indian states (up to May 31, 2022)

Sl. No.	State	Farmers (in lakhs)	Traders	Commission agents	FPOs	Total stakeholders (in lakhs)
1.	Chhattisgarh	1.35	3124	233	22	1.386
2.	Jharkhand	2.46	2287	0	116	2.485
3.	Uttar Pradesh	33.15	34901	8533	271	33.59
4.	West Bengal	0.47	3865	124	171	0.515
5.	Odisha	2.73	7247	0	201	2.805
	All India	173.30	224156	104256	2179	176.60

Proportion of farmers registered on e-NAM

Among all the eastern states, Uttar Pradesh leads in terms of farmers registered on e-NAM as 17.4% of the farmers in this state are already on e-NAM platform. In other eastern states a very limited number of farmers are registered (Fig. 19.4). Out of total farmers, the percentage of farmers registered on e-NAM were 6.65%, 6.45%, 3.4% and 0.92% in Odisha, Jharkhand, Chhattisgarh and West Bengal respectively. Eastern states contributed only 21.7 % of total e-NAM Mandis in India. Among eastern states, UP has the highest no. of Mandis on e-NAM Platform 20.1%, followed by Jharkhand (10%) and Odisha (9.4%).
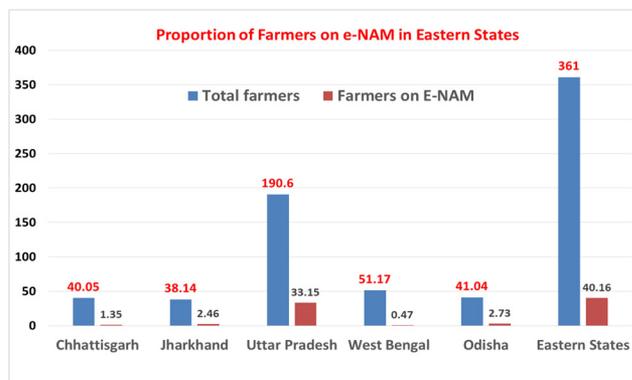
Fig. 19.4 No. of farmers (in lakhs) registered on e-NAM platform in Eastern states.

Impact of Trading through e-NAM on Price Realization

Secondary data on price received by farmers on e-NAM platform and in non e-NAM APMC Mandi was collected and analyzed. There was a clear-cut advantage for farmers who traded through e-NAM platform in case of paddy in both Chhattisgarh and Uttar Pradesh (Fig. 19.5).
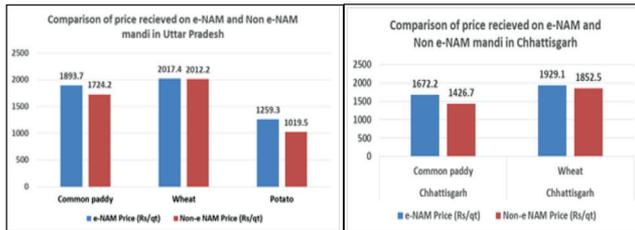
Fig. 19.5 Comparative advantage of price received on e-NAM platform in UP and Chhattisgarh

An e-NAM farmer on average received 17.2% higher price in Chhattisgarh and nearly 10% higher price in Uttar Pradesh for common paddy. Similarly, in the case of potato in Uttar Pradesh, 23.5% more price was received by e-NAM farmers as compared to non e-NAM farmers. There was no significant difference in price received for wheat grains between e-NAM and non e-NAM mandi.

Status of Food and Nutritional Security of Farm Households in Eastern India

The study was conducted in four eastern states Bihar, Jharkhand, West Bengal, and Eastern Uttar Pradesh. Under the objective suitable strategies for food and nutritional security influence of socio-economic and psychological variables in the adoption of Nutri-garden were studied in Eastern Uttar Pradesh (Varanasi) and West Bengal (Alipur Duar). The data was collected based on personal observation and household head interviews. Nutri-garden adoption was used as a proxy for farmers' intention to adopt healthy food consumption practices. The theory of planned behavior (Ajzen, 1991) was used with the addition of 5 health value practices and 11 socio-personal variables. Between the two samples (West Bengal and Eastern UP) attitude (t=1.747), perceived behavioral control (t=1.685), and health value (t=1.678) of the sample were found to be significantly different.

In both states, common features found that the attitude and social norms of farmers were found significantly linked with the adoption intention of Nutri garden. Furthermore, adoption intention was found significantly linked with health value, indicating that household's conscious of healthy practices and sanitation are more prone to adopt healthy food consumption practices. The study indicates the attitude of household's head and influences society to adopt healthy food consumption practices. The study was concluded in March 2022.

Development and Validation of Need Based Technology Delivery Model through Farmers' Producer Organization for Eastern Region of India

The project is funded by NASF with the objective to develope and validate technology delivery models using Farmers' Producer Organizaation (FPO) in India's eastern region. For seed production, vegetable production, organic farming, and natural resource management, four separate models of technology transfer through FPO have been developed at ICAR-RCER, Patna, ICAR-IIVR, Varanasi, ICAR-RCER, FSRCHPR, Ranchi, and UBKV, Cooch Behar, respectively. A generalized process model was also developed for wider use across eastern states. The "generalized process model of FPO based technology delivery" is a framework that outlines the stages involved in delivering technology to farmers through FPOs (Fig. 19.6). This model is based on the idea that technology adoption is a process that involves several stages *viz.* pre contemplation; engagement; linkage; motivation and action; monitoring and maintenance; and sustenance. The success of this model depends on effectively navigating each stage.
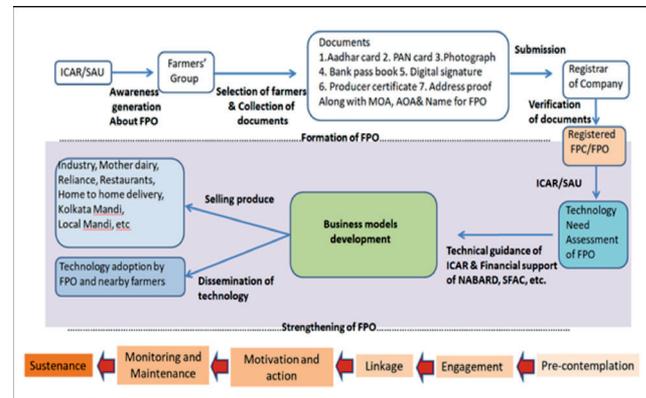
Fig 19.6 Need Based Technology Delivery through FPO (Generalized Process Model)

Outscaling of Technology through FPO

The lead Center at Patna is working on seed production. This year the model of technology transfer was extended from one FPO i.e. Champaran Krishak Producer Company Limited to ten other FPOs and the technology multiplication and delivery effectiveness was studied. Majority of the FPOs (8) shown the similar and level of effectiveness with the Champaran Krishak Producer Company Limited. The difference of the technology delivery efficiency was found significant in case of 2 FPOs

Table 19.7 List of FPOs for outscaling of Paddy Seed Production Technology delivery under NASF Project

Sl. No.	Name of FPO	Address	Rice Breeder Seed Provided (kg)			Area (ha)
			Swarna Shreya	Swarna Shakti Dhan	Swarna Samrid-dhi	
1	Champran Krishak Producer Company Ltd.	Diphi, Cheraiya, East Champaran	210	105	90	16.2
2	Chakiya Prakhand Kisan Utpadak Sangathan Sahkari Samiti Ltd.	Vill-Kudiya, Piprakothi, Chakiya, East Champaran	40	0	0	1.6
3	Someshwar Nath Kisan Utpadak Sangathan Sahkari Samiti Ltd.	Dariyapur, Sangrampur, East Champaran	120	70	70	10.4
4	Kausaliya Kisan Utpadak Sangathan SahkariSamiti Ltd.	ManikpurChowk, Harsiddhi, East Champaran	40	0	0	1.6
5	Bochaha Krishak Producer Company Ltd.	Bochaha New Market, Bochaha, Muzaffarpur	0	35	0	1.4
6	Saraiya Kisan Utpadak Krishak Ltd.	Saraiya, Bhatauliya, Muzaffarpur	0	35	0	1.4
7	Laxmi Kisan Utpadak Sangathan Sahkari Samiti Ltd.	Paratapur, Mehasi, East Champaran	40	0	0	1.6
8	Ghandhi Gram Kisan Utpadak Sangathan Sahkari Samiti Ltd.	MalahiAashram, East Champaran	0	0	35	1.4
9	Samridhi Kisan Utpadak Sangathan Sahkari Samiti Ltd.	BridhabanTolaNardarwa, East Champaran	0	0	35	1.4
10	Uday Krishak Producer Company Ltd.	Pakridayal, East Champaran	40	0	0	1.6
11	Atal Shree Kisan Utpadak Sangathan SahkariSamiti Ltd.	Pataura, East Champaran	0	35	0	1.4
	Total		**490**	**280**	**230**	**40**

A total of 10 quintals breeder seed of rice varieties i.e Swarna Shreya (490 Kg), Swarna Shakti Dhan (280 Kg) and Swarna Samriddhi (230 Kg) were provided to 11 FPOs (Table 19.7) based on their need assessment. These varieries were grown in total 40 hectares area in Muzaffarpur and East Champaran in North Bihar. Through seed certification, 22 tons of foundation seed were prepared for further multiplication and sale to the fellow farmers.

Registration of FPOs under the Project

In this project, 4 FPCs have been already registerd one in Jharkhand, one in Uttar Pradesh and two in West Bengal in the year 2021. This year another FPO was registerd in Bihar the details of FPO is given in table 19.8.

Table 19.8 List of FPOs registerd under the NASF project in the year 2022

S.N	Name	Registration number
1	Someswar Nath Kisan Utpadak Sahakari Samiti Ltd.,Sangrampur, East Champaran, Bihar (FPO)	B R - 0 7 - 0 4 - 0 1 - OTH-03-2022

Social Network Analysis of FPO and Non FPO farmers'communication

The results of the Social Network Analysis indicated that the communication pattern among FPO farmers is more cohesive, less sparse, and has a higher degree of influence compared to non-FPO farmers. This suggests that the FPO farmers are better able to communicate with each other and have a greater impact on each other's decisions and opinions.

The network plot from the SNA was also found to be an important tool for leadership identification. This suggests that the analysis of the communication pattern can be used to identify key individuals or groups who play a leadership role within the network, and who have a significant impact on the decisions and opinions of others. The results of the SNA of the communication pattern among FPO and non-FPO farmers indicated that being part of an FPO can lead to more effective communication and greater influence within a network of farmers.
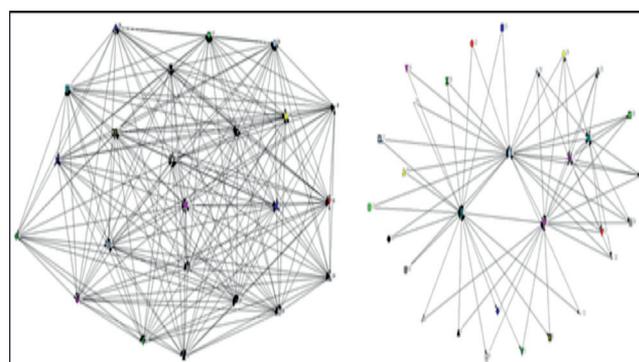
Fig. 19.7 Communication Network among FPO members

Fig. 19.8 Communication Network of Non FPO members

Impact of FPO based Technology delivery Model in Cooch Behar, West Bengal

Selected technologies like mulching in vegetables and scientific cultivation of mushroom, maize and jute were demonstrated and disseminated to farmers in Cooch Behar, West Bengal using FPO based model. Nearly 700 farmers benefitted from these technologies. The incremental gain in yield was to the extent of 5 to 15 quintals/ha (Table 19.9).

Table 19.9 FPO based Technology Delivery Model impact November, 2021 to September, 2022 (UBKV, Cooch Behar, West Bengal Centre)

Parameters	Best Management Practices of Jute	Mulching in vegetables and garlic	Mushroom cultivation and processing	Scientific Maize cultivation through CA Technology	Scientific Mustard cultivation through CA
Number of beneficiary farmers	178	124	36	323	32
Incremental yield (per ha, 1000 cylinder for mushroom) in t	0.75	1.5	0.5	0.5	0.5
Average Profit made (in Rs.)	61,000	66,900	89,000	53,552	78,542

FLD of scientific vegetable cultivation at Varanasi

The IIVR Centre was involved in organizing demonstrations of scientific cultivation of different vegetables at farmers' field i.e cowpea, okra, bottle gourd, sponge gourd, pea, bitter gourd and mushroom. Quality seed of improved varieties for these crops were provided to farmers along with technological backstopping (Table 19.10).

Table 19.10 Seed distributed/ FLD conducted under NASF Project at IIVR, Varanasi

S.No.	Crop	Variety	Quantity of seed distributed (kg)	No. of farmers adopted	Total FLD area under each variety (ha)
1	Cowpea	Kashi Nidhi	150	80	7.8
2	Okra	Kashi Kranti	7.5	54	0.5
3	Bottle gourd	Narendra Rashmi	5	45	1
4	Sponge gourd	Kashi Shreya	2	50	1.00
5	Pea	Kashi Uday	250	7	2
6	Bitter gourd	VRBTG-10	1.5	20	0.25
7	Mushroom spawn	Oyster	50	20	5 mushroom unit

E-extension services to farmers

WhatsApp is a very popular electronic media for social networking. Under this project, 13 WhatsApp group were created by implementing partners based on categories of farmers growing various crops. There are almost 1000 farmers added through these groups. These farmers get regular advisory on crops and get the solution to their problems by the expert scientists (Table 19.11)

Table 19.11 e-extension service provided under NASF FPO Project

Sl.No	Centre	No. of WhatsApp group	Number of users
1	ICAR- RCER-Patna	2	172
2.	ICAR- RCER- FSRCHPR, Plandu, Ranchi	1	136
3.	ICAR- IIVR, Varanasi	1	78
4.	UBKV, Cooch Behar, West Bengal	9	569

Resource Inventorization of Floodplains Wetlands in Eastern India

Resource mapping of Brahmputra floodplain wetlands in Lakhimpur, Assam

A study was conducted in the three wetlands area of Assam namely Ranganodi Brahmaputra, SubonShri and Dholnadi Brahmaputra river. Areas of Kuhhimari, Amtalar, Mohanjaan, kuhhimari and Amtalar Joinpur panchayat villages of Lakhimpur district was covered during this study. Schedule based survey was conducted among 115 farmers. Observation showed that flood affected area in the villages was from 75 ha to 590 ha. Flood comes every year mainly during the month of May to August. Around 65 to 85% of the area of villages faced flood every year. The depth of water is approximately 1.5 metre. The population in the surveyed villages ranged from 450 to 2100. The livestock population in the surveyed villages varied from 350-675. The range of agriculture size of farm holding was 0.5 to 20 acre. Almost 92% of the population was from schedule caste category in the surveyed area. None of the farmers belonged to any social institutions. Nearly 78% of farmers depend on agriculture and 22% farmers have other occupations in the surveyed village. Moreover, 90% farmers had kachha houses. It was also observed that 62% farmers have bikes, 5% have tractors, 32% have smart phone. The average number of cows is 4±2 to the 58% farmers while 64% farmers had 4±2 goats. Also, 57% farmers had 6±4 hens and some had pigs also. Farmers' primary occupation in the surbveyed villages was agriculture followed by animal husbandry, fishery and others. Television and mobile app were the most preferred information technology used by the 85% farmers. Farmers have no institution linkages. Only 5% of farmers used seed treatment in agriculture.

In Brahmaputra flood plain wetland, most farmers grow rice in summer, winter and autumn seasons. Rice based farming system was the most prevalent system in the region i.e., rice + maize/pulses. The rice productivity was found to be in the range of 1.9 to 2.3 t/ha. However, cropping system productivity was found to be 2.8 to 3.6 t/ha. The average annual income (INR/ha) from crops, horticulture and fishery was found to be 81,437/-, 159,865/- and 255,190/- respectively. There is a significant difference in annual income from these resources (Fig.19.9). The annual income per family from animal husbandry was measured to be INR180,464/household per ha. The average crop land holdings, horticulture and pond area was found to be 0.65 ha, 0.18 ha and 0.14 ha respectively. Farmers weremostly employed as daily wage workers for around 135 days annually.
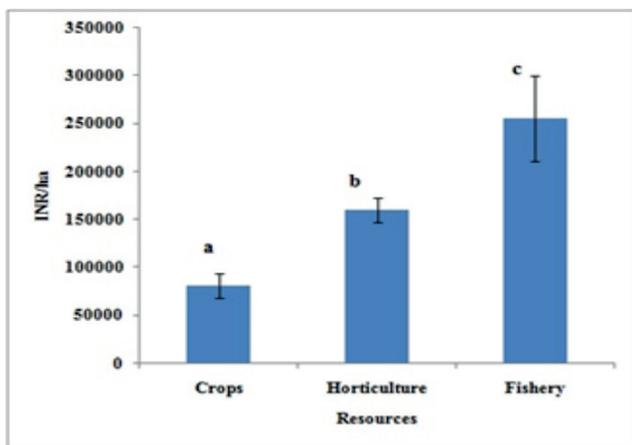
Fig. 19.9 Farmers' income from different agricultural resources in Brahmaputra flood plain wetland at Lakhimpur, Assam

Table 19.12 ARIMAX i.e., ARIMA (2,1,0) + rainfall model validation for *Kharif* rice production in Bihar

Year	Actual Production (MT)	Predicted production (MT)	% Error prediction
2016	7065,073	7367,422	4.28
2017	7046,043	7530,120	6.87

Time series ARIMAX (Auto Regressive Integrated Moving Average with regressors) based model was developed for rice production and forecasting using SAS 9.3 software. Akaike information criterion (AIC) is applied for best model selection. Maximum production was 7.18 million tons during the year 2011 and minimum was 1.82 MT in 2004. Maximum observed rainfall was 1433.48 (mm) during 2007 and minimum 792.63 mm during 2009. ARIMAX i.e., ARIMA (2,1,0) with regressor (*Kharif* rainfall) model having AIC 481.75 was found to be the best model developed for rice production. Rainfall showed positive significance ($p < 0.03$) on rice production. Per unit change in rainfall impact observed to be around 4808 MT on rice production. ARIMAX model validated with original rice production for the year 2016 and 2017 with less than 7 % prediction error (Table 19.12). Rice production was forecasted till the year 2025 results showed that it will increase in the upcoming years (Table 19.13)

Model Based Inference on Agricultural Crops For Food Security in Eastern India

*ARIMAX **(ARIMA (2,1,0) + rainfall) model based Kharif rice production forecasting in Bihar***

Rice is mainly grown in *Kharif* season in Bihar. Rainfall is one of the major weather variables that affects productivity of rice. Rice is grown in more than 80% area (around 28 lakh ha) of total rice cultivation land (33 lakh ha) during *Kharif* season in Bihar. A study has been conducted with the aim to quantify the influence of rainfall on rice production during *Kharif* season using a time series model. Rice production was also forecasted till 2025 through the developed model. Time series annual data on rice production (MT) and rainfall (mm) during *Kharif* season for the period 2000 to 2017 were taken from secondary published source for the study. Data for the period 2000 to 2015 was used for model development and 2016-17 for model validation

Table 19.13 *Kharif* rice production forecast from 2021 to 2025 in Bihar using ARIMAX

(ARIMA (2,1,0) + rainfall model)

Year	Production (MT)
2021	8092,107
2022	8251,071
2023	8486,585
2024	8738,327
2025	8938,736
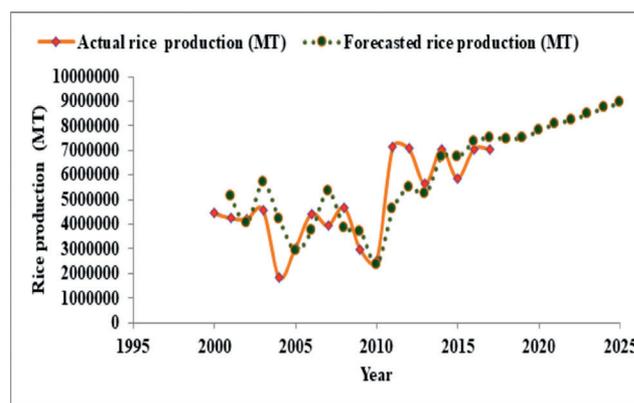
Fig.19.10 Annual actual vs forecasted *Kharif* rice production during 2001 to 2025 in Bihar

Spatial Interpolation IDW Model-based Rainfall Assessment in Bihar

Using 17 years of average annual rainfall data from 2001 to 2017 of 38 districts of Bihar, spatial interpolation of rainfall was carried out using two models i.e. Simple kriging and Inverse Distance Weighting (IDW) interpolation. For comparing the interpolation accuracy of estimates of these two models at unknown locations points, Root Mean Square Error (RMSE) statistics has been used. Smaller RMSE value showed more accuracy of the model. Analysis and mapping was performed using ArcGIS 10.3. Results showed that IDW method is more accurate for predicting average annual rainfall than kriging with RMSE value 163.8 as compared to kriging 182.5. IDW spatial interpolation method based rainfall distribution pattern is mapped (Fig. 19.11).
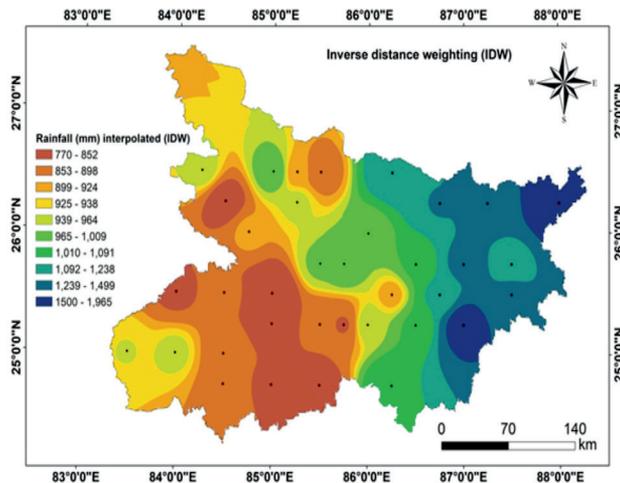
Fig. 19.11 Average *Kharif* rainfall (mm) distribution in different districts of Bihar during 2001-17

Standardization of Hydroponic Technology for Horticultural Crops

Development of foldable NFT hydroponic structure for growing of leafy vegetables: A foldable hydroponics structure for growing of leafy vegetables were designed and fabricated. 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 frames were 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.

Fig. 19.12 Lettuce in NFT hydroponics system

Performance evaluation of lettuce in NFT structure:

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 (Fig. 19.12). 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.

Evaluation of radish genotype for hydroponics:

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 as shown in Fig. 19.13.

Fig. 19.13 : Unique genotype of radish

Socio-Economic Status Scale for Characterization of Farmers

The multidimensional scaling method Maheshwari-Kumar-Jhamtani-Bhaskaran-Dandapani (M-K-J-B-D) was used to construct the socio-economic status (SES) scale for farmers of Bihar and Jharkhand. The general methodology of scale development is depicted in Fig. 19.14. The attribute data was collected from 492 farmers from different districts of Bihar and Jharkhand.

181 variables	Data from 100 farmers, experts' advice and review of literature
127 variables	Trivedi criteria for selection of variables
64 variables	Relevancy test by 30 experts, inter-item correlation score
17 variables	Data from 492 farmers, Factor analysis, SES scale, Reliability and Validity
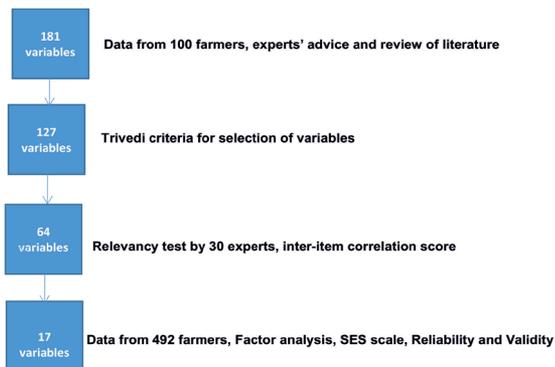
Fig. 19.14 General methodology of scale development

Factor analysis was applied to the data for identification of factors (indicators), variables (sub-indicators) and their weightage in the socio-economic status scale (Fig. 19.15). It was observed that, among all the factors, ten components (factors) could explain 93% of total variance. After restricting the number of components to ten, factor analysis was again employed to obtain the beta values for each variable. The variables which have major contribution to a particular component have higher beta values than for other components. On the basis of beta values of variables to a particular component, the components are given a name to represent the group of variables. Since these components are uncorrelated, there is no covariance hence no overlapping scores. Now, these components could be used to obtain scores of individual respondents. Mathematically it could be represented as:

Total Multidimensional Score (Y) = Y1 + Y2 + Y3 + Y4 + …………………. Y10.

Based on factors and formula for component score, the socio-economic status scale for farmers of Bihar and Jharkhand was developed which had 10 factors and 17 variables. Correlation and reliability coefficients of the developed scale were 0.96 and 0.97, respectively indicating that the scale was highly reliable. Validity (p<0.001) of the developed scale was established using Known Group Technique. The general socio-personal profile of respondents as derived from the survey data for Bihar and Jharkhand is presented in Table 19.14.
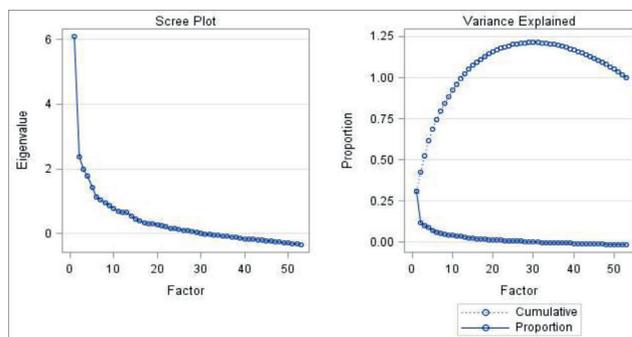
Fig. 19.15 Factor analysis of variables

Table 19.14 Socio-personal profile of respondents

Socio-personal variables	Category	Frequency (%)	
		Bihar (N= 178)	Jharkhand (N= 314)
Caste	General	52 (29)	1 (0.32)
	OBC	83 (47)	25 (8)
	SC	36 (20)	107 (34)
	ST	3 (2)	177 (56)
	Others	4 (2)	4 (1.28)
Family type	Nuclear	131 (74)	221 (70)
	Joint	47 (26)	93 (30)
Education	Illiterate	7 (4)	67 (21)
	Literate	171(96)	247 (79)
Health status	Healthy	173 (97)	255 (81)
	Not healthy	5 (3)	59 (19)
PM Jan Arogya Yojana	Having knowledge	157 (88)	140 (45)
	Having no knowledge	21 (12)	174 (55)
Type of house	Kuchcha	78 (44)	232 (74)
	Mixed	42 (24)	51 (16)
	Pucca	58 (32)	31 (10)
Toilet facility	Yes	145 (82)	162 (52)
	No	32 (18)	152 (48)

The application of scale to the farmers of Bihar and Jharkhand showed that, lower middle-class farmers predominate in both states. In Bihar, the population of lower middle class (40.64%) is followed by middle class (39.44), upper middle class (9.96%), upper class (5.58%) and lower-class (4.38%) farmers respectively (Table 19.15). However, in Jharkhand, lower middle class is followed by lower class, middle class, upper class and upper middle-class farmers, respectively.

Table 19.15 Categories of farmers based on socio-economic status scale

S. No.	Socio-economic categories of farmers	Socio-economic Status score range	Bihar (N=251)	Jharkhand (N= 315)
1	Lower class	13-30	11(4.38)	121(38.41)
2	Lower middle class	30-47	102(40.64)	137(43.49)
3	Middle class	47-64	99(39.44)	48 (15.24)
4	Upper middle class	64-81	25(9.96)	4 (1.27)
5	Upper class	>81	14(5.58)	5 (1.59)

Agri-Business Incubation Centre

Under the aegis of Agri-Business Incubation Project of ICAR, five potential candidates/firms signed the MoUs with ABI Center, FSRCHPR, Ranchi. The details of the incubatees and the present status is presented in Table 19.16.

Table 19.16 Details of the incubatees with ABI Center, FSRCHPR, Ranchi

Sl. No	Incubatee's name	Area specification	Date of MoA	Current activity/ Status
1.	Smt. Albina Ekka	ITK based Ayurvedic medicinal formulation	27/01/2022	Successfully running of business with Brand name given
2.	Smt. Bandana Ranjan	Button Mushroom	05/02/2022	Not yet started
3.	M/s Murhu Nari Shakti Kisan Producer Co. Ltd.	Seed Production (OP Varieties of Tomato)	02/07/2022	Seed sapling of tomato (S. Anmol) Hyb. Syngenta Variety- 1156 Sahoo
4.	M/s Jagruk Mahila Farmer Producer Co. Ltd.	Hybrid Seed production in Tomato	02/07/2022	Seed sapling of tomato (S. Anmol) Hyb. Syngenta Variety- 1156 Sahoo
5.	M/s Homekhet Agritech Pvt.Ltd	Modular Farming Nursery, Mushroom. Livestock	15/09/2022	Certification of Start-up India, from Misintry of Commerce and Industry, Govt. of India.

Plant Variety/Germplasm Registration under the Project

- Plant Variety registration certificate received for bottle gourd variety Swarna Sneha (REG/2019/134) and Swarna Yamini (REG/2019/130) from PPV&FRA, New Delhi.

- Germplasm registration was obtained from ICAR NBPGR, New Delhi for Swarna Apurva (IC 645425), Swarna Arohi (IC 645426) in chilli, Swarna Prakash (IC 645623) in tomato and Swarna Sushk Dhan (IC 645444), Swarna Purvi Dhan-1 (IC 645445), Swarna Purvi Dhan-2 (IC 645446) in rice

- The application form of vegetable cowpea variety Swarna Mukut (Application No. REG/2022/0040

Dated 30.03.2022) has been submitted for registration under PPV&FRA, New Delhi.

Commercialization of Technology

Memorandum of Understanding (MoU) signed

- MoU was signed with M/s VNR Seeds Pvt Ltd., Raipur for large scale seed production of different open pollinated varieties *viz.*, Swarna Prakash, Swarna Kanchan, Swarna Atulya, Swarna Praphulya, Swarna Arohi, Swarna Apurva, Swarna Tejaswi, Swarna Priya, Swarna Vasundhara, Swarna Yamini, developed by the institute on December 28, 2022.

Material Transfer Agreements (MTA)

- MTA was signed with ICAR Indian Institute of

Agricultural Biotechnology, Ranchi for Swarna Safal (Faba bean) on June 23, 2022

- MTA was signed with Dr Panjabrao Deshmukh Krishi Vidyapeeth, Akola for Swarna Vasundhara

(Vegetable soyabean) on June 13, 2022.

- MTA signed with Birsa Agricultural University, Ranchi for HAFB-4 (French bean) on May 25, 2022.

International Collaborations:

Research Area	Collaborating Institute/organization
Development of Solar Irrigation Pump Sizing Tool	International Water Management Institute, New Delhi
Other Collaborations	
Research Area	Collaborating Institute/organization
Impact evaluation of watershed development projects	National Bank for Agriculture and Rural Development, Ranchi
Economic development of aspirational districts	Grant Thornton Bharat LLP, Hazaribagh, Jharkhand

Linkages

Besides having linkages with leading ICAR institutions, SAUs and State Govt. of various eastern states, the details of other linkages is depicted below:

International Collaborations :

Research areas	Collaborating institutes
Conservation Agriculture	CIMMYT
Climate resilient cropping systems	CIMMYT
Improving water use for dry season agriculture	CIMMYT
Sustainable and resilient farming system intensification for EIGP	CIMMYT
Development of submergence tolerance rice varieties for flood plain and flood prone areas of eastern region	IRRI
Development of drought tolerance rice varieties for eastern region	IRRI
Restoration of degraded lands, water congested areas and carbon sequestration	World Agroforestry Centre
Developing suitable pulse varieties of lentil, grass pea and pigeonpeafor drought tolerance in eastern states	ICARDA
Small ruminants improvement and production system	ILRI

Other Collaborations:

Research areas	Collaborating institutes/ Regional Centres
Integrated Farming System	IVRI RC, Kolkata; IISWC RC, Koraput; IARI RS, Pusa (Bihar); CIFRI; CPRS RS, Patna, IIFSR, Modipuram, MGIFRI, Motihari and NBSS&LUP
Tribal Farming System	IISWC RC, Koraput, Odisha, and NBSS&LUP
Quality brood management, fish seed, enclosure culture and wetland rehabilitation	CIFA; CIFRI; CRRI; NRC (Pig); AAU and CTCRI
Livestock & Avian Production System	IVRI; NRC (Pig); NDRI; AAU; UBKV; BAU (Bihar); BAU (Ranchi) and CARI
Seed production of agri-horti crops including production technology	DSR, Mau; IARI RS, Pusa; BISA (CIMMYT) Pusa; CRRI; BAU (Bihar & Ranchi); RAU, Pusa; IIVR; CTCRI; CHES; NRC, Litchi; CSISA; DMR; CPRS-RS, Patna & UBKV.

20 Training and Capacity Buildings

Trainings and Capacity Building

Training and capacity building is an integral part of developmental efforts of ICAR-RCER, Patna. The institute organizes and facilitates numerous training programs every year for farmers, agricultural stakeholders, and scientists alike. These programs aim to improve the skills and knowledge of all participants in the field of agriculture and encourage sustainable practices. By providing such education and training opportunities, ICAR RCER, Patna is playing a significant role in advancing the agricultural sector and promoting rural economic growth in eastern Region.

Table 20.1 List of employees undergone training 2022

Category	Total No. of employees	No. of trainings planned for each category during 2022-23 as per ATP	Total No. of employees undergone training during 2022-23	% Realization of trainings planned during 2022-23
Scientist	70	12	11	91.07
Technical	39	2	0	0
Administrative & Finance	23	1	0	0
SSS	28	0	0	0
Total	160	15	11	73.33

S. No.	BE 2022-23 for HRD	Actual expenditure during 2022-23	% Utilization
1	0.90	0.87	96.66

Table 20.2 Sponsored Training Programmes Organised at FSRCHPR, Ranchi

Name of training program	Duration	No. of participants	Sponsoring agency
Nursery management in horticultural crops	08-10 Feb, 2022	24	KVK, Bhagalpur (Bihar)
Integrated farming for livelihood security in Jharkhand	15-17 Feb, 2022	25	Farmers first project, ICAR RCER Ranchi
Scientific cultivation of vegetables	22-26 Feb, 2022	25	ATMA, Samastipur (Bihar)
Agri-entrepreneurship opportunities in Jharkhand	28 Feb-2 Mar, 2022	37	ICAR-ABI project
Fruiting stage scientific cultivation of mango	03-05 Mar, 2022	27	AICRP on fruits
Fruiting stage scientific cultivation of mango	05-07 Mar, 2022	20	AICRP on fruits
Scientific management of fruiting orchards	08-10 Mar, 2022	22	NABARD, Jharkhand
Improved mushroom production techniques	09-11 Mar, 2022	25	AICRP on Mushroom
Agri-entrepreneurship opportunities in Jharkhand	11-13 Mar, 2022	25	ICAR-ABI project
Improved mushroom production techniques	14-16 Mar, 2022	24	AICRP on Mushroom
Scientific management of fruiting orchards	14-16 Mar, 2022	21	NABARD, Jharkhand
Scientific management of fruiting orchards	21-23 Mar, 2022	20	NABARD, Jharkhand

Name of training program	Duration	No. of participants	Sponsoring agency
Scientific management of fruiting orchards	24-26 Mar, 2022	20	NABARD, Jharkhand
Scientific management of fruiting orchards	28-30 Mar, 2022	25	NABARD, Jharkhand
Scientific management of fruiting orchards	04-08 Apr, 2022	25	ATMA, Supol
Scientific cultivations of vegetables	23-25 Jun, 2022	50	GT Bharat LLP, Hazaribagh
Scientific cultivations of vegetables	21-23 Sept, 2022	54	GT Bharat LLP, Hazaribagh
Scientific cultivations of vegetables	8-10 Dec, 2022	44	GT Bharat LLP, Hazaribagh
Opportunities in the processing of vegetable soybean	10 Jan, 2023	79	ICAR-RCER, Patna
Hybrid seed production in vegetables	10-12 Jan, 2023	26	ABI project, ICAR RCER
Rice-fallow Management by CA Technologies	22 Jun, 2022	25	CRP CA project, ICAR-RCER
Cultivation technology of oyster mushroom and their value addition	27 Sept, 2022	25	AICRP on Mushroom

Table 20.3 Training of Master Trainers at FSRCHPR, Ranchi

Name of master training programme	Duration	No. of participants	Sponsoring authority
Soil testing and fertilizers recommendation	09-20 May, 2022	14	YBN University, Ranchi
Advances in insect pest management	09-22 Nov, 2022	19	BBMKU, Dhanbad
Propagation and nursery management in horticultural crops	26 Dec - 5 Jan, 2023	21	BAU, Ranchi

Table 20.4 Trainings /Field Day/FLDs organized at RCM Darbhanga

Sl. No.	Name of training programme	Sponsor	Date	No. of farmers participated
01.	Farmers training programme on "Vaigyanik tareeke se makhana utpadan, mulya sanwardhan ewam vipnana"	ATMA, Purnea	08.03.2022 to 12.03.2022	40
02.	Farmers training programme on "Makhana Ki Vaigyanik Kheti"	ATMA, Saharsa	22.03.2022 to 26.03.22	40
03.	Farmers training programme on "Makhana Ki Utpadan Badhane Hetu Khar-Patwar Niantran"	Under SCSP Project of ICAR-RCER, Patna	30.03.2022	30
04.	One day brain storming workshop for promotion of FPOs for makhana development	Kaushalya Foundation & Makhana Development Mission	27.04.2022	81
05.	Awareness programme for makhana growers on Celebration of Amrit Mahotsav	Makhana Development Mission	28.04.2022	66
06.	One day Farmers training programme on "Makhana Ki Vaigyanik Kheti"	Makhana Development Mission	28.05.2022	71
07.	Seven days farmers training programme on Skill Training of Rural Youth (STRY) under Sub-Mission of Agricultural Extension on "Makhana Processing, marketing and Branding from Bihar"	MANAGE, Hyderabad, Ministry of Agriculture and Farmers Welfare	18.06.2022 to 24.06.2022	47

Sl. No.	Name of training programme	Sponsor	Date	No. of farmers participated
08.	One day farmers training programme on " Makhana Ki Kheti Se Adra Bhumi Ka Vikas	Makhana Development Mission	14.07.2022	25
09.	One day farmers training programme on " Makhana harvesting and Processing"	SAKHI, NGO, Rudrapur, Andhrathadi, Madhubani & RCM, Darbhanga	20.07.2022	33
10.	One day farmers training programme on "Makhana Harvesting and Processing"	SAKHI, NGO, Rudrapur, Andhrathadi, Madhubani & RCM, Darbhanga	22.07.2022	37
11.	One day farmers training programme on "Makhana Utpadan Pranali Se Adra Bhumi Ka Vikas"	Makhana Development Mission	05.08.2022	17
12.	Farmers training-cum demonstration at farmers field and visited makhana industry at Village-Arer, Madhubani	Makhana Development Mission	09.08.2022	10
13.	Field day-cum-Farmers- Scientists Interaction on "Foliar application of Nutrients for Improving Makhana Productivity"	SCSP	28. 03. 2022	30
14.	Field day-cum-FLD on Swarna Shreya and Swarna Samriddhi Dhan	ICAR-RCER, Patna	26.10. 2022	50

Training Programmes Organised

A 3-day training program on 'Small Interventions in Agricultural Practices for Doubling Income' sponsored by ICAR-CIRB, Hisar organized at ICAR-RCER, Patna during 28-30 March, 2022

Training programme on "Improving agricultural productivity through efficient land and water management practices" sponsored by ATMA, Gopalganj at ICAR-RCER, Patna from 23-26 March, 2022

A one-day awareness programme on 'Protection of plant varieties and farmer's rights (PPV&FR) act-2001' was organized at Gola, Ramgarh, Jharkhand on June 14, 2022.

Training programme on "Repair, Maintenance and Operation of Power Tiller" under CRP on Farm Mechanization & Precision Farming project at KVK, Ramgarh from 01-03 August, 2022.

Training programme on "Suitable agricultural equipments and machinery for improving land and water productivity in hill and plateau region" under CRP on Farm Mechanization & Precision Farming project at KVK, Ramgarh from 04-06 August, 2022.

Skill Development Training programme on "Land & Water Management Techniques in Agriculture" of 8 B-Tech (Agril. Engg.) students from College of Agricultural Engineering & Technology, Dr. RPCAU, Pusa during 01-30 November, 2022.

Training programme on "small agricultural interventions to improve the livelihood of scheduled caste farmers" SCSP scheme at Kanhauli and Kashi Beegha villages of Sheikhpura District, Bihar from 22-23 August, 2022.

Practical Training for a B.Sc. Agriculture Student of Amity Institute of Organic Agriculture, Amity University, Noida-125, Uttar Pradesh on "Assessment of weed diversity and soil nutrient availability in direct seeded rice (*Oryza sativa* L.) under different tillage practices in eastern Indo- Gangetic Plains".

Training on Recent advances in Integrated Fish Farming System during 6-10 June, 2022 for Munger district at ICAR Research Complex for Eastern Region, Patna for 30 farmers.

Training on Recent advances in Integrated Fish Farming System for the farmers of Lakhisarai district during 25-29 July, 2022 at ICAR Research Complex for Eastern Region, Patna for 30 farmers.

Training programme for field assistants on

"Characterization of Animal Genetic Resources of Bihar" during December 13-15, 2022.

A students training program on "Study of microbial and plant biochemical parameters in agriculture system" at ICAR Research Complex for Eastern Region, Patna from 22 September, 2022 to 21 October, 2022.

Field Day/Kisan Goshthi/Mass awareness programme

- Field visit on Integrated Farming Systems for Patna for 30 farmers at ICAR RCER, Patna on Feb 24, 2022 funded by ATMA, Patna.

- Field visit on Mushroom cultivation under BSDM for 30 farmers at ICAR RCER, Patna on April 26, 2022 funded by Patliputra University, Patna.

- Field day on "Livelihood improvement of scheduled caste farmers through agricultural technology inputs" on May 27, 2022 at Hinduni village of Phulwari Sharif, in SCSP scheme.

- Field day on "Livelihood improvement of scheduled caste farmers through agricultural technology inputs" at Naubatpur, Patna on July 25, 2022 under SCSP scheme.

- An awareness programme on "Livelihood improvement of scheduled caste farmers through agricultural technology inputs" under SCSP project on December 22, 2022 at Abupur village of Naubatpur block, Patna.

- Field day-cum-awareness programme on "Livelihood improvement of scheduled caste farmers through agricultural technology inputs" under SCSP project on Nov. 18, 2022 at Saristabad village of Naubatpur block, Patna.

- Field day on "Livelihood improvement of SC farmers through agricultural technology inputs" at Nad village, (block-Sirdala, Nawada) on June 9, 2022 in Schedule Caste Sub-Plan.

- Farmer's awareness-cum-agricultural input distribution programme under SCSP project was organised during 8-12 August, 2022 at ICAR-RCER, Patna.

- An animal health camp was organised under Farmer's FIRST project in Tetri village of Ranchi, Jharkhand on February 07, 2022.

- A vaccination camp was organized under Farmer's FIRST project at Tetri village of Ranchi, Jharkhand on February 11, 2022

- Field demonstration-cum-input distribution program was organised under SCSP programme at Lawaloung village in Chatra district of Jharkhand on March 23, 2022.

- Awareness-cum-input distribution program was organised under SCSP programme at Bahagara village in Chatra district of Jharkhand on May 7, 2022.

- Awareness-cum-input distribution program was organised under SCSP programme at Lawaloung village in Chatra district of Jharkhand on August 26, 2022.

- Animal health-cum-vaccination camp and input distribution programs were organised under SCSP programme at Lawaloung village of Chatra district of Jharkhand on June 15, 2022

- Field Day-cum-input distribution program was organised under SCSP programme on at Lawaloung village in Chatra district of Jharkhand December 2, 2022.

- A mass awareness program for promotion of Natural and Organic farming 'Anndata Devo Bhava Abhiyaan' was organized at FSRCHPR, Ranchi on April 23, 2022.

- A one-day training-cum-kisan ghoshti on 'Mushroom Cultivation' organized at Panchayat Bhawan, Itki, Ranchi on December 12, 2023.

- A one-day awareness programme on 'Protection of plant varieties and farmer's rights (PPV&FR) act-2001' was organized at Gola, Ramgarh, Jharkhand on June 14, 2022.

- Field day on "Application of precision farming technology in increasing farm productivity" on 4 August, 2022 at Barka Chumba village, Ramgarh, Jharkhand under CRP on FM & PF.

- Field Wday-cum-awareness programme on "Livelihood Improvement of Scheduled Caste Farmers through Agricultural Technology Inputs" on 11 November, 2022 at Saristabad village, Naubatpur, Bihar under Schedules Caste Sub-Plan (SCSP).

- Awareness programme on "Livelihood Improvement of Scheduled Caste Farmers through Agricultural Technology Inputs" on 22 December, 2022 at Abupur village, Naubatpur, Bihar under Schedules Caste Sub-Plan (SCSP).

Trainings Attended by the Employees during 2022

A.K. Chaudhary, attended Pre-launching NICRA Workshop on February 07, 2022.at KVK, Jale Darbhanga.

Akram Ahmed attended online training programme on "Advances in Web and Mobile Application Development" during 02-06 August, 2022 organized by ICAR-NAARM, Hyderabad.

Akram Ahmed attended online training programme on "Analysis of Experimental Data" from 17-22 January, 2022 Organized by ICAR-NAARM, Hyderabad.

Manibhushan attended winter school on "Artificial Intelligence in Agriculture" through on line mode during 15 February to 7 March, 2022 organized by ICAR- Indian Agricultural Statistics Research Institute, New Delhi.

Jaipal Singh Choudhary attended online training programme on 'Metagenomic Data Analysis' during January 19-24, 2022 organized at ICAR-Indian Agricultural Statistics Research Institute, New Delhi.

Jaspreet Singh attended a short course on "Bycatch Reduction in Fisheries- Recent Advances" 17-26 Jan, 2022 organized by ICAR-Central Institute of Fisheries Technology, Kochi.

Jaspreet Singh 2022 attended a training programme on "Ornamental Fish Breeding and Culture" 16-18 Feb., 2022 organized by ICAR-Central Institute of Freshwater Aquaculture, Bhubaneswar Odisha.

Saurabh Kumar attended 5 days International Workshop on "Environmental Metagenomics" from 4-8 April 2022, organized by Physalia-courses, Berlin Germany.

S.S. Mali attended online training programme 'Integrated Watershed Management for Strengthening PMKSY' organized by ICAR-Indian Institute of Soil and Water Conservation, Research Centre, Udhagamandalam and MANAGE, Hyderabad during July 11-14, 2022.

S.S. Mali attended a training Workshop on Data Visualization using R organized by National Academy of Agricultural Sciences (online mode) during March 9-11, 2022.

Manisha Tamta attended "German Language A1 Certificate Course" from 15th November 2021 - 28th February, 2022 under Institutional Development Plan of National Agricultural Higher Educational Project (IDP-NAHEP) at G.B. Pant University of Agriculture & Technology, Pantnagar, Uttarakhand.

Meenu Kumari attended 'Analysis of Multi-Environment Trials (online mode)' organized by ICAR-NAARM, Hyderabad during November 3-8, 2022.

Meenu Kumari attended 'QTL analysis and genome-wide association studies (online mode)' organized by ICAR-IASRI, New Delhi during February 15–24, 2022.

SK Naik attended Online Training Programme on 'Geospatial Analysis using QGIS & R' Organized by ICAR-NAARM, Hyderabad during 14-19 February, 2022

Rachana Dubey undergone training on 'Analysis of Greenhouse Gas and Its Interpolation' during 7-10 September, 2022 at Division of Environmental Sciences, ICAR-IARI, New Delhi.

Reena Kumari Kamal attended Two-days 'Regional Training Programme' for the Nominees of CPCSEA' organized at Academy of Animal Resources Management (AARM), Haringhata, Nadia, West Bengal during November 17-18, 2022.

Shankar Dayal participated in Five Days Hands-on-Training on 'Advanced biotechnological approaches to augment productivity in poultry for ensuring food and nutritional security' jointly organised by the ILRI and ICAR from 20-24 September, 2022 at ICAR-Directorate of Poultry Research (DPR), Hyderabad.

Shankar Dayal participated in five days online training program on "Analysis of Experimental Data, organized by NAARM, Hyderabad from 17-22 January, 2022

Ujjwal Kumar attended Management Development Programme on Leadership Development (a pre-RMP Programme), ICAR- NAARM during 14-25 June, 2022

Shivani attended traning programme on Leadership and Organization Development for Women Scientists/ Technologist during 12-16 September, 2022 at the Centre for Organization Development, Hyderabad.

Ved Prakash attended Training workshop on "Advances in Simulation Modeling and Climate Change Research Towards Knowledge-Based Research" from Nov. 17-Dec. 7, 2022 at Division of Environmental Science, IARI, New Delhi.

Vivekanand Bharti participated in online training course on 'Monitoring Microbial Quality of Water' under the auspices of ONWARD (Open Network on Water-Related Disease) Project, held from 11-28 February, 2022.

Participation in Conferences/Seminars/Workshops/Symposia/Meetings/Brain Storming Sessions

AK Jha attended National workshop (virtual mode) on 'Shitake Mushroom Possible source as Nutraceutical and New Generation Functional Food' organized by ICAR-Research Complex for NEH Region, Manipur in collaboration with SPBB during February 22-24, 2022.

AK Jha attended Webinar on 'Integration of landscape resource conservation with field scale climate resilient technologies for strengthening rural livelihoods in drylands' organized by ICAR-RCER, Patna on April 11, 2022.

AK Jha attended XXIVth Group Meeting of AICRP-Mushroom organized at Mushroom Research Centre, Sonipat, Haryana during July 11-12, 2022.

AK Jha, SS Mali and R Shinde attended Webinar on **NEWs ,odkleu till kulesfy, Hie ,oat y l j{kkrdubla** organized by ICAR-RCER, Patna on February 19, 2022.

AK Jha participated in VIIth International Conference on Global Research Initiatives for Sustainable Agriculture and Allied Sciences (GRISAAS-2022) held at Birsa Agricultural University, Ranchi, Jharkhand during November 21-23, 2022.

Akram Ahmed participated in the National Conference on "Managing weather and climate risks in agriculture" jointly organized by Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir (SKUAST-K), Srinagar, Kashmir and Association of Agrometeorologists, Anand, Gujrat during March 24-26, 2022 at SKAUAST, Srinagar.

Arti Kumari participated in the National Convention organized by the Central Institute of Agricultural Engineering, Bhopal on 26-27 May 2022 on the topic 'Contribution of Artificial Intelligence and Internet of Things in Agricultural Engineering'.

Manibhushan presented a paper on "Image classification for different land use and land covers of East Champaram district using maximum likelihood technique" in 13th International Conference on Agriculture, Horticulture and Plant Sciences organized by The Society of Tropical Agriculture, New Delhi during 25-26 June, 2022.

Rachana Dubey participated in 86th Annual Convention of Indian Society of Soil Science and National Seminar on "Developments in Soil Science" at Rahuri, Maharashtra during 14-17 November, 2022.

I.S. Singh attended a meeting through video conferencing for Makhana promotion on 01.08.2022 held at Krishi Bhawan, New Delhi.

I.S. Singh attended a webinar on "One District One Product-Makhana (Araria, Darbhanga and Katihar)" under PMFME scheme on zoom on 17.06.2021 organized by Directorate of Horticulture, Bihar and delivered one lecture on "Makhana Value Chain Analysis".

I.S. Singh attended Stakeholders Meet on Makhana followed by two days training programme, organized by ICAR-CIPHET, Ludhiana, Punjab at RCM, Darbhanga from 05-07 Sept., 2022.

I.S. Singh attended the Ist National Makhana Conference on Innovative Approaches for Promotion of Makhana organized by International Makhana Centre & PHD Chamber of Commerce and Industry in association with Chandragupt Institute of Management (CIMP), Patna on 20th September, 2022 and delivered a lecture as a lead speaker on "Increasing Production and Role of Technologies".

I.S. Singh attended the Ist National Summit-cum-Festival on Makhana, 2022 organized by Directorate of Horticulture, Department of Agriculture, Patna, Bihar at Gyan Bhawan, Patna from 29-30 Nov., 2022, was invited as a lead speaker in technical session conducted on Nov. 30, 2022.

I.S. Singh attended the meeting called by District Officer-cum- Member Secretary of District Rural Development Agency, Vikas Bhawan, Darbhanga on 07-08 July, 2022.

I.S. Singh attended the workshop on "Makhana and Other Horticultural Crops" organized by District Horticulture Officer, Madhubani under National Horticulture Mission Plan on March 24, 2022 at District Agriculture Office, Madhubani.

I.S. Singh attended the workshop on "Makhana Research and Processing under Bihar Agricultural Investment Promotion Policy organized by Directorate of Horticulture, Agriculture Department, Bihar at Dalan resort, Sonki, Darbhanga on Sep. 15, 2022.

I.S. Singh attended a Review Meeting on Development of Research Centre for Makhana, Darbhanga under the Chairmanship of Sh. Kumar Sarvjeet, Hon' ble Agricultural Minister, Bihar at Research Centre for Makhana, Darbhanga on Nov. 02, 2022.

JS Choudhary attended National Seminar on 'Fruit production in Eastern Tropical Region of India: Challenges and Opportunities' organized by Central Horticultural Experiment Station (ICAR-IIHR), Bhubaneswar during March 24-26, 2022.

Sarma Kamal and P. C. Chandran attended an interface

meeting on "Mission towards Zero non-descript AnGR of Bihar" on July 30, 2022.

Sarma Kamal and Vivekanand Bharti attended one day seminar on Small Indigenous Fish for Nutritional and Livelihood Security organized by BAMETI at BAMETI, Patna on 31 March, 2022.

Sanjeev Kumar participated in the 3rd International Weed Conference (IWC) Organized by DWR and AAU, Anand from December 20-23, 2022.

Sanjeev Kumar participated in the Meeting called for preparation of "Feed and Fodder Platform" for Bihar at BASU, Patna.

Santosh Kumar participated in "34th State Seed sub-committee (UP) meeting" held on March 22, 2022.

Santosh Kumar participated in "Annual review meeting with the CG Centres to discuss their ongoing projects/activities taken up during 2021 as per the approved Work Plan and future plan/activity to be taken in the year 2022" on Feb 7, 2022 (virtual mode).

Santosh Kumar participated in State Coordinated Varietal meetings for *Kharif* 2022 organized by Bihar Agricultural University, Sabour on June 24, 2022.

Santosh Kumar participated in State Seed sub-committee (Jharkhand) meeting held on March 24, 2022 at Secretariat (Department of Agriculture), Govt. of Jharkhand.

Santosh Kumar participated in training on "Users Training cum Workshop on AICRIP Intranet functionalities" organized by ICAR-IIRR, Hyderabad (in virtual mode) during 15-17th February 2022.

Shivani attended meeting-cum-awareness programme on Prevention of Sexual Harassment of Woman at Workplace at ICAR-MGIFRI, Pipralothi, Motihari on July 2, 2022.

S.S. Mali and R Shinde attended Webinar on 'Evolution of smart Agriculture System' organized by ICAR-RCER, Patna on May 20, 2022.

Dhiraj Kumar Singh presented a paper on "Assessment of zero tillage technology in wheat and lentil through on farm demonstrations: Evidences from Gaya, Bihar" in International Conference on "Global research initiatives for sustainable agriculture & allied sciences (GRISAAS-2022)" organized by Astha Foundation, Merrut, UP during 21-23 November, 2022 at BAU, Ranchi.

Dhiraj Kumar Singh presented a paper on "Yield gap analysis of summer mungbean (Vigna radiate) through on farm demonstrations of zero tillage technology in Gaya, Bihar" in International

Conference on "Vision 2047: Sustainable Developments towards Atma Nirbhar Bharat (VSANB-2022)" organized by SFSN, Lucknow during 23-24 December, 2022 at FDDI, Chandigarh.

Rohan Kumar Raman, presented a paper on "Augmenting Farmers' Income through Technological Interventions: A case Study in Bihar, India". Paper presented in International Conference on "Vision 2047: Sustainable Developments towards Atma Nirbhar Bharat (VSANB-2022)" organized by SFSN, Lucknow during 23-24 December, 2022 at FDDI, Chandigarh.

Rohan Kumar Raman, presented a paper on "Influence of climate change on Kharif rice production in Bihar, India" in 4 th International Conference on "Global Agriculture, Forestry, Environment and Food Security (GAFEF-2022)" organized during 17-19 September 2022, Pokhara, Nepal.

Abhay Kumar presented a paper on "Impact of zero tillage on *rabi* crops: a case study in Bihar, India", in 4th International Conference on "Global Agriculture, Forestry, Environment and Food Security (GAFEF-2022)" organized during 17-19 September, 2022, Pokhara, Nepal.

Manoj Kumar presented paper "Inevitability of micronutrients fertilization under the rising atmospheric CO_2: A perspective on nutrition security in India" in the International multidisciplinary webinar on "Climate change impact on agriculture, environment and sustainable development" jointly organized by IASR, Kolkata, Gurukul Edutech Education and Research Foundation, Kolkata, and SERI, Kolkata during 11-13 February, 2022.

Manoj Kumar presented paper on "Curtailing water requirement for Makhana farming: A case report" in the National Webinar on "Sustainable Interventions towards Resource Conservation and Natural Farming" organized by Academy of Natural Resource Conservation and Management, Lucknow & Assam Agricultural University Jorhat during 22-23 April, 2022.

Manoj Kumar presented paper "Makhana for livelihood improvement of farmers in Eastern India" in the International Conference on "Agricultural development, its challenges and future needs" jointly organized by S.K. Chaudhary Educational Trust, KVK, Madhubani, Bihar during 9-11 April, 2022.

S. Mondal, Oral presentation in International Conference on "Global Research Initiatives for Sustainable Agriculture & Allied Sciences" during 21-23 November, 2022 at Birsa Agricultural University, Ranchi, Jharkhand, India.

S. Mondal, participated in International conference on "Reimaging Rainfed Agro-ecosystems: Challenges & Opportunities" (ICRA-2022) organized by the Indian Society of Dryland Agriculture at ICAR CRIDA, Hyderabad, India, during 22-24 December 2022.

S. Mondal, participated in National Seminar on "Agrophysics for Smart Agriculture" held at NASC Complex, New Delhi from 22-23 February 2022.

P Nath and SS Mali attended 56th Annual Convention of Indian Society of Agricultural Engineers on 'Agricultural Engineering Innovation for Global Food Security and International Symposium on India @2047: Agricultural Engineering Perspective' at Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu during November 9-11, 2022.

Pawan Jeet participated in National Conference on "Promotion of Kisan Drones: Issues, Challenges and Way Forward" held on 2nd May, 2022 at A.P. Shinde Hall, NASC Complex, New Delhi.

Pawan Jeet participated in National Conference on Landscape Management for Preventing Flood and Reservoir Sedimentation (LMPFRS-2022)" held during 22-24 September, 2022 organized at Birsa Agriculture University, Ranchi, Jharkhand by Indian Association of Soil and Water Conservationists (IASWC), Dehradun, Uttarakhand.

Pawan Jeet participated in National Conference on Organic & Natural Farming in Context to Indian Agriculture held during 13-14th May, 2022 at Chandra Shekhar Azad University of Agriculture and Technology, Kanpur.

R Shinde participated in 'The Global Symposium on Soils for Nutrition' organized by Food and Agriculture Organization of the United Nations held virtually during July 26-29, 2022.

R Shinde participated in VIIth International Conference on Global Research Initiatives for Sustainable Agriculture and Allied Sciences (GRISAAS-2022) held at Birsa Agricultural University, Ranchi, Jharkhand during November 21-23, 2022.

R Shinde participated in Webinar on 'Carbon Sequestration in Indian Tropical Soils: Factors and Enhancement Strategies' organized by ISSS Kolkata Chapter Lecture Series on April 7, 2022.

Reena Kumari Kamal attended Online Interface Meet on 'Characterization and Documentation of Animal Genetic Resources of Punjab: A Mission towards Zero Non-Descript population' organized by NDRI, Karnal, Haryana India on February 8, 2022.

Reena Kumari Kamal. Attended Online Interface Meet on 'Characterization and Documentation of Animal Genetic Resources of Haryana: A Mission towards Zero Non-Descript population' organized by NDRI, Karnal, Haryana India held on February 10, 2022.

RK Raman Attended online hindi workshop on "राजभाषा के प्रयोग में सूचना प्रौद्योगिकी की उपयोगिता" during 20-22 December, 2022 organized by ICAR IASRI, Pusa, New Delhi.

RS Pan attended 40th Group Meeting of AICRP (Vegetable Crops) through online mode on June 15-17, 2022.

RS Pan attended Meeting with Smt. Annapurna Devi, Union Minister of State for Education at State Guest House, Ranchi and briefed about the activities of the ICAR-RCER FSRCHPR, Ranchi on December 1, 2022.

RS Pan attended Seminar on "Integrated crop management with use of bio-agents for sustainable agriculture" organized by NGO Gramin Vikas Kendra, Qumruddinganj, Bihar Sharif, Nalanda, Bihar on November 24-25, 2022 and delivered lecture on "Cultivation practices of vegetable legumes" .

RS Pan attended Webinar on "Chhote evam Seemant Kishano ke liye Bhumi evam Jal Sanrakshan Taknike" organized by ICAR-Research Complex for Eastern Region, Patna on February 19, 2022.

Shankar Dayal participated in 26th Project Governing Council (PGC) meeting of Livestock Development Agency, Patna held on June 7, 2022 at Animal & Fisheries Department (AFRD), Patna.

SK NaiK attended Workshop on 'Best management practices for healthy soil and healthy crops' organized by Fertilizer Associations of India at Ramakrishna Mission Ashram, Morabadi, Ranchi on November 24, 2022.

SK Naik attended National Conference on 'Landscape management for preventing flood and reservoir sedimentation (LMPFRS-2022)' at Birsa Agricultural University, Ranchi (Jharkhand), Organized by ICAR-IISWC, Dehradun, September 22-24, 2022.

SK. Naik attended National Seminar on 'Fruit production in Eastern Tropical Region of India: Challenges and Opportunities' at Central Horticultural Experiment Station (ICAR-IIHR), Bhubaneswar during March 24-26, 2022.

SS Mali attended Brainstorming Meeting on Boosting Water Productivity and Storage Management under the One CGIAR initiative: NEXUS Gains organised by International Water Management Institute, New Delhi at Hotel Jaypee Siddharth, New Delhi on August 10, 2022.

SS Mali attended National Conference on 'Landscape management for preventing flood and reservoir sedimentation (LMPFRS-2022)' at Birsa Agricultural University, Ranchi (Jharkhand), Organized by ICAR-IISWC, Dehradun, September 22-24, 2022.

SS Mali attended National Seminar on 'Agrophysics for Smart Agriculture' organized by International Water Management Institute (IWMI) at NAS Complex, New Delhi during February 22-23, 2022.

SS Mali attended Webinar on 'Integration of landscape resource conservation with field scale climate resilient technologies for strengthening rural livelihoods in drylands' organized by ICAR-RCER, Patna on April 11, 2022.

Shivani particited in farmers-scientist sangoshthi on the importance of nutricereals at ICAR-RCER, Patna on April 28, 2022.

TK Koley attended 6th International symposium on "Minor fruits, medicinal & aromatic plants: health, wealth and sustainability" at Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar (WB) during 24-26 Nov., 2022.

TK Koley attended National Seminar on horticulture for sustainable development, nutritional & livelihood security at Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar (WB) on May 26-27, 2022

Ujjwal Kumar participated in 5th Annual Zonal Workshop of KVKs 2022 and co-chaired session at International Convention Centre, Rajgir during 6-8 August 2023.

Ujjwal Kumar participated in Inter deptt. working group (IDWG) meeting of centrally sponsored scheme on National mission on agriculture & technology under submission on Agril. extension (ATMA scheme) at Bikas Bhawan on 17 May, 2022.

Ujjwal Kumar participated in the OFT finalization Workshop of Agril Extension at ICAR-ATARI, Patna as an expert on 26th September, 2022.

Ved Prakash attended Five days International Workshop on "Progress in Adoption of Sustainable Agriculture in India: Barriers and Opportunities", Organized by National Institute of Technology Surathkal, Karnataka from April 25-29, 2022.

Ved Prakash attended IVth International Conference on "Innovative and Current Advances in Agriculture & Allied Sciences (ICAAAS 2022) held on 12-14 June 2022, Organized by the Society of scientific development in agriculture & technology, Meerut (U.P.)

Ved Prakash attended National conference on "Managing Weather and Climate Risk in Agriculture" organized by Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir (SKUAT-K), Srinagar in collaboration with the association of Agrometeorologists, Anand, Gujarat, from 24-26 March, 2022.

Ved Prakash attended National Webinar on "Quit India Movement to Food Secured India" on 08th August 2022 organized by MPUAT, Udaipur, Rajasthan.

Ved Prakash Attended Two days webinar on" Satellite Farming" organized by the center for agricultural market intelligence, NAHEP-CAAST, AAU, Anand in collaboration with Collage of Agriculture Information Technology, AAU, Anand, on 9-10th May 2022.

Ved Prakash attended Webinar on "Climate Change and Agriculture" organized by the Indian Meteorological Society, Ahmedabad Chapter, and Centre for Agricultural Market Intelligence, NAHEP-CAAST, AAU, Anand on 20 April, 2022.

Vivekanand Bharti attended one-day seminar on the occasion of World Wetland Day organized by Directorate of Fisheries, Patna, Bihar at BAMETI, Patna on 25 February, 2022.

Vivekanand Bharti participated in the webinar on 'Biospatial Modeling for Assessment and Prediction of Natural Resources' held at ICAR-RCER, Patna on 12 July, 2022.

Vivekanand Bharti was the committee member for the removal of Eichhornia and renovation of Kasaraiya Dhar Maun organized by the Directorate of Fisheries, Patna and visited Kasaraiya, Khagaria on 19 November, 2022.

Lectures delivered

A.K. Chaudhary, delivered a Lead lecture (online mode) on "Providing Nutritional Security to Rural Households in Eastern India through Genetic Enhancement of Vegetable Legumes" on June 14, 2022 in an International Conference on "Innovative and Current Advances in Agriculture and Allied Sciences" organized at Himachal Pradesh University, Shimla during June 12-14, 2022.

A.K. Chaudhary, delivered a lecture on "Sustainable Intensification through Pulses by Adopting Systems Approaches in the Rice-Fallow Cropping system of India" on March 9, 2022 in an ICAR Sponsored Short Course "Pulses as the Climate Smart Crops for Resource Conservation and Economic

Intensification/Diversification of Cropping Systems" organized at ICAR-IIPR, Kanpur during March 02-11, 2022.

A.K. Chaudhary, delivered a lecture on "Sustaining livestock through quality seed production in forage crops" on Jan. 25,2022 in a 21 days' Winter School on "Agri premiership Development for Doubling Farmers' Income through Recent Approaches in Livestock and Allied Sector" organized at Bihar Animal Science University, Patna during January 10-30, 2022.

Dhiraj Kumar Singh delivered a lecture on "Role of value chain analysis in market driven extension" during Training programme on"Approaches to link farmers with markets" at MANAGE, Hyderabad on 6th September, 2022 in online mode.

Dhiraj Kumar Singh delivered lecture on "AC &ABC: A practical model for agripreneurship development" in 21 days Winter School on "Agri-preneurship development for doubling farmers income through recent approaches in livestock and allied sector" during 10-30 January, 2022 at BASU, Patna.

Dhiraj Kumar Singh delivered lecture on "Contract Farming in India: Issues and Challenges" in 21 days Winter School on "Agri-preneurship development for doubling farmers income through recent approaches in livestock and allied sector" during 10-30 January, 2022 at BASU, Patna.

Dhiraj Kumar Singh delivered lecture on "Front Line Extension Programmes of ICAR: Krishi Vigyan Kendras (KVKs).TAR-IVLP, NATP, NAIP" during e-Training Course on ICAR JRF/SRF, NET/ ARS Exam. Organized by MPKV, Rahuri during 15 Feb. to 22 March, 2022.

Rachana Dubey, delivered an invited lecture on "Women in the field of Agricultural Sciences: The importance of choice" under theme "Women in S&T and S&T for Women" Showcasing efforts at state of Bihar-by-Bihar Council on Science and Technology (BCST) under Azadi Ka Amrit Mahotsav, State Science And Technology Programme (SSTP), Department of Science and Technology, Govt. of India on 8th March, 2022.

Santosh Kumar, delivered a lecture on "Improved seed production Techniques (Dhan ke unnat beej utpadan taknik)" during one day technical workshop on "Out scaling of Seed Production technologies for *Kharif* Crops Programme" on 4th June, 2022, at ICAR-MGIFRI, Motihari, East Champaran, Bihar

TK Koley delivered lecture on "Bioactive compounds in Underutilized Horticultural Crops andtheir potential health benefit" in 6th International symposium on "Minor fruits, medicinal & aromatic plants: health, wealth and sustainability" at Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar (WB) on 24-26th Nov., 2022

TK Koley delivered lecture on "Phenolics in Horticulture: food and non-food use for sustainable livelihood in National Seminar on horticulture for sustainable development, nutritional & livelihood security at Uttar Banga Krishi Viswavidyalaya, Pundibari, CoochBehar (WB)"on May 26-27, 2022.

Ujjwal Kumar delivered lecture on "Strategies for Technology Outscaling" during five days training programme on Effective extension skill and methods for better performance. organized by Extension Education Institute, Nilokheri and BASU, Patna on December 7, 2022.

Ujjwal Kumar delivered lecture on "Outscaling of climate resilient technology" during 5-days online MANAGE sponsored training programme on "Extension strategies for promotion of climate resilient Agriculture' BAU, Sabour on 24 August, 2022.

Ujjwal Kumar delivered lecture on "ICT based marketing information system" during 4-days online MANAGE sponsored training programme on Market driven extension approaches for enhancing farmers' income on 23 August, 2022.

Ujjwal Kumar delivered lecture on "Project Management techniques for newly recruited SMSs of KVKs at Dr RPCAU, Pusa on 28 April, 2022.

Webinar Organized

• Webinar on 'Evolution of Smart Agricultural Systems' on 20 May, 2022.

• Webinar on 'Integration of landscape resource conservation with field scale climate resilient technologies for strengthening rural livelihoods in drylands' on 11 April, 2022

• Webinar on 'Towards carbon neutral crop production in changing climate: Issues, opportunities and challenges' on 8 August, 2022

• Webinar on "Artifical Intelligence for Smart Agriculture" on 22 July, 2022 at ICAR RCER, Patna.

• Webinar on "Biospatial Modeling for Assessment and Prediction of Natural Resources" on 12 July, 2022 at ICAR RCER, Patna.

21 Events Organized

Training on "Market Driven Extension Approaches for Enhancing Farmers' Income"

A four-days online collaborative training programme on "Market driven extension approaches for enhancing farmer's income" was organized by the ICAR-RCER, Patna from August 23-26, 2022. The programme was sponsored by the National Institute of Agricultural Extension Management (MANAGE), Hyderabad. A total of 40 participants attended this online training, which included Subject Matter Specialists from KVKs, Scientists from SAUs and ICAR Institutes, agricultural entrepreneurs and post-graduate students from different states of India. During this training a total of 16 technical sessions were organized on different aspects of market driven extension systems and models related to Farmer Producer Organizations or Company, Market Intelligence, Entrepreneurship Development etc. and followed by discussions with resource persons. Emergence of FPO based agricultural marketing system, development of agripreneurs and focused approach on agri startups were major learnings points for the trainees.

Fig 21.1. Inauguration of online training at ICAR RCER

Webinar on "Bio-spatial Modeling for Assessment and Prediction of Natural Resources"

The institute organized a webinar on "Bio-spatial Modeling for Assessment and Prediction of Natural Resources" on July 12, 2022 in online mode as a part of "*Azadi ka Amrut Mahaotsav*". The aim of this webinar was to create awareness and update the knowledge of scientists, faculties, policy makers, students, and other stakeholders regarding types of modeling, practical application of various models in assessment of natural resources *viz.* water, soil, forest area, crop and animal resources etc, and their future prediction in agricultural and fisheries sectors. Around 120 participants attended the webinar from all parts of the country and got benefited from the lectures followed by discussions. The lead speaker of the webinar, Dr. J. Jayasankar, Principal Scientist, ICAR-CMFRI, Kochi delivered a very informative presentation on "Bio-spatial Modeling for Assessment and Prediction of Natural Resources". The trainees raised their concern about use of topographical, environmental and spatial data through linear and non-linear modeling for prediction of natural habitat/resources.
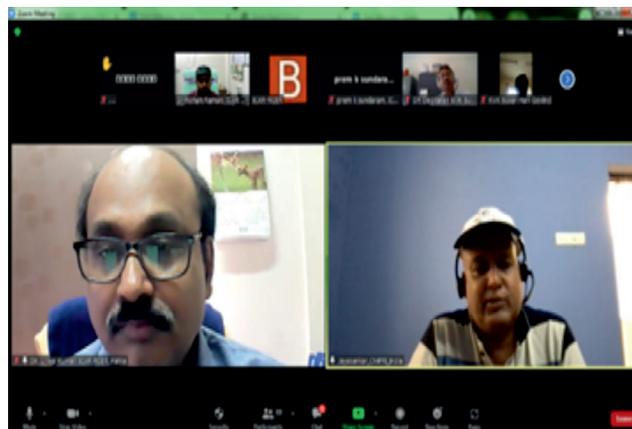
Fig 21.2. Online session of webinar on bio-spatial modeling

Workshop on Out-scaling of Rice Seed Production through FPO

A one-day technical workshop on out-scaling of Rice Seed Production, under the project "Development and validation of need-based technology delivery model through FPO for eastern region of India", funded by NASF, was organized by ICAR-RCER, Patna on June 4, 2022 at ICAR-IGIFRI, Motihari, Piprakoti, East Champaran. Issue of seed availability was discussed by the farmers. Germination problem of seed taken from private agencies were also raised as major issue. In the program subjects related to advanced seed production technology, process of Seed registration and seed marketing. Members from 11 FPOs from East Champaran and Muzaffarpur

districts participated in this workshop. Breeder seed of Paddy of Swarna Shreya, Swarna Shakti Dhan and Swarna Samridhhi varieties was also distributed among the FPOs members.

Fig 21.3. Interaction of Scientists with the participants

Field-day-cum Training Program at East-Champaran District of Bihar

Field day cum training on wheat cultivation was organized under the NASF funded project "Development and validation of Need based technology delivery model through FPO in eastern region of India" on March 14 -15, 2022. The programme was held at Dariyarpur Village and Diphi Village of East Champaran. Foundation seed of high yielding wheat variety HD-2967 was distributed during the *rabi* season to the members of Someshwarnath Kisan Utpadak Sangathan Sahkari Samiti Ltd. At Sangrampur and Champaran Farmers Producer Company Ltd. in Chiraiya block of East Champaran. During the field day programme, seed production technology of wheat was discussed and necessary advisories were given for summer moong cultivation in the project area. The Non FPO farmers expressed their need for training on seed processing and certification.

Fig. 21.4. Wheat FLD at Sangrampur Block, East Champaran

Farmers' Field School on Goat farming

Under the NASF project a Farmers Field School was organized in Sangrampur, East Chaparan. The overall idea behind this farmers' field school was the FPO farmers wanted to develop goat based FIG for scientific goat farming. The trainee raised issues of goat breeds, premature death of kids and vaccination related problems in that area. A total of 59 FPO farmers participated in this programme. The farmers were inspired to raise goats in a scientific way. They were also suggested about the housing, feeding as well as disease management of the goat.

Fig. 21.4. Goat Farmers Field School at Sangrampur

Hindi Pakhwada - 2022 Organized at ICAR-RCER, Patna

The "Hindi Pakhwada-2022" was held at the ICAR-RCER in Patna from September 14-29 September, 2022. Dr. Ashutosh Upadhyaya, Director (A), ICAR-RCER, Patna inaugurated the programme and said that Hindi is not just a language, but also a way for people from all over India to connect with each other. He also encouraged all scientists to publish their works related to agriculture using simple Hindi. During the programme, the heads of all divisions expressed their views about Hindi. There were many competitions were conducted including a workshop on "Noting and Drafting" during the Pakhwada. On the last day, the winners of the different Hindi events were given cash prizes. Similar programmes were also organized in regional centres located at Ranchi, Darbhanga, Buxar and Ramgarh.

Fig. 21.5. Celebration of Hindi Pakhwada at HQ and regional centres

Celebrated the Kisan Diwas on 23 December, 2022

The institute celebrated the Kisan Diwas at its campus on December 23rd 2022. In this program 136 farmers and farm women from 4 districts (Jehanabad, Arrah, Patna and Vaishali) participated. There was also an interaction between farmers and scientists, which was led by the director of the institute and accompanied by division heads and other scientists. The farmers were very keen to know about the recent technologies that can reduce input cost of production, natural farming practices and dealing with problems of wild animals

Fig. 21.6. Kisan diwas celebration at ICAR RCER

Farmers' Awareness-cum-Agricultural Input Distribution Programme

Under the Scheduled Caste Sub Plan (SCSP) organized farmer's awareness cum agricultural input distribution programme from 8-12 August, 2022 at ICAR-RCER, Patna campus. A total 240 farmers of Hinduni village of Phulwari Sharif block, Patna had participated. Farmers were sensitized regarding the adoption of small agriculture interventions in different agricultural practices so that they could get maximum output. Similar programme were also held in other villages of Patna, Jamui and Nawada districts of Bihar. During this programme, grain storage bins, tarpolines, spades, and pick axes as well as paddy seeds (Swarn Shreya, Swarna Samridhi, and CR Dhan 909) were distributed among SC farmers.

Fig. 21.7. Input distribution under SCSP

Celebration of World Soil Day

World soil day-cum-Kishan Gosthi was organized on 5th December, 2022 at Ranchi center of the institute wherein 60 farmers from different districts of Jharkhand participated. Dr Abhijit Kar, Director, ICAR-NISA was the chief guest of the function. The participating farmers were advised on improving soil health through balanced use of organic and inorganic fertilizers and manures. Awareness was created on standard methods for preparation of good quality vermicompost and farm yard manure. The process of soil sample collection was discussed with the farmers and the information on labs available for soil testing in Jharkhand was provided. The similar events were also organized at Head quarter and other centres.

Fig. 21.8. Word soil Day Celebration

Swachhata Pakhwada

A Swachhata Pakhwada was organised during December 16-31, 2022. On the inaugural day a 'Swachhata Pledge' was administered to all the staff members and other participants of the event. During this period, various activities like cleaning of public places, cleaning of community market places, trainings on vermicompost, management of wastewater and waste utilization through mushroom cultivation were organised. An awareness camp & rally of students was also arranged in Malti village, Ranchi.

Fig. 21.9. Celebration of Swachhata Pakhwada

Industry Meet Organized

Under the joint auspices of Agri Business Incubation Project and Institute Technology Management Unit a 'Industry Meet" was organized at FSRCHPR, Ranchi on September 22, 2022 in collaboration with ICAR-IIAB, Ranchi and ICAR- IINRG, Ranchi. In this programme, Dr. Arunav Pattnaik, Director, ICAR-IIAB, Ranchi, Dr. Shivendra Kumar, Member, RAC, ICAR-RCER, Patna, Dr. Kewal Krishna Sharma, Director, ICAR-IINRG, Ranchi, Mr. Gautam Kumar Singh, GM, NABARD Regional Office, Jharkhand, Dr. Subhash Singh, Director, SAMETI and a large number of farmers and entrepreneurs of Jharkhand participated. Through this meeting linkage was created between FPOs and some private companies for purchasing and processing of vegetables. The main emphasis of this meeting was establishment of research – industry- farmers linkage for efficient supply chain of fruits and vegetables in Jharkhand.

Fig. 21.10. Celebration of Swachhata Pakhwada

Mushroom Day Celebration

Mushroom Day was organized under AICRP- Mushroom on 23rd December, 2022. and a field day under Farmer FIRST Project, on "Production and Value Addition in Mushroom" on 04th February 2022 at FSRCHPR, Ranchi. A total of 120 farmers of Ranchi district participated in both the programme. Exposure and hands on training on production techniques of mushroom along with processing possibilities and value addition in mushroom were provided to the participating farmers.

Fig. 21.11. Mushroom Day Celebration

Visit of RAC Members at FSRCHPR

The Hon'ble members of the Research Advisory Committee of ICAR RCER, Patna visited the Ranchi center of the institute on 20th April, 2022. After visiting the institute farms, an interactive session with all the scientists and staff of the center was arranged wherein the achievements of center were presented. The members gave many valuable inputs and suggestions on various ongoing and on-farm trials to improve the productivity and management. The members of the RAC appreciated the work on inter-specific grafted tomato hybrids and stressed on the need for organising more training programs for farmers. RAC team also visited the farm of the progressive farmer under ABI Project stressed on upscaling of seed processing sector through entrepreneurship development.

Fig. 21.12. Visit of RAC Member at FSRCHPR

National Campaign on Efficient and Balanced use of Fertilizers

National level campaign on "Efficient and balanced use of fertilizers including nano-fertilizers" was organised at ICAR-RCER, FSRCHPR, Ranchi on 21st June, 2022. A total of 50 farmers of Jharkhand participated in the programme. Farmers were sensitized on balanced use of fertilizers for sustainable agriculture and were advised to adopt innovative technologies like 'nano-fertilizer' for effective and efficient use of nutrients. Farmers were also informed about organic and natural ways of farming through the use of Farm Yard Manure, Ghan Jivamrit and Jivamrit. The interlinking between water and nutrients and importance of micro-irrigation in fertilizer management was also explained to the participating farmers.

Fig. 21.13. National Campaign on Fertilizers use

Awareness-cum-Input distribution under SCSP programme

Under the SCSP programme a total of five awareness building-cum-input distribution programmes were organised in Kunda block of the Chatra district, Jharkhand. It benefitted more than 350 farmers. The programs mainly focused on promotion of short duration varieties to enable the cultivation of second crop after the harvest of paddy. Improved varieties of crops like tomato, garden pea, pole bean, capsicum and brinjal were provided to the farmers. Besides, other agricultural inputs like vermicompost, *Trichoderma*, micronutrients and seaweed extract were also distributed to the participating farmers. An animal vaccination camp was organized in which a total of 150 cattle from different villages were vaccinated.

Fig. 21.14. Awareness-cum-Input distribution under SCSP programme

Celebration of International Yoga day

International Yoga Day was celebrated on 21st June, 2022 at ICAR RCER, Patna and its regional centres. At Ranchi centre, a session on 'Health benefits of Yoga' was arranged wherein the yoga experts demonstrated various Asanas and Pranayam. All the staff members of the center participated in the event and performed various Yoga Asanas were performed by the staff members under the supervision of the yoga instructors.

Fig 21.15. Celebration of International Yoga day

National e-workshop & e-showcasing Organized at ICAR RCER, Patna

National e-workshop & e-showcasing on "Horticulture Start-up opportunity in Eastern India: Connecting youth to Agri-Start-up ecosystem" was organised during 24-26 February, 2022 at zoom platform under the Agri Business Incubation project. Chief Guest, Dr. A.K. Singh, DDG (Agril. Extension), ICAR, New Delhi in his address emphasized on improvement of skills of rural youth for starting their own agri-enterprise and promotion of start-ups in agriculture/horticultural sectors. He also mentioned very good scope of start-up in agricultural residue management and custom hiring services. Earlier, Dr. Ujjwal Kumar, Director (A), briefed about the importance of Horticultural start-up for employment generation for farming community. Possible entrepreneurship in fields like floriculture, nursery raising, banana processing, potato processing, moringa cultivation and marketing, floriculture etc were discussed. A total of 80 participants including the state department officials, young entrepreneurs, buyers, students, NGOs and progressive farmers have participated in the e-workshop.

22 Krishi Vigyan Kendra

ICAR RCER, Patna has two Krishi Vigyan Kendras (KVKs) under its administrative control, located at Buxar, Bihar and Ramgarh, Jharkhand. The KVK Buxar, Bihar was established during November, 2008 while KVK, Ramgarh, Jharkhand) came into existence during July, 2014. The mandate of these KVKs are technology assessment, refinement and demonstration of technologies for its application and Capacity Development of farmers

Fig. 22.2 Krishi Vigyan Kendra, Ramgarh

Presently, these Krishi Vigyan Kendras are involved in multifarious activities *viz.* laying out Cluster FLDs, On Farm Testing of technologies, organizing training programmes for farmers and other stakeholders, conducting research activities under NICRA, CRA Programme, Natural farming, creating awareness through exposure visits, kisan gosthies and seed production.

Krishi Vigyan Kendra, Buxar

Cluster Frontline Demonstration on Pulses and Oilseeds

KVK Buxar laid out cluster front line demonstration on pulses funded by NFSM and oilseeds funded by National Mission on Oilseed and Oil Palm for adoption of scientific management practices of pulses and oilseed crops among the farmers. The details are given in Table 22.1

Fig. 22.1 Krishi Vigyan Kendra, Buxar

Table 22.1 Cluster frontline demonstrations conducted at KVK, Buxar

S. No.	Crop	Technology	Area (ha)	No of beneficiaries			Village covered
				Male	Female	Total	
1.	Pigeonpea	IPA 203+seed treatment with FIR (Fungicide insecticide and Rhizobium culture)+foliar spray of micronutrient (Molybdenum and Boron) @1ml/lit water before flowering and management of Legume pod borer (*Maruca vitrata*) using Emamectin benzoate 10 g/15 lit water	20	51	4	55	Tilak Rai ka hata, badki Basouli, Dafa Dehri, Pawani,Rampur, Chousa, Dullahpur, Chakrahasi, Sonpa

S. No.	Crop	Technology	Area (ha)	No of beneficiaries			Village covered
				Male	Female	Total	
2.	Chickpea	Pusa 3043+seed treatment with FIR+foliar spray of micronutrient agromin @1ml/lit. water before flowering and management of gram pod borer (Helicoverpa armigera) by using bioinsecticide.	20	65	5	70	Kulhariya, kathrai, majhariya, dhenuadih, mahila, sonpa, chotki basouli, Kushrupa
3.	Lentil	IPL 316 + seed treatment with FIR + management of aphid (*Aphis craccivora*) by using bioinsecticide	20	62	4	66	Boksa, Ekderva, Mahdah, Pandeypatti, CHotki Basouli, Sondhila
4.	Mustard	RH 725/PM 31 + Soil application of sulphur 20 kg/ha and management of aphid (*Lipaphis erysimi*) by using bioinsecticide	50	104	10	114	Basav Khurd, Majhariya, Indoor, Jagdishpur, Mahila, Dafa Dehri, Sondhila, Khatiba, Badka Rajpur
5.	Green gram	IPM 2-3+seed treatment with FIR+foliar spray of micronutrient agromin@1ml/lit water before flowering and management of white fly by using Thaimathoxam 5g/15 lit water or Acetamiprid 15 g/15 lit water.	10	34	5	40	Mahdah, Sondhila, Diwan ka badka gavn, Jagdishpur, Badki Basouli, Hukha, Parmanpur

Fig. 22.3 Field view of Cluster Frontline Demonstrations in lentil and mustard

On Farm Trials

Buxar has conducted following major on farm trials at different locations which benefitted a total of 78 farmers. Results from some major OFTs are given below:

1. **Assessment of new molecules for the management Rice Stem Borer (***Scirpophaga incertulas***)**

KVK, Buxar conducted On Farm trial at farmers field for the assessment of new molecules for the management of Rice Stem Borer (Scirpophaga incertulas) in rice field. This pest causes 5 to 50 percent damage if not controlled timely. The result of the experiment showed that Chlorantraniliprole 0. 5% + Thiamethoxam 1.0 % GR @ 2.5 kg/acre were found most effective for the control of Rice stem Borer in rice. The cost of cultivation (Rs. 29500/ha) and increased yield was 15.67% (52.33 q/ha) over the conventional practice of Rice stem borer management in rice. Net return (Rs.73066/ha) and BC ratio (2.47) were

also higher in application of Chlorantraniliprole 0. 5% + Thiamethoxam 1.0 % GR

Fig. 22.4 Field view of On Farm testing for Rice management

2. Assessment of new combination of insecticide against *Helicoverpa armigera* in chickpea crop

Chickpea is an important pulse crop of Buxar and the *Helicoverpa armigera* is the notorious pest which causes both quantitative and qualitative loss to the chickpea crop. KVK, Buxar conducted On Farm Trial for the assessment of new combination of insecticide against Helicoverpa in chickpea crop in *rabi* 2020 & 2021. The finding showed that Emamectin benzoate 1.5 + Fipronil 3.5 SC @ 200 ml/acre were found most effective for the control of *Helicoverpa armigera* in chickpea crop. The cost of cultivation (Rs. 25180/ha) and increased yield was 24.41 % (14.93 q/ha) over the conventional practice of Helicoverpa management in chickpea. Net retrun (Rs.50963/ha) and BC ratio (2.02) was also higher in application of Emamectin benzoate 1.5 + Fipronil 3.5 SC @ 200 ml/acre.

Fig. 22.5 OFT for Assessment of insecticide against *Helicoverpa armigera*

3. Management of Fall Army Worm (*Spodoptera frugiperda*) in maize:

Fall army worm is native to the tropical and subtropical region of America. It has infested crops in over 50 countries across two continents in just over two years. Incidence of FAW reported in India during May, 2018. The larvae bore into the plant resulting central shoot of the young plant having various holes which check the growth. It causes losses up to 20 to 80 per cent. It is essential to prevent its infestation in early stages in the field. KVK Buxar, Bihar conducted on-firm trial in 6 replications on different maize field. Results of the trial indicated that Spraying of thiamethoxam 12.6 % +lambdacyhalothrin 9.5 % @0.5 ml/l were found most effective for the control of fall Army worm. The cost of cultivation (Rs. 37000/ha) and increased yield was 9.91 % (47.0 q/ha) Over the farmer practice. Net retrun (Rs. 50890.0/ha) and BC ratio (2.37) was also higher in application of thiamethoxam 12.6 % +lambdacyhalothrin 9.5 % @ 0.5 ml/l

Fig. 22.6 Management of Fall Army Worm (*Spodoptera frugiperda*) in maize:

On Farm Testing and Front Line Demonstrations Conducted

A total of 10 OFTs were conducted on improvement of nitrogen use efficiency in wheat, effect of weed management practices on crop growth, assessment the performance of quality protein maize, evaluation of biofortified wheat, assessment of new combination of insecticide against Helicoverpa in chickpea, rice stem borer (*Scirpophaga incertulas)*, false smut Ustilaginoidea virens (cooke) in rice, management of fall army worm (*Spodoptera frugiperda*) and zinc & biofertilizer application in maize. Several front line demonstrations were also conducted to popularize new varieties and technologies among farmers.

Table 22.2 On Farm Testing of different technologies and their coverage

S.No.	Topic	Villages covered	No. of beneficiaries		
			Male	Female	Total
1.	On Farm Testing on 10 selected technologies	Pandeypatti, Lalganj, Chousa, Mahdah, Rajapur, Dumraon, Dafa Dehri, Pawani, Nathpur, Balua, Ekderva, Ramobariya, Jagdishpur, Harikishunpur, Sondhila, Simri, Ramopatti, Dudhipatti	77	01	78

Table 22.3 Front line demonstrations conducted and their coverage

S. No.	Crop	Technology	Area (ha)	No of beneficiaries			Villages covered
				Male	Female	Total	
1.	Rice	Drought tolerant rice variety Rajendra Kasturi, Rajendra Shweta, Swarna Samridhi dhan	12	15	1	15	Kajariyan, Indoor, Pokhraha Dhansoi, Karahasi, Rampur, Kathar Khurd, Nidhua
2.	Rice	Short Duration Rice Variety CO 51, Swarna Unnat Dhan	11	22	1	23	Chotka Rajpur, Hukha, Sonpa, Nadav Kulhariya, Chotki Basouli
3.	Wheat	Zinc Bio fortified variety BHU 31 & BHU 25	5	6	7	13	Jagdishpur, Bakulaha, Jalilpur, Mahila, Sondhila, Boksa, Chousa, Pandeypatti
4.	Waste Decomposer	Decomposition of rice crop residue	32	40	-	40	Mangrav, Udhura, Chunni, Javahi Jagahi
5	Nutritional Garden	Nutritional Garden kit	150	90	60	150	Hukha, Sondhila, Gurudas Mathiya, Chakarahasi, Lalganj, Kukurah

Fig. 22.7 Field view of frontline demonstration on Rice Crop

Training Programmes Organised

KVK Buxar conducted different training programmes for practicing farmers for up-gradation of their knowledge and importance of use of different agro-techniques in the farming for harnessing higher yield with minimum cost. This year total 88 off campus training programme were conducted in the subject area of crop production, seed production, plant protection, soil science and nutrient management. In this training program total 2326 farmers participated, out of that 16.29 % (379) were women and 83.66 % (1946) were men. Details of trainings conducted given below:

Table 22.4 Off Campus Training Programme for Practicing Farmers

S. No.	Topic	No. of beneficiaries		
		Male	Female	Total
1.	Crop production	486	90	576
2.	Seed production	299	143	442
3.	Plant protection	554	47	604
4.	Soil nutrient management	607	99	704
	Total	**1946**	**379**	**2326**

Table 22.5 On campus Training programme for Practicing Farmers, Extension Functionaries and Rural Youth

Topic	No. of beneficiaries		
	Male	Female	Total
Training Program for Farmers			
Three trainings conducted on quality seed production techniques of Onion, Wheat and Insect and pest management in Mango and Guava orchard	74	01	75
Training program for Extension Functionaries			
Six trainings conducted on Importance of organic farming, Contingent crop planning, IPM, Production of Organic manure and Quality Seed Production techniques	147	15	162
Training program for Rural Youth			
Six trainings conducted on IFS, organic farming, mushroom production, Vermicomposting and quality seed production technique	125	24	149

Fig. 22.8 Glimpses of different training programmes

Demonstration under Scheduled Caste Sub Plan (SCSP)

Under the SCSP project, 2 training on wheat was conducted. In this training a total 24 farmers participated

Table 22.6 Trainings under SCSP project

S. No.	Crop	Technology	Area (ha)	No. of beneficiaries			Villages covered
				Male	Female	Total	
1.	Wheat	Early sowing of high yielding wheat variety DBW 187 and DBW 222	4	17	7	24	Rahthua, Bhadura, Nai Bajar Sonbarsa, Nathpur, Gagoura

Field day on Oilseed, Pulses and Cereal crops

KVK Buxar organized several field days on different pulses and oilseeds *viz.* pigeonpea, chickpea, lentil, mustard and rice demonstrated in farmer's field to popularize the demonstrated technology. Details of field day is given below :

Table 22.7 Field day organized by KVK, Buxar

Sl. No.	Field day organized	Date and place of activity	No of participants		
			Male	Female	Total
1.	Field Day on Wheat var DBW 187	25.03.2022 Mahdah	71	29	100
2.	Field Day on Timely sown chickpea variety Pusa 3043	28.03.2022 Jamuaon	80	20	100
3.	Field day on Rapeseed & Mustard	26.03.2022 Pawani	56	30	85
4.	Field day on Early sown wheat	27.03.2022 Harikishunpur	60	36	96
5.	Field day on ZT sown wheat	28.03.2022 Lalganj/Mahdah	65	20	85
6.	Field day on Direct Seeded Rice	07.06.2022 Lalganj	10	30	40
7.	Field day on Drought tolerant rice variety Swarna Samridhi and Swarna Unnat Dhan	05.11.2022, Chotki Basouli	52	03	55

Fig. 22.9. Glimpse of Field Days organized

Seed production under Pulses Seed Hub Programme

KVK, Buxar produced the quality seed of chickpea, lentil and pigeonpea crop under seed hub programme in participatory mode. Details of seed production of different pulses is given below:

Table 22.8 Seed production of pulses under Pulse seed hub programme

S. No	Crop/Variety	Production (q)	Type of Seed	No of beneficiaries		
				Male	Female	Total
1.	Pigeonpea/IPA 203	70	FS	6	0	6
2.	Chickpea/RVG202	7.2	CS	1	0	1
3.	Chickpea/RVG 202	4.4	TLS	1	0	1
4.	Chickpea/Pusa 3043	90	FS	16	3	19
5.	Lentil/IPL316	108.5	CS	7	4	11
6.	Lentil/IPL220	1.5	CS	1	0	1

Note: FS: foundation seed; CS: certified seed, TLS: Truthfully labelled seed

Activities under NICRA Project at KVK, Buxar:

A total of 164 demonstrations on moisture conservation, soil health, crop production, livestock and fisheries were carried out at farmers' field under NICRA Project.

Table 22.9 Different activities under NICRA Project

Sl. No.	Activities	No. of demonstration/ program	Area under practice in the village (ha)
1.	In-situ moisture conservation measures	164	217.2
2.	Ex-situ moisture conservation measures (Water harvesting and efficient use/critical/supplemental irrigation)	122	304.5
3.	Soil health improvement interventions	77	114
4.	Crop Production Interventions	133	71
5.	Livestock & Fisheries related interventions	446	
6.	Capacity Building programmes organized (HRD)	5	150
7.	Extension Activities	10	380

Table 22.10 Adoption of successful interventions in the NICRA village and adjoining villages

Successful interventions	Crop	Variety	Area of Adoption (ha)
Natural Resource Management			
Raising bund height around rice field	Paddy	BPT5204	135
Rain water Harvesting structure	-	-	03/ 2.15
Micro irrigation system drip/sprinkler	Pulses	-	45
Trenching cum Bunding	Paddy	MTU7029	144
Crop Management			
Drought tolerant paddy var. Swarna Shreya	Paddy	Swarna Shreya	55
Flood tolerant Paddy Variety: Swarna Sub 1	Paddy	Swarna Sub 1	25
ZT in wheat	Wheat	HD2967	145
ZT in Lentil	Lentil	HUL-57	25
Livestock Management			
Fodder production of Hybrid Napier	Hybrid Napier	CO-3	-

Other Important Activities

Sustainable Back Yard poultry Vanraja production in improved shelter

In summer, temperature of Buxar rises up to 46 °C, causing high mortality rate of poultry (67%), resulting in low production. To combat this, 12 poultry unit of improved breed Vanraja were established along with improved shelter at village Bhitihara, Jamuaon & Kukurha. Vanaraja chicken is one of the coloured bird reared for both eggs and meat. The product from native fowls is widely preferred because of their pigmentation, taste, leanness, flavour and suitability in adverse temperature. The average body weight of 1.5 kg at 14 weeks of age was viable in rural condition and 160 eggs were produced after 165 days.

Fig. 22.10 View of back yard poultry

Integration of Summer Green gram Var. Virat (IPM 205-7) in Rice- Wheat Cropping System

Summer Green Gram Var. Virat (IPM 205-7) was demonstrated in 10 ha area of 33 farmers field in Rice-Wheat cropping system at NICRA Project adopted village: Kukurha, Jamuoan and Bhitihara for enhancing cropping intensity, crop intensification as well as improving soil fertility.

Fig. 22.11 Field view of summer green gram field

Animal Health Camp-cum-Farmer-Scientist Interaction

Two days animal health camp-cum-Farmer-Scientist Interaction was organized during 24-25 February, 2022 at NICRA Project adopted villages Bhitihara & Jamuaon for management of livestock related problems like ecto-parasites, anestrous, low feeding, repeat breeding, mastitis and vaccination. Scientists of ICAR-RCER Patna interacted with the farmers and provided basic information about veterinary health, nutrition, breeding, feeding, management, control and prevention of important livestock diseases. Prescribed veterinary medicines provided free of cost to the 99 animal growers for 350 large and small ruminants.

Fig 22.12 View of animal health camp

Demonstration of Pearl millet as Contingent Crop under Drought S ituation

Due to low precipitation in July and August 2022, farmers suffered and could not transplant rice. To combat the problem, short duration and less water requirement crop Pearl millet (Hybrid LG 1281) was demonstrated in total 15 ha area where 40 Farmers of NICRA Project adopted Villages Kukurha and Bhitihra participated. The average grain yield of demonstration field was 34.5 q/ha with BC ratio 1.9.

Fig. 22.13 Field view of Pearl millet field

Demonstration of Rice Var. Sabour Heera under Irrigated Farming System Typology

Under irrigated farming system typology of Village, Bhitihara and Jamuoan under NICRA project, technology demonstration of high yielding Rice Var. Sabour Hera was conducted in low land irrigated area 05 ha of 06 farmers. The average Demonstration grain yield was 63.5 q/ha followed by farmers' practice (BPT 5204) 54.3 q/ha.

Demonstration of Flood Tolerant Rice Var. Swarna sub-1 under Flood without Animal Farming System Typology

Under flood, without animal farming system typology of Village, Bhitihara under NICRA project, technology demonstration of flood tolerant Rice Var. Swarna Sub-1 was conducted in flooded 10 ha area of 22 farmers. This year, flood came in the second week of September month due to back push tributary of River Ganga and stagnate water up to 12 days in crop field. Resulted average grain yield was found 62.4 q/ha followed by farmer practice (MTU 7029) 43 q/ha and increased yield upto 45.1% more than farmer practice.

Fig 22.14 Field view of Swarna Sub-1

Foliar Application of Nano-Urea in Wheat through Ultra Aerial Vehicle, Drone

To create mass awareness about foliar application of Nano-Urea and other water soluble fertilizer through drone an awareness programme was organized on 26th Feb, 2022 at Bhitihara village. In this programme, 40 farmers and line department officer, extension workers participated. Resulted grain yield of demo field was found 41.5 q/ha followed by farmer practice 37.2 q/ha and increased yield of 11.5 % more than farmer practice was observed.

Fig 22.15 Nano urea spray by Drone

Zonal Workshop-cum-Field Visit under NICRA

One day Zonal workshop cum field visit was organized on 28 April, 2022 at Kukurha village, Buxar. Dr JVNS Prasad, National Coordinator, NICRA explained the change/new adoption of methodologies for selection of new NICRA KVKs. He said that components related to climate resilient agriculture which were not covered earlier must be taken in account in coming action plan. Contingency plan must be revised regular considering basic climatic factors like temperature, humidity, rainfall etc. In this workshop, all PIs of the project of 14 KVKs (12 KVKs from Bihar and 02 KVKs from Jharkhand) participated.

Fig 22.16 Workshop organized under NICRA

Table 22.11 On Farm Trial under KVK-CSISA Project

Topic	No. of beneficiaries	Location
Weed management in direct seeded rice	10	Indapur, Rajapur, Mahdah, Chotki Basouli, Gerua bandh
Effect of rice crop establishment methods on the growth and yield of wheat	5	Konawali, Mango dehri, Geruabandha
Reduction in seed rate of rice using rice nursery enterprises	10	Bocsa, Mahdah, Geruabandha, Diwan ka Badkagaon
Performance of timely sown and late sown wheat varieties under different sowing schedules across ecologies	10	Rajapur, Konawali, Basahi, Bocsa, Chotki Basouli, Mahdah, Mango dehri, Chougai, Gerua bandh
Assessing the role of additional irrigation during terminal heat stress period during grain filling stage to beat the heat stress and its effect on wheat productivity	10	Rajapur, Konawali, Basahi, Bocsa, Chotki Basouli, Mahdah, Mango dehri, Chougai, Gerua bandh

Demonstration and Awareness Programs on Natural Farming

Demonstration of natural farming production technologies i.e. *Bijamrit, Ghanjivamrit, Jivamrit* and natural plant protection measures in gram, wheat, vegetables and orchard were conducted on an area of 3.2 ha covering 8 farmers. Many awareness camps were also organized to popularize natural farming.

Table 22.12 Awareness Programmes on Natural Farming

S. No.	Topic	Date and Place	No of beneficiaries
1	Natural Farming	28.11.2022, Lalganj	25
2	Natural Farming: Principle and Practices	29.11.2022 Hukha	40
3	Prakritik Kheti Dwara Fasal Utpadan	14.12.2022 Gurudas Mathiya	40
4	Prakritik Kheti Dwara Bagwani	20.12.2022 Pandeypatti	50

Fig. 22.17 Natural farming demonstrations under different crops

Seed Production at KVK Farm, Buxar

KVK, Buxar is also involved in production of the foundation, certified and TL seed of paddy, wheat, field pea and pigeon pea. Details of seed production is given in Table 22.13.

Table 22.13 Details of seed production at KVK Farm, Buxar

Crop	Variety	Quantity of seed (q)	Types of Seed	Area (ha)
Paddy	BPT 5204	55	FS	1.8
	MTU 7029	30	FS	1.3
	Rajendra Shweta	12.5	FS	0.4
	CO 51	5	TL	0.4
Wheat	DBW 187	6	CS	0.2
	DBW 222	8.4	FS	0.25
Pigeon pea	IPA 203	1.5	TL	0.2
Lentil	IPL 316	2.40	CS	0.3
	IPL 220	2.0	FS	0.3
Chickpea	RVG 202	4.40	TL	0.5
	Pusa 3043	15.0	FS	1.6
Mustard	Pusa Shubhra	0.40	TL	0.1
	PM 31	0.5	TL	0.1
Grand Total		**143.10**		

Major Events Organized by KVK, Buxar

Several technology awareness and other programmes as suggested by ICAR have been organized by the centre during 2022. Details of these events are given in Table 22.14.

Table 22.14 Awareness Programme/Kisan Gosthi Organised

S. No.	Topic	Date	No of beneficiaries		
			Male	Female	Total
1	World Pulse Day	10.02.2022	25	55	80
2	Annadata Devo Bhav: Awareness Programme on Natural Farming and Organic Farming	23.04.2022	70	35	105
3	Kisan Bhagidari Prathmikta Hamari	26.04.2022	195	116	311
4	Garib Kalyan Sammelan	31.05.2022	45	10	55
5	Judicious and Balanced Use of Fertilizer including Nano Urea	21.06.2022	60	23	83
7	Application of Nano Urea by using Drone	09.09.2022	125	0	125
8	Poshan Maha Abhiyan and tree plantation	17.09.2022	70	05	75
9	PM Kisan Samman Karykram	17.10.2022	180	135	315

Kisan Bhagidari Prathmikta Hamari

KVK Buxar organized "Kisan Bhagidari Prahmikta Hamari" program on 26 April, 2022 which was inaugurated by Hon'ble Minister of Agriculture & Farmer Welfare Shri Narendra Singh Tomar Jee virtually. He addressed the farmers and requested for adoption of new techniques and varieties in agriculture. KVK, Buxar also organized a Kisan Gosthi inaugurated by MLA, Buxar, Shri Sanjay Kumar Tiwari. A total 311 farmers and farm women participated in the programme.

Interaction of Hon'ble Union Agriculture Minister with DFI farmers

A total of 224 farmers and farmwomen participated in the online programme "Interaction of Hon'ble Union Agriculture Minister with DFI (Doubling Farmers' income) farmers" on the occasion of 94th ICAR Foundation day on 16th July, 2022. Programme was inaugurated by Hon'ble Minister of Agriculture & Farmer Welfare Shri Narendra Singh Tomar Ji. He interacted with the DFI farmers about their innovative ideas and adoption of modern techniques in agriculture. MLA Buxar, Bihar Shri Sanjay Kumar Tiwari also participated in the event and addressed the gathering.

Fig. 22.18 A view of Kisan Gosthi Program

Application of Nano Urea by using Drone technology

KVK Buxar organized programme on "Application of Nano Urea by using Drone Technology" on 9th September, 2022. Minister of Agriculture, Govt. of Bihar, Shri Sudhakar Singh graced the occasion as chief guest and inaugurated the program. He saw the application of Drone in agriculture field. He also discussed with the farmers for application of drone in agriculture and different activities of KVK, Buxar. A total 125 farmers participated in the program.

Fig. 22.19 Application of drone in field

Scientific Advisory Committee Meeting

The 12th Scientific Advisory Committee meeting of KVK, Buxar was held on 2nd December, 2022 under the Chairmanship of the Nodal Officer, Dr. Ujjwal Kumar, KVK and Head DSEE, ICAR-RCER Patna. The meeting was also attended by Dr Amrendra Kumar, Principal Scienitist, ICAR-ATARI, Patna, Sri Manoj Kumar, DAO, Buxar, Progressive farmers and other members. Reflection of SC/ST beneficiaries in report, consideration of prevalent local crop varieties as check during FLDs and OFTs, organization of training on contingent crop planning during each season and sharing of quarterly training calendar in advance to line departments, FPOs, etc were major recommendations of the SAC meeting.

Fig. 22.20 SAC meeting at KVK, Buxar

Krishi Vigyan Kendra, Ramgarh

Cluster Front Line Demonstration (CFLD) on Pulses and Oilseed Crops

Cluster front line demonstrations (CFLDs) on Black gram in 20 ha and Sesame in 30.0 ha, was conducted on fellow land area during Kharif. CFLD on Mustard in 30.0 ha, Lentil on 20.0 ha and Chick pea in 20 ha area was also conducted under rice fellow area in *rabi* season under NFSM and NMOOP by Ministry of Agriculture & Farmers Welfare, Govt. of India. All these demonstrations were laid in cluster approach emphasizing on rice fallow and newly released varieties. Farmers were advised to adopt the good agronomic practices, balanced fertilization and IPM Practice to reduce the cost of cultivation to get better economic returns. KVK also demonstrated the cafeteria of each crop at their farm to popularize the varieties and production technology of pulse and oilseeds among the farmers.

Table 22.15 Cluster front line demonstration conducted by KVK, Ramgarh

S. N.	Crop &Variety/ Technology demonstrated	No. of Demo	Area (ha)
1	Black Gram: Variety- IPU 2-43 Rhizobium culture seed treatment +line sowing, Foliar spray of NPK 19:19:19 and use of neem oil	50	20
2	Sesame:Variety- Shekhar, Seed treatment with *Trichoderma viridi*+ Line sowing+ IPM	75	30
3	Lentil: Variety- HUL-57 @ 25kg/ha, Rhizobium culture seed treatment +line sowing, Foliar spray of NPK 19:19:19 and use of neem oil	50	20
4	Chick Pea: Variety-KPG-59, Rhizobium culture seed treatment +line sowing, Foliar spray of NPK 19:19:19 and use of neem oil	50	20
5	Mustard: Variety-Pusa Mustard-30 @5kg/ha,Line sowing, (30X10cm) application of sulphur and foliar spray of NPK 19:19:19: @ 2.5kg/ha Spray of neem oil at the time of flowering @ 5ml/liter water +Sulphur @2 gm/lt water	75	30

On Farm Trials and FLDs conducted by KVK, Ramgarh

KVK, Ramgarh conducted on farm trials on Integrated Pest Management and Integrated Nutrient Management in 3.5 ha area in which 30 farmers participated. Also, Effect of micronutrients on yield and quality of mango cv. Amrapali was evaluated on 72 plants on 6 farmers orchard under INM trials. The KVK has also conducted FLDs on drought resistance rice varieties and high yielding disease resistant vegetable varieties on an area of 25.5 ha area in which 116 farmers got benefitted. Along with this, oyster mushroom demonstration was also conducted for 20 farmers in Ramgarh.

Table 22.16 On-farm Trials conducted by KVK, Ramgarh

Sl. No.	Thematic Area	Technology Intervention	Technology Options	No. of farmer	Area (ha)
1.	IPM	Management of Fall Armyworm, *Spodoptera frugiperda* in maize	Farmers' practice (application of Carbofuran) **T. O. I**- i. Application of sand (After whorl formation and at 5% damage symptoms appearance) ii. Spraying of Emamectin benzoate 5SG @ 0.4g/l of water at 5 days of application of sand iii. Spraying of Thaimethoxam 12.6% + Lambda-cyhalothrin 9.5% @ 0.5 ml/l at 15 days of after 1st spray **T.O.II** - i. Application of soil (After whorl formation and at 5% damage symptoms appearance) ii. Spraying of Fipronil 5SC @ 1ml/l of water at 5 days of application of soil iii. Spraying of Spinosad @ 0.2 ml/l at 15 days after 1st spray.	10	1.0
2.	IPM	Assessment of module for thrips and sucking pest management in chilli crops	TO-I: Rotational strategy of insecticides : Spray of Sporomesifen 22.9 SC @ 0.6 ml/L followed by Imidacloprid 17.8SC @ 0.5ml/L and Fenpropathrin 30 EC @ 0.6ml/L and Fipronil 80WDG @ 0.25 GM/l and Emmamectin benzoate 5SG @ 0.5ml/L. TO-II: Integrated pest management strategy : Seedling root dip in Imidacloprid @2ml/l for sucking pests and first foliar spray of NSKE 4% 30 DAT and second foliar spray of imidacloprid 17.8 SL @ 0.5ml/l 40 DAT and third foliar spray of Fipronil 80WDG @0.25 gm/L 50 DAT and fourth foliar spray of Emmamectin benzoate 25 WG @0.4 g/l 60 DAT)	10	1.5

Sl. No.	Thematic Area	Technology Intervention	Technology Options	No. of farmer	Area (ha)
3.	INM	Integrated nutrient management of sweet potato (var. Shree Bhadra)	TO1: FYM @ 100 q/ha+ NPK-20:30:07 kg/ha TO2: FYM @ 150 q/ha + RDF (NPKB): 60:60:60:01 kg/ha + Lime @ 3 q/ha TO3: STCR based	10	01
4.	INM	Effect of micronutrients on yield and quality of mango cv. Amrapali	TO1: Farmers practices- FYM @ 10 kg / tree + Urea 0.5 kg/ tree after harvest. TO2: RDF (0.5:0.5:0.3 NPK Kg/ tree + 100 g zinc sulphate + 50 g boric acid + 01 kg lime (soil application) in basin after harvest) + 0.2% ZnSO4 + 0.1% boric acid - 2 foliar spray 1) before flowering and 2) at marble stage. TO3: RDF(0.5:0.5:0.3 NPK Kg/ tree + 100 g zinc sulphate + 50 g copper sulphate + 50 g boric acid + 01 kg lime (soil application) in basin after harvest) + 0.2% $ZnSO_4$ + 0.1% $CuSO_4$ + 0.1 % boric acid- 2 foliar spray 1) before flowering and 2) at marble stage.	06	72 Plants

Table 22.17 Front Line Demonstrations conducted by KVK, Ramgarh

Sl. No.	Crop & Variety/ Technology demonstrated	No. of Farmers	Area (ha)
1	Paddy, Variety –Swarna Shakti Dhan for resistance	20	8.0
2	Paddy, Variety –Swarna Shreya for Drought resistance	20	8.0
3	Paddy, Variety –Swarna Samridhi Dhan, Drought resistance	04	2.0
4	Paddy, Variety –Swarna Sukha Drought resistance	02	0.5
5	Oyster mushroom	20	20 Unit
6	Onion var. Arka Niketan, Popularization of var. for good shelf life	10	1.0
7	Bottle gourd var. Swarna Sneha (Popularization of downey mildew and powdery mildew tolerant variety)	10	1
8	Brinjal var. Swarna Shyamali (Wilt resistant varietal popularization)	10	1
9	Bitter gourd var.- Swarna Yamini (Popularization of high yielding variety)	10	1
10	Sponge gourd var- Swarna Sawani (Popularization of early flowering and fruiting satputiya)	10	1
11	Tomato var. Swarna Sampada (Popularization of bacterial wilt and early blight tolerant variety)	10	1
12	Cow pea var. Swarna Mukut (Popularization of bush type with good yield)	10	1

Training Programmes for Farmers/Youth and Extension Functionaries

A total of 43 trainings were organized by KVK, Ramgarh on Crop production, Plant protection, Rrice fallow management, Conservation agriculture, strengthening of FPOs, nursery raising, Poly house, drip based vegetable cultivation etc in which 1183 farmers were trained.

Table 22.18 Training organized for Practicing Farmers and Farm Women/Rural Youth/ Extension Functionaries by KVK Ramgarh

Sl. No.	Thematic Area	Total Training	Total farmers
1	Crop production, Plant protection, IPM and ICM	10	269
2	Rice fallow management, Conservation agriculture, Coal mining area rehabilitation	10	298
3	Strengthening of farmers group and FPOs	10	314
4	Nursery management, Polyhouse, drip based vegetables cultivation and seedling production	13	302

Activities Conducted under SCSP and TSP

Different trainings, exposure visits, awareness camps and animal health camps were organized under SCSP and TSP for the development of peoples of weaker sections of the society such as scheduled caste and scheduled tribe. These programmes benefitted a total of 796 SC farmers and 1324 ST farmers.

Table 22.19 Activity under Scheduled Caste Sub Plan (SCSP)

Sl. No.	Thematic area of activities	Place	No of activities	No. of participants
1	Cultivation of vegetable	Indrabad	3	96
2	Climate resilient technology and crops	Indrabad	5	89
3	Training on cultivation of summer vegetable	Govindpur	4	88
4	Vegetable cultivation and management	Udlu	5	134
5	Established as Model Village Indrabad, Mandu under SCSP scheme	Indrabad	1	35
6	Exposure visit	BAU, Ranchi	2	60
7	Distribution of mango Plants and management of nursery	Indrabad	2	29
8	Animal Health Camp	Indrabad	2	87
9	Advisory/Diognostic visit	Indrabad, Udlu and Govindpur	13	178

Table 22.20 Activity under Tribal Sub Plan (TSP)

Sl. No.	Title	Place	Total activity	Total participants
1	Advisory/Diagnostic visit	Chhotkachumba,Jamundaha, Sondiha, Keribanda, Pannatand, Jobla, Fusri & lodhma	33	269
2	Training on Vegetable, fruits cultivation and back yard poultry	Chhotkachumba, Jamundaha, Sondiha, Keribanda, Pannatand, Jobla, Fusri & lodhma	18	467
3	Distribution of plastic mulch, nursery media, Input, seeds	KVK, Ramgarh	6	325
4	Kisan gosthi/ Field Day	Chhotkachumba, Jamundaha, Sondiha, Keribanda, Pannatand, Jobla, Fusri	7	263

Activity/Training under DFI Village

Two villages namely Budhakhap and Takha, from Mandu

block, Ramgarh was selected for implementing activities under doubling farmers' income initiative. Following activities were undertaken:

Table 22.21 Activities conducted under DFI initiative

Name of activities	No. of activities	Total no. of beneficiaries	No. of activities	Total no. of beneficiaries
Training	3	90	3	90
FLD	2	40	2	21
OFT	1	10	1	10
CFLD	2	35	2	21
Field day	1	65	-	-
Advisory & Diagnostic visit	12	95	18	195

Skill Development and Vocational Training

A total of eight skill development trainings were organized by KVK, Ramgarh in which 426 farmers and farm women participated. These training were organized on important employment oriented enterprises *viz.* goatary, dairy, poultry, duckery, hatchery etc

Table 22.22 List of skill development trainings organized by KVK, Ramgarh

Sl. No.	Topics of Training	Date	Duration	Location	No. of trainees		
					M	F	Total
1.	Management of goatary unit	03-05 Feb, 2022	3 days	Indrabad	16	32	48
2.	Management of dairy unit	04-06 Feb, 2022.	3 days	KVK,	2	45	47
3.	Management of goatary, poultry and duckery unit	10-12 Feb, 2022	3 days	KVK,	2	45	47
4.	Management of goatary unit	14-16 Feb, 2022	3 days	Indrabad	8	40	48
5.	Backyard poultry and hatchery management	07- 09 Feb, 2022	3 days	Jamundah	14	26	40
6.	Feeding management of Livestock and Poultry	10-12 March, 2022	3 days	Belsagra	53	38	91
7	Use , repair and maintenance of power tiller	01-03 Aug, 2022	3 Days	KVK	20	20	40
8	Suitable agricultural equipment and machinery for improving land and water productivity	04-06 Aug, 2022	3 Days	KVK	45	20	65

Table 22.23 Sponsored/Vocational Training Programme Organized by KVKs

Sl. No.	Topics of Training	Date	No of Course	No of Participants			Sponsoring Agency
				M	F	Total	
1.	Gardener	02-26 March, 2022	1	4	4	08	DHO, Ramgarh
2.	15 Days certificate Course on Integrated nutrient management	10-24 Feb, 2022	1	36	4	40	Self-Finance
3.	15 Days certificate course on INM	11–25 July 2022	1	37	3	40	Self-Finance

Exposure-cum-Practical Visits /Kisan Gosthi of practicing farmers and rural youth

A total of 13 Exposure cum practical visits /Kisan Gosthis

were organized for 2017 rural youth on various aspects of farming

Table 22.24 Exposure cum practical visits /Kisan Gosthi organized at KVK Ramgarh

Sl. No.	Program/Organizer	Date	Location	No. of Participants
1.	Integrated Nutrient Management	22/02/2022 & 23/07/2022	FSRCHPR Plandu, Ranchi	45
2.	Gardener	24/03/2022	FSRCHPR, Plandu,Ranchi	10
3.	Srijan Foundation Kujju, Ramgarh	18/11/2022	KVK, Ramgarh	45
4.	DAV Public School Sandi, Ramgarh	30/11/2022	KVK, Ramgarh	87
5.	DAV Public School Topa, Ramgarh	02/12/2022	KVK, Ramgarh	35
	Kisan Gosthi/Workshop/Group Meeting			
1.	Kisan Gosthi cum PM prgrogrmme of Kisan Bhagidari Prathmikta Hamari	26/04/2022	KVK, Ramgarh	357
2.	Farmers scientist interaction on agricultural technology	27/05/2022	KVK, Ramgarh	43
3.	Kisan Gosthi cum farmers awareness programme	14/06/2022	Gola Block, Ramgarh	96
4.	Workshop on Digital Marketing	20/08/2022	KVK, Ramgarh	
5.	Nutritional campaign and tree plantation cum Kisan Gosthi	17/09/2022	KVK, Ramgarh	103
6.	Kisan Gosthi cum Live telecast of PM Kisan samman nidhi programme	31/05/2022	KVK, Ramgarh	972
7.	Kisan Gosthi cum Live telecast of PM Kisan Samman Nidhi programme	17/10/2022	Village- Badgao, Mandu	197
8.	Kisan Goshti on *rabi* season crop planning and management	23/12/2022	Village Indrabad, Mandu	27

Field Days Conducted by KVK, Ramgarh

Five field days were conducted on demonstration of Mustard variety PM-30 and rice variety Swarna Shreya, Shakti Dhan & IR 64 (Drt-1) at farmers' field in which total 162 farmers participated.

Table 22.25 Field Days conducted by KVK, Ramgarh

S.N.	Program/ Organizer	Date	Village	Total Participants
1	Field day on demonstration of Mustard variety PM-30 at farmers field	14/03/2022	Ukrid, Dulmi	42
2	Field day on enhancing in agricultural productivity by precision farming	04/08/2022	Badkachumba, Mandu	60
3	Field day on demonstration of paddy variety Swarna Shreya, Shakti Dhan and IR 64 (Drt-1) at farmers field	09/11/2022, 10/11/2022 23/11/2022	Badkachumba, Bumari, Mandu and Chhotkachumb	60

Events Organized at KVK, Ramgarh

KVK Ramgarh has celebrated several important events *viz*. International Women's Day, world water day, International Yoga Day, Constitution day, World Soil day, vigilance awareness week etc.

Table 22.26 Events organized at KVK, Ramgarh

S.N.	Title	Date	No. of participants			
			SC	ST	Other	Total
1	Celebration of International Women's Day	08.03.2022	22	10	23	55
2	Celebration of world water day	22.03.2022	4	3	12	19
3	Celebration of International Yoga Day	21.06.2022	2	1	5	8
4	Parthenium awareness	22.08.2022	7	5	10	22
5	Celebration of Vigilance awareness week	27.10.2022	2	2	6	10
6	Jal Shakti Abhiyan	16.11.2022	8	5	17	30
7	Celebration of Constitution day	26.11.2022	0	0	6	6
8	Celebration of World Soil day	05.12.2022	17	10	12	39
9	Celebration of Farmers day	23.12.2022	17	8	12	37

Fig. 22.21 Field Day organized by KVK, Ramgarh

Workshop on up scaling of Natural Farming

A district level workshop on "Up scaling of Natural Farming" in Ramgarh district was organized on December 24, 2022 for creating awareness among the farmers through FPOs at District Headquarter. This program was chaired by Ms. Madhvi Mishra, IAS, Development Commissioner of Ramgarh. In this meeting issues like creating awareness among farmers about Natural Farming, cluster based production and ease of marketing of naturally produced crops and certification of these produce were emphasised. All the line department of agriculture and allied sectors were present. A total of 58 farmers participated including 21 FPO representatives.

Fig. 22.22 Workshop on up scaling of Natural Farming

15 Days Integrated Nutrient Management (INM) Training

A 15-days NABARD Sponsored training on "Integrated Nutrient Management" was organized from 10-24 Feb, 2022 at Krishi Vigyan Kendra, Ramgarh. This program was inaugurated virtually by Smt. Nisha Orawn, Director Agriculture, Govt. of Jharkhand. She emphasized to involve the FPOs in Govt. scheme for large scale adoption of technology. In this training, 47 Board of Director (BODs) of 47 Farmers' Producers Organization (FPOs) from 14 district of Jharkhand participated. Valedictory remark was given virtually by Dr. S.K. Chaudhari, DDG (NRM), ICAR, New Delhi. He emphasized on the need of technological approach in farming and collective effort through FPOs in income generation through agriculture. On this occasion, special guest was Sri Jay Nigam, DGM, NABARD, Ranchi emphasized the importance of capacity building by KVKs for FPOs sustainability.

Fig. 22.23 Snaps of Online training on Integrated Nutrient Management Training

World Soil Day celebration

The World Soil Day was celebrated on December 5, 2022 at KVK, Ramgarh. Altogether, 72 farmers from different villages of Ramgarh district attended the programme. On the occasion, suggestions were given to farmers for balanced use of fertilizers based on soil test for crop productivity and maintain the soil health and bio-diversity. Also, 50 Soil samples were collected and sent for testing on this occasion.

Fig. 22.24 Celebration of world soil day

Organization of *Swachhta Abhiyan*

Swachhta awareness programmes were conducted by KVK, Ramgarh this year by displaying banners at prominent places, taking Swachhata pledge, Stock taking & briefing of the activities and plantation of trees. During the programme, date wise various activities were carried out under the Swachhta Pakhawada.

Fig. 22.25 Organization of cleanliness campaign

Awards and Recognitions

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Awards and Recognitions

- Rohan Kumar Raman, '**Young Scientist Award 2022'** by Agricultural and Environmental Technology Development Society (AETDS), U. S. Nagar, Uttarakhand, India.

- Tanmay K Koley, '**Associateship'** by Indian Academy of Horticultural Science 2021.

- Tanmay K Koley, **'Young Scientist Award 2022'** by Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar (WB).

- Sundaram P K, **'Young Scientist Award 2022'** by Lali Rural & Agricultural Development Society, Uttar Pradesh.

- Team of FSRCHPR, **'Rajbhasha First Prize'** for the efficient implementation of the official language policy of the Union in 'A' region for the year 2020-21 by the Ministry of Home Affairs, Govt. of India, New Delhi.

- Reena Kumari Kamal, **'Scientist of the Year Award 2022'** by Kalash Research and Welfare Society, Prayagraj, Uttar Pradesh.

- Reena Kumari Kamal, **'Women Scientist Award 2022 '** by Birsa Agricultural University, Kanke, Ranchi, Jharkhand.

- Pawan Jeet, **'Young Scientist Award 2022'** by Lali Rural & Agricultural Development Society, Uttar Pradesh.

- Meenu Kumari, **'Women Scientist Award 2022'** by Scientific Development in Agriculture & Technology, Meerut (U.P.).

- Manoj Kumar, **'Outstanding Soil Scientist'** by the Green Planet Agrotech Foundation, West Bengal.

- Dr. Manoj Kumar, **'Kalki Gaurav Award 2022'** by Kalki News & Kalki Foundation Trust.

- Jaspreet Singh, **'Young Scientist Award 2022'** by Agro Environmental Education and Farmer Welfare Society, Punjab.

- Kirti Saurabh, **'Young Scientist Award-2022'**, by Jan Jagriti Sewa Samiti Society, Kanpur.

- Ajit Kumar Jha, **'Excellence in Research Award'** by Astha Foundation, Meerut.

- Rakesh Kumar, **'Fellow of Indian Society of Weed Science (ISWS) 2021"** by Indian Society of Weed Science

- Govind Makarana, **'Young Scientist Award 2022'** by All Indian Association of Plant and Agriculture Researchers.

- Santosh Kumar, **'Scientist of Year Award 2022'** by Society for Scientific Development in Agriculture and Technology (SSDAT), Meerut (U.P).

- Saurabh Kumar, **'Young scientist award Year 2022'** by Association of Plant Science Research (APSR), Plantica group of Researchers (PGR), India.

- Sonaka Ghosh, **'Young Scientist Travel Grant Award'** by Indian Society of Weed Science in 8th International Weed Science Congress on **"Weed Science in a Climate of Change"** in Bangkok, Thailand during 4th - 9th December, 2022.

Best Paper/Poster/Presentation Awards

- Rohan Kumar Raman, '**Best oral presentation award'** in the 4th International Conference on Global Efforts on Agriculture, Forestry, Environment and Food Security (GAFEF-2022) at Pokhra, Nepal during 17-19 September 2022.

- Rohan Kumar Raman, **'Best oral presentation award'** in the international conference on Vision 2047: sustainable developments towards Atma-Nirbhar Bharat (VSANB-2022) at Chandigadh during 23-24 December, 2022.

- Dhiraj Kumar Singh, **'Best Oral Presentation Award'** in International Conference on "Global research initiatives for sustainable agriculture & allied sciences (GRISAAS-2022)" organized by Astha Foundation, Merrut, UP during 21-23 November, 2022 at BAU, Ranchi.

- Pawan Jeet, **'Certificate of Excellence'** by American Journal of Climate Change.

- Pawan Jeet, **'Certificate of Excellence for Reviewing'** by International Journal of Climatology.

- Arti Kumari, **'Certificate of Excellence in Reviewing'** by International Journal of Environment and Climate Change (2022).

- Ved Prakash, **'Certificate of Excellence in Reviewing'** by International Journal of Environment and Climate Change.

- Rajni Kumari, **'Best Oral Presentation award'** for the paper 'Cytokine RT-qPCR for immune system assessment in goats' at National Seminar on "Recent Biotechnological Advances in Health and Management Practices to Augment Productivity of Livestock and Poultry" held at VCRI, Tirunelveli

during 22-24 September 2022

- Rajni Kumari, **'Best Oral Presentation award'** for the paper "Expression profiling of hsp 70 gene in duck breeds under humid subtropical climate" at National Seminar on "Recent Biotechnological Advances in Health and Management Practices to Augment Productivity of Livestock and Poultry" held at VCRI, Tirunelveli during 22-24 September 2022.

- Reena Kumari Kamal, **'Best Oral Presentation award'** for the paper "Characterization of Indigenous chicken production systems and their performance in Hill & Plateau Region of Jharkhand" in National conference by the Directorate of centre for Animal Production Studies, Chennai and Indian Poultry Science Association-Tamil Nadu Chapter held at Madras Veterinary College, Chennai held during September 22-23, 2022.

- Reena Kumari Kamal, **'Best Oral Presentation Award'** for the paper "Production performance of ducks under extensive system of management in Middle Gangetic Plain (MGP) of Bihar in VIIth International Conference on Global Research Initiatives for Sustainable Agriculture and Allied Sciences (GRISAAS-2022) held at Birsa Agricultural University, Ranchi, Jharkhand during November 21-23, 2022.

- Kumari Meenu, **'Best Oral Presentation award'** for paper "Evaluation of French bean against rust in Eastern Plateau and Hill region of Jharkhand" In VIIth International conference in hybrid mode on Sustainable Agriculture and Allied Sciences held at Birsa Agriculture University, Kanke, Ranchi, Jharkhand during November 21-23, 2022.

- Santosh S Mali, **'ISAE JAE Best Paper Award'** for the paper "Impact of Gridded Weather Data Sources and its Temporal Resolution on Crop Evapotranspiration and Effective Rainfall of Major Crops in Eastern Region of India" by the Indian Society of Agricultural Engineers, New Delhi.

- Reshma Shinde, **'Best Oral Presentation Award'** for the paper "Isolation and screening of lignocelluloses degrading microbes from soil" in VIIth International Conference on 'Global Research Initiatives for Sustainable Agriculture & Allied Sciences (GRISAAS-2022)' held at Birsa Agricultural University, Ranchi, Jharkhand during November 21-23, 2022.

- Ajit Kumar Jha, **'Best Oral Presentation Award'** for the paper "Management of green mold of Oyster mushroom (Pleurotus ostreatus) by fungicides and plant extracts" presented in VIIth International Conference on Global Research Initiatives for Sustainable Agriculture & Allied Sciences (GRISAAS-2022) organised at Birsa Agricultural University, Ranchi during November 21-23,2022.

- Jeet Pawan, Singh AK, Kumar A, Kumari A and Upadhyaya A, **'Best Paper Award'** for the paper "Drought analysis with different indices for the Sakri river basin of Bihar and Jharkhand" in "National Conference on Landscape Management for Preventing Flood and Reservoir Sedimentation (LMPFRS-2022)" held during 22-24 September, 2022 organized at Birsa Agriculture University, Ranchi, Jharkhand by Indian Association of Soil and Water Conservationists (IASWC), Dehradun, Uttarakhand.

- Kumar Manoj, Pal S, Khola OPS, Yadav D, Jeet P and Neeraj, **'Best Article Award'** for the article "Groundwater Pumping: Impacts and Sustainable Management Options" by Agriculture and Food: e-Newsletter.

- Akram Ahmed, **'Oral Presentation Award'** by SKAUST-K & Association of Agrometeorologists, Kashmir Chapter.

- Ved Prakash, **'Best Oral Presentation Award'** for the paper 'Analysis of the microclimatic behavior of an agrivoltaic system used to produce wheat crop' in National Conference on 'Managing weather and climate risks in agriculture' held on 24-26th March 2022 at SKUAST-K, Kashmir

- Manoj Kumar, **'Best Oral Presentation Award'** for the paper "Curtailing water requirement for Makhana farming: A case report" in the National Webinar on "Sustainable Interventions towards Resource Conservation and Natural Farming" organized by Academy of Natural Resource Conservation and Management, Lucknow & Assam Agricultural University Jorhat during 22-23 April 2022.

- Surajit Mondal, **'Best Oral Presentation Award'** at International Conference "Global Research Initiatives for Sustainable Agriculture & Allied Sciences" during 21-23 November 2022 at BAU, Ranchi, Jharkhand.

- Rachana Dubey, Kumar S and Choudhary AK, **'Best Article Award'** for "Heat Stress management in Wheat" by Agriculture & Food e-Newsletter.

- Santosh Kumar, **'Best Oral Presentation'** for "Agro-morphological, physiological and anatomical changes in rice genotypes under stage specific & cumulative drought conditions in eastern region of India" in 7th International Conference in Hybrid Mode on "Global Research Initiative for Sustainable Agriculture and Allied Sciences (GRISAAS-2022)" during 21-23 November 2022 held at BAU, Kanke, Ranchi, Jharkhand.

- Tamta M, Arya S and Nain AS, **'Best Article Award'** for article 'Need of Digital Tool for Crop Disease Identification & Management: A Concept by Agriculture & Food: E-Newsletter Magazine.

Publications

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Research Papers

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25 PERSONNEL

Division of Crop Research

Scientists

Dr. Sanjeev Kumar, Pr. Scientist (Agronomy) & Acting Head

Dr. A.K. Choudhary, Pr. Scientist (Plant Breeding)

Dr. Shivani, Pr. Scientist (Agronomy)

Dr. Md. Monobrullah, Pr. Scientist (Entomology)

Dr. Narayan Bhakta, Pr. Scientist (Plant Breeding)

Dr. Santosh Kumar, Sr. Scientist (Plant Breeding)

Dr. Rakesh Kumar, Sr. Scientist (Agronomy)

Dr. Surojit Mondal, Sr. Scientist (Soil Science)

Mr. Ved Prakash, Scientist (Agril. Meteorology)

Mr. Karnena Koteswara Rao, Scientist (Soil Science) (on study leave)

Mr. Abhishek Kumar Dubey, Scientist (Plant Pathology)

Ms. Manisha Tamta, Scientist (Agricultural Meteorology)

Dr. Kumari Shubha, Scientist (Vegetable Science)

Dr. Rachana Dubey, Scientist (Environmental Science)

Mr. Govind Makarana, Scientist (Agronomy)

Mr. Saurabh Kumar, Scientist (Microbiology)

Division of Livestock and Fisheries Management

Scientists

Dr. Kamal Sarma, Pr. Scientist (Fishery) & Head

Dr. A. Dey, Pr. Scientist (Animal Nutrition)

Dr. S. Dayal, Pr. Scientist (Animal Genetics & Breeding)

Dr. Pankaj Kumar, Sr. Scientist (Veterinary Medicine)

Dr. P.C. Chandran, Sr. Scientist (Animal Genetics and Breeding)

Dr. P. K. Ray, Scientist (Veterinary Pathology)

Dr. Rajni Kumari, Scientist (Animal Biotechnology)

Dr. Tarkeshwar Kumar, Scientist (Aquaculture)

Dr. Manoj Kumar Tripathi, Scientist (Animal Physiology)

Mr. Surendra Kumar Ahirwal, Scientist (Fisheries Resource Management)

Sh. Jaspreet Singh, Scientist (FRM)

Dr. Jyoti Kumar, Scientist (Vet. Microbilogy)

Technical Officer

Sh. Amrendra Kumar, Technical Officer

Sh. Dev Narayan, Technical Officer upto 31.07.2022

Division of Land and Water Management

Scientists

Dr. A. Upadhyaya, Pr. Scientist (SWCE) & Head

Dr. A. Rahman, Pr. Scientist (Physics)

Dr. Anil Kumar Singh, Pr Scientist (Agronomy)

Dr. Bikash Sarkar, Pr. Scientist (FMPE)

Dr. Ajay Kumar, Pr. Scientist (SWCE)

Dr. Manibhushan, Sr. Scientist (Comp. App.)

Dr. P.K. Sundaram, Scientist (FMP)

Dr. Pawan Jeet, Scientist (L&WME)

Dr. Akram Ahmed, Scientist (L&WME)

Dr. Kirti Saurabh, Scientist (Soil Science)

Mrs. Mridusmita Debnath, Scientist (L&WME)

Mrs. Arti Kumari, Scientist (L&WME)

Dr. Sonaka Ghosh, Scientist (Agronomy)

Technical Officer

Mr. Prem Pal Kumar, Technical Officer w.e.f. 10.08.2022

Division of Socio-Economics and Extension

Scientists

Dr. Ujjwal Kumar, Pr. Scientist (Agril. Extension) & Acting Head

Dr. Abhay Kumar, Pr. Scientist (Agril. Statatics)

Dr. N. Chandra, Pr. Scientist (Agril. Economics)

Dr. Tanmay Kumar Koley, Sr. Scientist (Horticulture)

Dr. Dhiraj Kumar Singh, Sr. Scientist (Ag. Extension)

Dr. Anirban Mukherjee, Scientist (Agril. Extension)

Dr. Rohan Kumar Raman, Sr. Scientist (Agil. Statistics)

Technical Officer

Mr. Sanjay Rajput, Technical Officer

Prioritization Monitoring & Evaluation Cell

Dr. Abhay Kumar, Pr. Scientist (Agril. Statatics) & I/c PME Cell

Technical Officer

Mr. Sarfaraj Ahmad, Sr. Technical Officer (Computer)

ARIS Cell

Dr. Manibhushan, Sr. Scientist (Comp. App.) & I/c ARIS

Technical Officer

Sh. Anil Kumar, ACTO

Farm Section

Mr. Abhishek Kumar, Assistant Chief Technical Officer

Mr. P.K. Singh, ACTO

Mr. A.S. Mahapatra, Sr. Technical Officer

ICAR RCER Farming System Research Centre for Hill & Plateau Region, Ranchi

Scientists

Dr. A.K. Singh, Pr. Scientist (Horticulture) & Head

Dr. R.S. Pan, Pr. Scientist (Horticulture)

Dr. B.K. Jha, Pr. Scientist (Horticulture)

Dr. Bikash Das, Pr. Scientist (Horticulture) upto 01.02.2023

Dr. S. K. Naik, Pr. Scientist (Soil Science)

Dr. V.K. Yadav, Pr. Scientist (Ag. Extension)

Dr. S.S. Mali, Sr. Scientist (SWCE)

Dr. P. Bhavana, Sr. Scientist (Plant Breeding)

Dr. Ajit Kumar Jha, Sr. Scientist (Plant Pathology)

Dr. J.S. Choudhary, Scientist (Entomology)

Ms. Reshma Shinde, Scientist

Dr. Reena Kumari Kamal, Scientist (LPM)

Mr. M.K. Dhakar, Scientist (Fruits Science)

Dr. Meenu Kumari, Scientist (Veg. Science)

Dr. Prerna Nath, Scientist (Food Technology)

Technical Officers

Dr. G. P. Singh, Chief Technical Officer

Mr. Paul Sanjay Sircar, Assistant Chief Technical Officer (Computer)

Mr. Suresh Kumar, Senior Technical Officer (Farm)

Mr. Dhananjay Kumar, T-6 (Farm)

Mr. Arun Kumar, Technical Officer (Electrical)

Mrs. Anima Prabha, Technical Officer (Press & Editorial)

Mr. Vijay Kumar Singh, Technical Officer (Lab.)

Sh. Shashi Kumar Azad, Technical Officer (Field/Farm)

Sh. Ganga Ram, ACTO (T-7-8)

Sh. Chandrakant, ACTO (T-7-8)

ICAR RCER, Research Centre for Makhana, Darbhanga

Dr. Manoj Kumar, Sr. Scientist (Soil Science) & Acting Head

Dr. I.S. Singh, Pr. Scientist (Soil Science)

Dr. B.R. Jana, Sr. Scientist (Horticulture)

Mr. Shailendra Mohan Raut, Scientist (FRM)

Mr. Padala Vinod Kumar, Scientist (Agronomy)

Technical

Sh. Ashok Kumar, T-5

ICAR RCER, Krishi Vigyan Kendra, Buxar

Subject Matter Specialists

Dr. Deokaran, SMS CTO (T-9) (Soil Science)

Mr. Ramkewal, SMS ACTO (T-7-8) (Plant Protection)

Dr. Mandhata Singh, SMS ACTO (T-7-8) (Agronomy)

Dr. Hari Govind Jaiswal, SMS CTO (T-9) (Plant Breeding)

Technicals

Mr. Arif Parwez, Farm Manager (T-6)

Administrative

Mr. Rakesh Mani, Assistant

ICAR RCER, Krishi Vigyan Kendra, Ramgarh

Subject Matter Specialists

Dr. Dushyant Kumar Raghav, SMS ACTO (T-7-8) (Plant Protection)

Dr. Indrajeet, SMS CTO (T-9) (Ag. Extension)

Dr. Dharmjeet Kherwar, SMS (Agroforestry/ Horticulture) ACTO

Technical

Shri Sunny Kumar, Farm Manager

Administration & Finance Section

Mr. Pushpanayak, CAO (Study Leave w.e.f. 16.01.2023)

Sh. Rajat Kumar Das, FAO (w.e.f. 02.06.2022)

Mr. Prem Chandra, PPS w.e.f. 16.08.2022

Mr. K.K. Lal, AF&AO

Mrs. Prabha Kumari, AAO (P)

Mr. Dayanand Prasad, AAO

Mr. Ravi Shankar, AAO

Mr. Md. Sajid Mustaque, AAO (w.e.f. 01.09.2022)

Mr. Madan Paswan, Assistant

Ms. Divyadarshini, Assistant

Mr. Nagendra Kumar, Assistant

Promotion

Scientists

Er. Prem Kumar Sundram, Sr. Scientist (FMP) promoted to Level-12 w.e.f. 15.12.2019

Dr. Rakesh Kumar, Sr. Scientist (Agronomy promoted to Level-13A w.e.f. 20.04.2022

Dr. Surjit Mondal, Sr. Scientist (Soil Science) promoted to Level-12 w.e.f. 15.09.2021

Dr. Rajni Kumari, Sr. Scientist (Animal Biotechnology) promoted to Level-12 w.e.f. 23.06.2019

Mr. Surendra Kumar Ahirwal, Scientist (Fisheries Resource Management) promoted to Level-11 w.e.f. 01.01.2021)

Dr. Tanmay Kumar Koley, Sr. Scientist (Horticulture) promoted to Level-13A w.e.f. 11.05.2022

Dr. Dhiraj Kumar Singh, Sr. Scientist (Ag. Extension) promoted to Level-13A w.e.f. 20.04.2022

Dr. Rohan Kumar Raman, Sr. Scientist (Agil. Statistics) promoted to Level-12 w.e.f. 01.07.2022

Dr Santosh S. Mali, Senior Scientist (SWCE) promoted to Level 13A w.e.f. 12-06-2020.

Dr (Mrs.) P. Bhavana, Senior Scientist (Plant Breeding) promoted to Sr. Scientist (Level 13A) w.e.f. 21-04-2021.

Dr. J.S. Choudhary, Sr. Scientist (Entomology) promoted to Level-12 w.e.f. 01.09.2019)

Dr. Sharad Kumar Dwivedi, Sr. Scientist promoted to Level-12 w.e.f. 02.07.2021)

Dr. Manoj Kumar, Sr. Scientist (Soil Science) promoted to Level-13A w.e.f. 23.06.2021)

Dr. B.R. Jana, Scientist (Horticulture) promoted to Level-11 w.e.f. 20.11.2006 and Level-12 w.e.f. 27.04.2012

Subject Matter Specialists

Dr. Deokaran, SMS CTO (T-9) (Soil Science) promoted to Level- 12 w.e.f. 10.10.2020

Mr. Ramkewal, SMS ACTO (T-7-8) (Plant Protection) promoted to Level- 11 w.e.f. 02.09.2015

Dr. Mandhata Singh, SMS ACTO (T-7-8) (Agronomy) promoted to Level- 11 w.e.f. 27.04.2017

Dr. Hari Govind Jaiswal, SMS CTO (T-9) (Plant Breeding) promoted to Level- 12 w.e.f. 22.08.2017

Dr. Indrajeet, SMS ACTO (T-7-8) (Ag. Extension) promoted to Level- 11 w.e.f. 21.08.2020

Dr. Dharmjeet Kherwar, SMS (Agroforestry/ Horticulture) ACTO promoted to Level- 11 w.e.f. 09.12.2020

Technical

Sh. Amrendra Kumar, Technical Officer promoted to Level- 17 w.e.f. 13.01.2021

Sh. Surendra Kumar Yadav, T-2 promoted to Level-4 w.e.f. 08.08.2022

Sh. Manoj Kuamr Singh, T-2 promoted to Level-4 w.e.f. 09.03.2021

Sh. Kalyan Kumar, T-3 promoted to Level-5 w.e.f. 08.06.2020

Sh. Sanjay Lal Srivastava, T-3 promoted to Level-5 w.e.f. 01.01.2023

Mr. P.K. Singh, ACTO promoted to Level-11 w.e.f. 18.03.2022

Mr. A.S. Mahapatra, Sr. Technical Officer promoted to Level-10 w.e.f. 29.12.2020

Dr. G. P. Singh, Chief Technical Officer promoted to Level-12 w.e.f. 16.07.2017

Mr. Dhananjay Kumar, T-6 (Farm) promoted to Level-10 w.e.f. 01.01.2020

Sh. Shashi Kumar Azad, Technical Officer (Field/Farm) promoted to Level-7 w.e.f. 16.02.2021

Sh. Ganga Ram, ACTO (T-7-8) promoted to Level-11 w.e.f. 10.06.2019

Sh. Chandrakant, ACTO (T-7-8) promoted to Level-11 w.e.f. 10.06.2019

Sh. Ashok Kumar, T-5 promoted to Level-7 w.e.f. 16.09.2020

Sh. Kamlesh Mahto, T-4 promoted to Level-6 w.e.f. 06.09.2017

Mr. Arif Parwez, Farm Manager (T-6) promoted to Level-10 w.e.f. 30.03.2019

Mr. Afroz Sultan, Programme Assistant (Lab. Tech.)/ T-6 promoted to Level-10 w.e.f. 13.08.2020

Sh. Deva Narayan, TO (T-6) promoted to Level-10 w.e.f. 28.12.2021

Shri Sunny Kumar, Farm Manager promoted to Level-7 w.e.f. 31.08.2020

New Joining
Scientists

Dr. Anup Das, Director w.e.f., 06.02.2023

Dr. Rakesh Kumar w.e.f., 07.06.20222

Administrative

Sh. Rajat Kumar Das, FAO w.e.f. 02.06.2022

Sh. Prem Chandra, PPS w.e.f. 16.08.2022

Sh. Md. Sajid Mustaque, AAO w.e.f. 01.09.2022

Sh. Vipul Raj, AO w.e.f. 21.02.2023

Sh. Alok Raj, LDC w.e.f. 27.08.2022

Sh. Jyoti Kumar Mani, LDC w.e.f. 27.09.2022

Technical

Sh. Prem Pal Kumar, TO w.e.f. 10.08.2022

Sh. Ravi Ranjan Singh, Sr. Technician w.e.f. 23.11.2022

Transfer
Scientist

Dr. Surajit Modal, Scientist transferred to CCRI, Nagpur w.e.f., 24.03.2023

Dr. A. Rahman, Pr. Scientist transferred to CSSRI RS, Lucknow w.e.f., 22.03.2023

Technical

Sh. Vikas Kumar, Senior Technical Officer (T-6), transferred to ICAR-NBFGR, Lucknow w.e.f., 30.07.2022

Sh. Deva Narayan, Technical Officer (T-5) transferred to ICAR-NBFGR, Lucknow w.e.f., 30.07.2022

Sh. Sanjay Lal Srivastava, Senior Technician (T-2: Lab Technician) transferred to ICAR-IISR, Lucknow w.e.f. 06.08.2022

Retirements
Scientist

Dr. R.C. Bharati, Pr. Scientists w.e.f. 31.01.202

Technical

Sh. H.P. Kashi, Ex-STO, w.e.f. 28.02.2022

Sh. Om Prakash, ACTO (Civil), w.e.f. 30.06.2022

Sh. D.C. Kujur, Ex-TO, w.e.f. 31.07.2022

Administrative

Mrs. Sangeeta Chakraborty, Asstt. – 09.12.2022

26 ON-GOING RESEARCH PROJECTS

Sl. No.	Project code	Project Title	Name of PI & Co-PI	Start year	Completion Year	Funding agency
Theme 1. Farming System Research including Climate Resilient Agriculture						
1.0	**Integrated Farming System and Cropping System for Eastern Region**					
1.1	ICAR-RCER/ AICRP/ IFS/ EF/ 2010/ 25(i)	Development of location specific Integrated Farming System models for small and marginal farmers of Bihar	Sanjeev Kumar A. Dey Ujjwal Kumar N. Chandra Kamal Sarma Shivani Ajay Kumar Rachana Dubey Kirti Saurabh R.K. Raman Kumari Shubha Saurabh Kumar	June, 2010	Sep., 2025	AICRP on IFS
1.2	ICAR-RCER/ RC Ranchi/ 2011/ 25(iii)	Development of location specific Integrated Farming System models for rainfed eco-system of Eastern Plateau Hill region	M.K. Dhakar S.K. Naik Reena K. Kamal	June, 2011	July, 2023	ICAR-RCER
1.3	ICAR-RCER/ RC Ranchi/ 2014/147	Development of multi-tier cropping system for rainfed uplands of eastern plateau and hills	M.K. Dhakar Reshma Shinde Bikas Das	Sept., 2014	Sept., 2023	ICAR-RCER
1.4	ICAR-RCER/ RC Ranchi/2019/ 225	Evaluation of Zero Budget Natural Farming (ZBNF) for Eastern Plateau and Hill Region **Modified title** Evaluation of Natural Farming for Eastern Plateau and Hill Region"	B.K. Jha S.K. Naik A.K. Jha S.S. Mali J.S. Choudhary	2019	2024	ICAR-RCER
1.5	ICAR-RCER/ RC Ranchi/ 2020/237	Development of multipurpose trees and medicinal plants based agroforestry models for Eastern Plateau and Hill Region	Reshma Shinde M.K. Dhakar	2020	2025	ICAR-RCER

Sl. No.	Project code	Project Title	Name of PI & Co-PI	Start year	Completion Year	Funding agency
1.6	-	Optimum land allocation of different integrated farming systems components to maximize resource use efficiency and net return.	Manibhushan A. Upadhyaya Sanjeev Kumar Bikas Das S.S. Mali	Sept.,2020	Aug., 2023	ICAR-RCER
1.7	-	Consortia Research Platform (CRP) on Farm Mechanization and Precision Farmin	Bikash Sarkar Ujjwal Kumar P. K. Sundaram Pawan Jeet Ramkewal D.K. Raghav	April, 2016	Dec., 2021 Extd March 2023	ICAR
2.0	**Resource Conservation Technology**					
2.1	ICAR-RCER/ DCR/EF/ 2015/ 40	Evaluation of Conservation Agricultural (CA) practices under Rice-fallow system of Eastern Region	Rakesh Kumar B. K. Jha S. K. Naik S.S. Mali Rachana Dubey S.K. Mondal	2015	2026	Consortium Research Platform on CA (ICAR)
2.2	ICAR-RCER/ DCR/EF/ 2016/	Cereal Systems Initiative for South Asia (CSISA) Phase III	Rakesh Kumar S. Mondal Rachana Dubey G. Makarana Saurabh Kumar	2016	Dec., 2021 Extd. March 2025	CIMMYT
2.3	ICAR-RCER/ RC Ranchi/2011 / 196	Evaluation of leaching loss of nutrients in acidic soils of Jharkhand under different cropping systems	S. K. Naik S. S. Mali	Oct., 2018	Sept., 2021 Extd. March, 2023	ICAR-RCER
2.4	--	Network project on Conservation of lac insect genetic resources (NPCLIGR)	M. Monobrullah	Jan. 2019	Dec., 2023 Extd. March 2023	AINP on CLIGR
2.5	--	Impact of long- term conservation agriculture on greenhouse gas fluxes from middle Indo-gangetic plains of India.	Rachana Dubey G.Makarana	Aug., 2020	July, 2023	ICAR-RCER
2.6	--	Soil organic carbon and crop productivity as influenced by tillage operations in India	Surajit Mondal	Dec 2020	Dec 2023	(SERB-DST funded)
3.0	**Climate Resilient Agriculture**					
3.1	ICAR-RCER/ DCR/ 2018/ 208	Effect of water deficit and heat stress on wheat : Changes in plant physiological traits and yield attributes	Rachana Dubey Santosh Kumar Ved Prakash	2018	2022 Extd. 2023	ICAR-RCER

Sl. No.	Project code	Project Title	Name of PI & Co-PI	Start year	Completion Year	Funding agency
3.2	ICAR-RCER/ DCR/ EF/2018/	Long term conservation agriculture impact on micro biome and soil health indicators for resource efficiency and resilience in maize systems	Rakesh Kumar S. Mondal	Nov., 2018	Oct, 2021 Extd Oct., 2022	NASF
3.3	ICAR-RCER/ DSEE/ EF/2019/	Climate Resilient Agriculture Programme	Abhay Kumar Ujjwal Kumar M. Monobrullah P.K. Sundaram Rakesh Kumar Surajit Mondal Dhiraj Kr. Singh R.K. Raman	Nov., 2019	Mar., 2024	Govt. of Bihar
3.4	ICAR-RCER/ DCR/ EF/2019/	Climate-smart management for stress-prone environment	Santosh Kumar Rakesh Kumar Kirti Saurabh	2019	2022 Extd. 2023	(IRRI Funded)
3.5	ICAR-RCER/ DCR/ EF/2020/	Optimizing soil organic carbon stock in rice-based cropping system in irrigated ecosystem	Rachana Dubey S. Mondal	2020	2022 Extd. 2023	SERB-DST
3.6	--	Climate change impact studies at selected location in Bihar	Ved Prakash Kirti Saurabh Sonaka Ghosh A. Upadhyaya Akram Ahmed	2021	2024	ICAR-RCER
Theme- 2. Genetic Resource Management and Improvement of Field, Horticultural and Aquatic crops						
4.0	**Varietal Development**					
4.1	ICAR-RCER / HARP/ 2001/ 03	Plant genetic resource and improvement of fruit crops	M.K. Dhakar Bikash Das J. S. Choudhary D. Kherwar	2001	Long term	ICAR-RCER
4.2	ICAR-RCER/ RC Ranchi/ 2017/215	Genetic resource management in vegetable crops	A.K. Singh P. Bhavna R. S. Pan V.K. Yadav J.S. Chaudhary	Sept, 2017	Long term project	ICAR-RCER
4.3	ICAR-RCER/ DCR/EF 2017/	Frontiers in Rice Science (New Science), Sub Project 1: Resource remobilization during grain filling under drought (erstwhile Identification of traits, genes, physiological mechanisms to develop climate smart varieties for unfavourable environment)	Santosh Kumar	2017	2022 Extd. 2023	IRRI

Sl. No.	Project code	Project Title	Name of PI & Co-PI	Start year	Completion Year	Funding agency
4.4	ICAR-RCER/ DCR/2019/227	Evaluation, characterization and identification of rice genotypes for combine tolerance to drought and submergence	Santosh Kumar N. Bhakta	July, 2019	June, 2023	ICAR-RCER
4.5	ICAR-RCER/ RC Ranchi/ 2019/ 226	Development of multiple disease resistant hybrids in solanaceous vegetables	P. Bhavana A.K. Singh A.K. Jha J.S. Choudhary	2019	2024	ICAR-RCER
4.6	ICAR-RCER/ RC Ranchi/ 2020/ 244	Genetic enhancement of pigeon pea for yield and biotic stress resistance	P. Bhavana Kishor Tribhuvan (ICAR-IIAB) J. S. Choudhary A.K. Jha	June, 2020	Dec, 2025	ICAR-RCER
4.7	--	Improvement of French bean for rust resistance **Modified:** Improvement of French Bean for disease resistance	Meenu Kumari R.S. Pan A.K. Jha J.S. Chaudhary	July, 2021	June, 2025	ICAR-RCER
4.8	--	Genetic enhancement of selected vegetable legumes for Eastern India	Kumari Shubha A.K. Choudhary A.K. Dubey R.S. Pan V.K. Padala	2021	2024	ICAR-RCER
4.9	--	Characterization of aquatic nut, Rhizome and tuber crops under wetland ecosystem of North Bihar	B.R. Jana I.S. Singh	2021	2024	ICAR-RCER
4.10	--	Development of high moisture tolerant pigeon pea and its agronomic practices for eastern India	Anil Kr. Singh A.K.Choudhary A. Upadhyay Kirti Saurabh M. Monobrullah Pawan Jeet	2021	2026	ICAR-RCER
Theme- 3. Improved Production and Protection Technologies for Agri-Horti Crops						
5.0	**Production Technologies**					
5.1	--	Creation of seed hubs for increasing indigenous production of pulses in India	A.K. Choudhary G. Makarana Hari Govind (KVK, Buxar)	2016	2021	ICAR

Sl. No.	Project code	Project Title	Name of PI & Co-PI	Start year	Completion Year	Funding agency
5.2	ICAR-RCER/ RCM/ 2019/	Effect of secondary and micronutrients on yield and quality of makhana in field condition	Manoj Kumar I.S. Singh S.M. Raut	Aug, 2019	July, 2022 Extd. July, 2023	ICAR-RCER
5.3	ICAR-RCER/ DCR/ 2019/ 228	Enhancing nutritional security of rural households through vegetable based Nutri garden in Bihar	Kumari Shubha T.K. Koley Akram Ahmed Abhishek Kumar	Oct. 2019	Sep. 2022 Extd. Sept. 2023	ICAR-RCER
5.4	ICAR-RCER/ RC Ranchi/ 2020/238	Standardization of basin enrichment in bearing orchards of Bael, Mango and Guava under eastern plateau and hill region	Bikash Das M. K.Dhakar	2020	2025	ICAR-RCER
5.5	ICAR-RCER/ DCR/ 2020/ 236	Standardization of agro-techniques in nutri-cereals for enhancing the productivity in eastern Indo-Gangetic plains	Rakesh Kumar Surajit Mondal	July, 2020	Dec., 2025	ICAR-RCER
5.6	--	Improving nutrient use efficiency and productivity by customizing nutrient application methods in Makhana	Manoj Kumar I.S. Singh	June, 2020	May, 2023	ICAR-RCER
5.7		Studies on soils in relation to makhana production in north Bihar	Manoj Kumar I.S. Singh	June, 2020	May, 2023	ICAR-RCER
5.8	--	Phosphorous mobilization through organic amendments in acidic soils of Hill and Plateau region	Reshma Shinde S.K. Naik A.K. Jha	2021	2026	ICAR-RCER
5.9	ICAR-RCER/ DCR/EF/ 2020/	Developing precision nutrient management protocols for rice-wheat-maize system in IGP	Surajit Mondal Rakesh Kumar	2020	2023	NASF
5.10	--	Evaluation of vegetable soybean for horticultural and nutritional traits	R S Pan Meenu Kumari Reshma Shinde Sujit Bishi (ICAR-IIAB, Ranchi)	July, 2021	June, 2026	ICAR-RCER
5.11	--	Sustainable fodder production system under different nitrogen and zinc management practices in eastern India	G. Makarana Sanjeev Kumar A. Dey Saurabh Kumar	2021	2024	ICAR-RCER

Sl. No.	Project code	Project Title	Name of PI & Co-PI	Start year	Completion Year	Funding agency
5.12	--	Standardization of hydroponic technology for horticultural crops	T.K. Koley Kumari Shubha Kirti Saurabh P.K. Sundram A. Rahman	2021	2024	ICAR-RCER
5.13	--	Effect of nano-DAP fertilizer on the performance and yield of rice-wheat crop	Kirti Saurabh Santosh Kumar Ved Prakash Sonaka Ghosh A.K. Dubey	2021	2024	IFFCO
5.14	--	Development of technology for post-harvest management and value addition of jackfruit in Eastern region	Prerna Nath M.K. Dhakar Ajit K Jha S. J. Kale, IINRG	Jan, 2022	Dec, 2024	ICAR-RCER
6.0	**Protection Technologies**					
6.1	ICAR-RCER/ DCR/ 2019/ 229	Studies on weed and seed bank dynamics in different cropping systems in the middle Indo Gangetic Plains	Sanjeev Kumar Ajay Kumar Surajit Mondal	Nov., 2019	Oct., 2022 Extd. Oct., 2023	ICAR-RCER
6.2	--	Insect pest dynamics in litchi and their linking with digital tools for better management	J.S. Choudhary S.S. Mali M.K. Dhakar	July, 2021	June, 2026	ICAR-RCER
6.3	--	Morphological and molecular characterization of bottle gourd wilt complex	Ajit Kumar Jha J.S. Chaudhary P. Bhavana Meenu Kumari A.K. Singh	July, 2021	June, 2025	ICAR-RCER
6.4	--	Evaluation of different genotypes of Water chestnut (*Trapa natans* L.) for Singhara beetle (*Galerucella birmanica* Jacoby) resistance	Manoj Kumar V.K. Padala S.M. Raut M. Monobrullah B.R. Jana	2021	2024	ICAR-RCER
6.5	--	Weed seed bank dynamics, resource-use efficiency and greenhouse gas foot print under diverse tillage production systems in Eastern Indo-Gangetic Plains	Sonaka Ghosh Rakesh Kumar R. K. Raman Saurabh Kumar Rachana Dubey S. Mondal (Associate)	July, 2021	June, 2024	ICAR-RCER
6.6	--	Arthropod diversity and development of weather based forecasting models for Makhana pests	Manoj Kumar Vinod K. Padala M. Monobrullah	Jan, 2021	Dec, 2023	ICAR-RCER

Sl. No.	Project code	Project Title	Name of PI & Co-PI	Start year	Completion Year	Funding agency
Theme- 4. Integrated Land & Water Management						
7.0	**Land & Water Management**					
7.1	ICAR-RCER /RC Ranchi/ 2014/150	Rehabilitation of coal mine affected areas through agroforestry interventions	Bikash Das M.K. Dhakar S.S. Mali D. Kherwar	Sept, 2014	Aug, 2023	ICAR RCER
7.2	ICAR-RCER/ DLWM/ 2018/222	Water conservation under different irrigation and tillage management in rice based cropping system	Surajit Mondal Rakesh Kumar (Associate)	Oct., 2018	Sep, 2022	ICAR-RCER
7.3	--	Evaluation of existing solar pump for irrigation potential in eastern region of India	A. Rahman Anil K. Singh N. Chandra Pawan Jeet	June, 2020	May, 2023	ICAR-RCER
7.4	ICAR-RCER/ DLWM/ 2020/ 235	Budgeting and auditing of water for better planning and management in agriculture.	Pawan Jeet A. Upadhyaya Ved Prakash Kirti Saurabh	2020	2023	ICAR-RCER
7.5	ICAR-RCER/ DLWM/ 2020/ 234	Land feasibility analysis for rainwater harvesting planning at watershed level in Nalanda, Bihar.	Pawan Jeet A. Upadhyaya	2020	2023	ICAR-RCER
7.6	ICAR-RCER/ DLWM/ 2020/ 239	Refinement of indigenous plough and weeding rake in Eastern Hill and Plateau region	Bikash Sarkar P.K. Sundaram D.K. Raghav (Associate)	2020	2023	ICAR-RCER
7.7 (i)	DCR/2020	Collection, evaluation and characterization of popular rice landraces in floodplains of eastern India.	N. Bhakta	July 2020	June 2024	
7.7 (ii)	DSEE/ 2020/ 242	M. Monobrullah	R. K. Raman Jyoti Kumar Dhiraj Kr Singh Associates: Jaspreet Singh			ICAR-RCER
7.7 (iii)	DLWM/2020	A. K. Dubey	Akram Ahmed Anil K. Singh Shivani			
7.7 (iv)	DLFM/ 2021	Resource assessment and management framework for sustainable fisheries in selected wetland	V. Bharti T. Kumar Jaspreet Singh R.K. Raman S.K. Ahirwal	2021	2024	ICAR-RCER

Sl. No.	Project code	Project Title	Name of PI & Co-PI	Start year	Completion Year	Funding agency
7.8	ICAR-RCER/ DCR/ 2021	Assessment of bacterial diversity and characterization of PGPR in arsenic contaminated soil	Saurabh Kumar Kirti Saurabh S K Naik (Associate)	Jan., 2021	Dec., 2024	ICAR-RCER
7.9	ICAR-RCER/ DLWM/ 2021	Irrigation and nitrogen management of diversified rice based cropping system in middle Indo-Gangetic Plains	Shivani Kirti Saurabh Akram Ahmed	2021	2026	ICAR-RCER
7.10	ICAR-RCER/ DLWM/2021	Design and development of motorized cole crop harvester	P.K. Sundaram Bikash Sarkar A. Rahman	2021	2024	ICAR-RCER
7.11	ICAR-RCER/ DLWM/2021	Integrated Modeling approach for developing drought management strategies in the Sakri river basin, Bihar and Jharkhand	Pawan Jeet A.K. Singh Ajay Kumar Arti Kumari	2021	2024	ICAR-RCER
7.12	ICAR-RCER/ DLWM/2022	Determining optimum decision variables in furrow irrigated system	Ajay Kumar A. Upadhyay Sanjeev Kumar Pawan Jeet Kirti Saurabh	2022	2025	ICAR-RCER
Theme- 5. Livestock & Fisheries Management						
8.0 Livestock and Avian Management						
8.1	ICAR-RCER /DLFM/EF/ 2011/ 31	Network project on Buffalo improvement	P.C. Chandran Pankaj Kumar P.K. Ray Rajni Kumari Rakesh Kumar A.Dey(Associate)	June, 2012	Dec., 2022	ICAR-RCER
8.2	ICAR-RCER / DLFM/ 2013/ 135	Characterization of lesser known breeds of farm animals in Eastern India	P.C. Chandran R.K. Kamal Shankar Dayal Rakesh Kumar	July, 2013	June, 2022 Extd 2023	ICAR-RCER
8.3	ICAR-RCER/ DLFM/ 2018/202	Assessing genetic variability in ducks of eastern states	Rajni Kumari P.K. Ray S. Dayal Ratna Prabha (IASRI, N.Delhi) R.K. Kamal (Associate)	2018	2022 Extd. 2023	2022 Extd. 2023
8.4	ICAR-RCER/ DLFM/ 2018/209	Molecular epidemiology and therapeutic management of bovine Theileriosis	Pankaj Kumar M.K. Tripathi NIAB, Hyderabad IIT, Guwahati	July, 2018	Dec., 2022	ICAR-RCER

Sl. No.	Project code	Project Title	Name of PI & Co-PI	Start year	Completion Year	Funding agency
8.5	ICAR-RCER/ DLFM/ 2019/ 231	Development of meat and egg strains of duck suitable for backyard farming	P.C. Chandran R.K. Kamal A. Dey Rajni Kumari	2019	2024	ICAR-RCER
8.6	ICAR-RCER/ DLFM/ 2019/ 232	Effect of genetic and non-genetic factors on prolificacy of Bengal goat	R.K. Kamal A. Dey P.C. Chandran Rajni Kumari P.K. Ray	Aug.,2019	July, 2023	ICAR-RCER
8.7	--	AICRP on Goat Improvement	A. Dey R.K. Kamal P.C. Chandran Pankaj Kumar Rajni Kumari P.K. Ray M.K. Tripathi	July, 2019	Mar, 2025	ICAR
8.8	--	Evaluation of traditionally used growth promoters on production performances in pig and poultry	Reena K. Kamal A. Dey Sushil Prasad Singrav S. Kullu	July 2020	June 2023	ICAR-RCER
8.9	ICAR-RCER/ DLFM/ 2020/243	Assessment of antimicrobial drug resistance in bacteria of animal origin	Jyoti Kumar Shankar Dayal P.K. Ray	July 2020	June 2025	ICAR-RCER
8.10	--	Reproductive abnormalities and associated common pathogens in special reference to Leptospirosis	Pankaj Kumar Abhay Kumar M.K. Tripathi A. Mukherjee Manish Kumar (IITG)	2021	2026	ICAR-RCER
8.11	--	Exploring genetic basis of Mastitis resistance in livestock	Shankar Dayal Rajni Kumari Jyoti Kumar P.C.Chandran M.K. Tripathi Rakesh Kumar	2021	2025	ICAR-RCER
8.12	--	Model Project and Demonstration Unit for Backyard Poultry, Livestock, Vermifarming and Moringa Integration	Rakesh Kumar. R.K. Kamal A. Dey P.C. Chandran Jyoti Kumar P.K. Ray V. Bharti	2021	2023	Lead centre ICAR CARI, Izatnagar (Bareilly)

Sl. No.	Project code	Project Title	Name of PI & Co-PI	Start year	Completion Year	Funding agency
8.13	--	Effect of environmental exposure of arsenic in Animals and Fisheries in Bihar	M.K. Tripathi Pankaj Kumar A. Dey Kamal Sarma Arun Kumar (Mahavir Cancer Institute & Research Centre)	Jan, 2022	Dec, 2026	ICAR-RCER
8.14	--	Characterization & evaluation of chicken germplasm in Eastern Region	Reena K Kamal A. Dey P.C. Chandran	2022	2026	ICAR-RCER
9.0 Fisheries Management						
9.1	ICAR-RCER/ DLFM/ 2018/201	Culture potential of selected Indian minor carp	S.K. Ahirwal Kamal Sarma T. Kumar Jaspreet Singh V. Bharti	2018	2023	ICAR-RCER
9.2	ICAR-RCER/ DLFM/ 2019/	Economic feasibility of integrated prawn cum fish farming in Polyculture system in Eastern region	Tarkeshwar Kumar Jaspreet Singh V. Bharti	Sep., 2019	Aug., 2023	ICAR-RCER
9.3	ICAR-RCER/ DLFM/ 2020/241	Effect of different manures on fish productivity	Kamal Sarma T. Kumar Jaspreet Singh Jyoti Kumar A. Dey S.K. Ahirwal S.Mondal (Associate)	July, 2020	June, 2023	ICAR-RCER
9.4	--	Assessment of fish production potential in makhana-periphyton system in North Bihar	I.S. Singh Jaspreet Singh	June, 2020	May, 2023	ICAR-RCER
Theme- 6. Socio-Economics, Extension and Policy Research						
10.0 Socio-economic Research						
10.1	--	Enhancing food, nutritional and livelihood security of marginal and tenant farmers in Jharkhand through need based agricultural technologies	Bikash Das V.K. Yadav R.S. Pan A.K. Jha Reena K. Kamal	June, 2018	Extd. March, 2023	Farmer FIRST Project (Externally funded)
10.2	--	Value addition of principal food grains by farmers of Bihar	N. Chandra Ujjwal Kumar Dhiraj Kr. Singh P.K. Sundaram R.C. Bharati	2018	2021 Extd, 2022	ICAR RCER

Sl. No.	Project code	Project Title	Name of PI & Co-PI	Start year	Completion Year	Funding agency
10.3	ICAR-RCER/ DSEE/ 2019/ 230	Status of utilization of digital tools in agriculture sector in Eastern India	R.C. Bharati Ujjwal Kumar N. Chandra Dhiraj K. Singh T.K. Koley R.K. Raman PC, KVK Buxar Indrajeet, SMS, KVK Ramgarh	Oct., 2019	Sep., 2024	ICAR-RCER
10.4	--	Agri-Business Incubation Project	A.K. Singh Bikash Das S.S. Mali V.K. Yadav P. Bhavana M.K. Dhakar Dhiraj Kr. Singh T.K. Koley	2020	2025	
10.5	--	ITMU Project (NAIF Component I)	P. Bhavana A.K. Singh	2011	Long term	NAIF
10.6	--	Development and validation of need based technology delivery model through farmers' producer organization for eastern region of India	A. Mukherjee Ujjwal Kumar Dhiraj Kr. Singh Shubha Kumari V.K. Yadav R.S. Pan D.K. Raghav	Dec., 2019	Nov., 2022	NASF
10.7	--	Model based inference on agricultural crops for food security in Eastern India	R. K. Raman Abhay Kumar Ujjwal Kumar Akram Ahmed	2021	2024	ICAR-RCER
10.8	--	Impact of e-NAM on improving marketing of agricultural produce in eastern India	D.K. Singh Abhay Kumar V.K. Yadav Naresh Chandra A. Mukherjee	2021	2024	ICAR-RCER

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Theme wise Approved New Research Projects 2022-23

Sl. No.	Project code	Project Title	Name of PI & Co-PI	Start year	Comp Year	Funding agency
Theme 1. Farming System Research including Climate Resilient Agriculture						
1.0	Integrated Farming System and Cropping System for Eastern Region					
1.1	New	Studies on efficacy of natural farming and comparison with existing farming	A.K. Singh A. Upadhyaya Md. Monobrullah Rakesh Kumar Pawan Jeet Rachana Dubey Ved Prakash Kirti Saurabh Sonaka Ghosh R.K. Raman A.K. Dubey	2022	2028	ICAR-RCER
Theme- 3. Improved Production and Protection Technologies for Agri-Horti Crops						
5.0	**Production Technologies**					
5.1	New	Understanding temporal variation in fruit maturity behaviour of litchi growing in Jharkhand and Bihar	Bikash Das M.K. Dhakar Santosh S. Mali S.K. Naik S.D. Pandey (ICAR- NRC for Litchi, Muzaffarpur) S.K. Mehta (ICAR- NRC for Litchi, Muzaffarpur)	July, 2022	June, 2025	ICAR RCER
5.2	New	Promotion of Commercial Custard Apple Cultivation in Jharkhand	M.K. Dhakar Bikash Das	April, 2022	March, 2025	MIDH
6.0	**Protection Technologies**					
6.1	New	Bio-intensive management of fall armyworm (Spodoptera frugiperda) on maize	Md. Monobrullah Abhishek Kumar Dubey	2022	2026	ICAR-RCER
6.2	New	Management of false smut through modification in sowing dates and establishing disease relation with weather parameters	A.K. Dubey Santosh Kumar Manisha Tamta Govind Makrana	2022	2026	ICAR-RCER
Theme- 4. Integrated Land & Water Management						
7.0 Land & Water Management						
7.1	New	Simulation of soil water dynamics in rice-wheat-moong bean cropping system	A. Upadhyaya Pawan Jeet A.K. Singh Kirti Saurabh	2022	2026	ICAR-RCER
7.2	New	Assessment of Evapotranspiration and Crop Coefficients of fruit crops using Remotely Sensed Data and METRIC approach	S.S. Mali S.K. Naik M.K. Dhakar Akram Ahmed	July, 2022	June, 2025	ICAR RCER
Theme- 5. Livestock & Fisheries Management						

Sl. No.	Project code	Project Title	Name of PI & Co-PI	Start year	Comp Year	Funding agency
8.0 Livestock and Avian Management						
8.1	New	Identification and characterization of common Zoonotic pathogens in domestic animals	Pradeep Kr. Ray Jyoti Kumar P.C. Chandran Rakesh Kumar	2022	2026	ICAR-RCER
8.2	New	Study of Genetic polymorphisms of candidate genes associated with production traits in Goats in Eastern Region.	Rakesh Kumar Shankar Dayal P.K. Ray MK Tripathi Rajni Kumari	2022	2026	ICAR-RCER

Status of new, on-going and closed activities 2022

S. No.	Title of Activities	PI
New Activities		
1.	Use of Biofertilizers for improving soil nutrient status and crop productivity (rice-wheat-moong cropping system)	S. Mondal
2.	Impact of rice straw biochar on drought stress tolerance in rice-wheat-moong cropping system	Rachana Dubey Santosh Kumar
3.	Improving water application uniformity and coverage area of micro-irrigation system fed by a low capacity solar pump under communicating vessels arrangement	A Rahman
4.	Status of fluorosis in livestock of Bihar and evaluating the ameliorative effect of nutraceuticals on affected cattle population	Pankaj Kumar
5.	Evaluation of toria genotypes	N. Bhakta
6.	Extraction of mango kernel starch from east Indian cultivars and its characterization	T.K. Koley
7.	Nutritional quality evaluation of water chestnut growing under diverse nature of water bodies	I.S. Singh
8.	Effect of foliar fertilization on performance of water chestnut	Manoj Kumar
9.	Biofloc technology: Exploring production optimization and economic viability for the Eastern region	Jaspreet Singh
10.	Development of nutrient rich lines of pulse legumes for eastern India	A.K. Choudhary
11.	Development of native Trichoderma based bioformulations for management of soil-borne diseases	A.K. Dubey
Ongoing Activities		
1.	Breeding for submergence tolerance in rice	N. Bhakta
2.	Evaluation of lentil genotypes	N. Bhakta
3.	Evaluation and development of drought tolerant rice for Eastern region	Santosh Kumar
4.	Evaluation and identification of rice genotypes for tolerance to drought stress at different growth stages.	Santosh Kumar
5.	Maintenance of advance breeding lines of cool season pulses	A.K. Choudhary
6.	Multi-objective optimization of integrated farming system	Akram Ahmed

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