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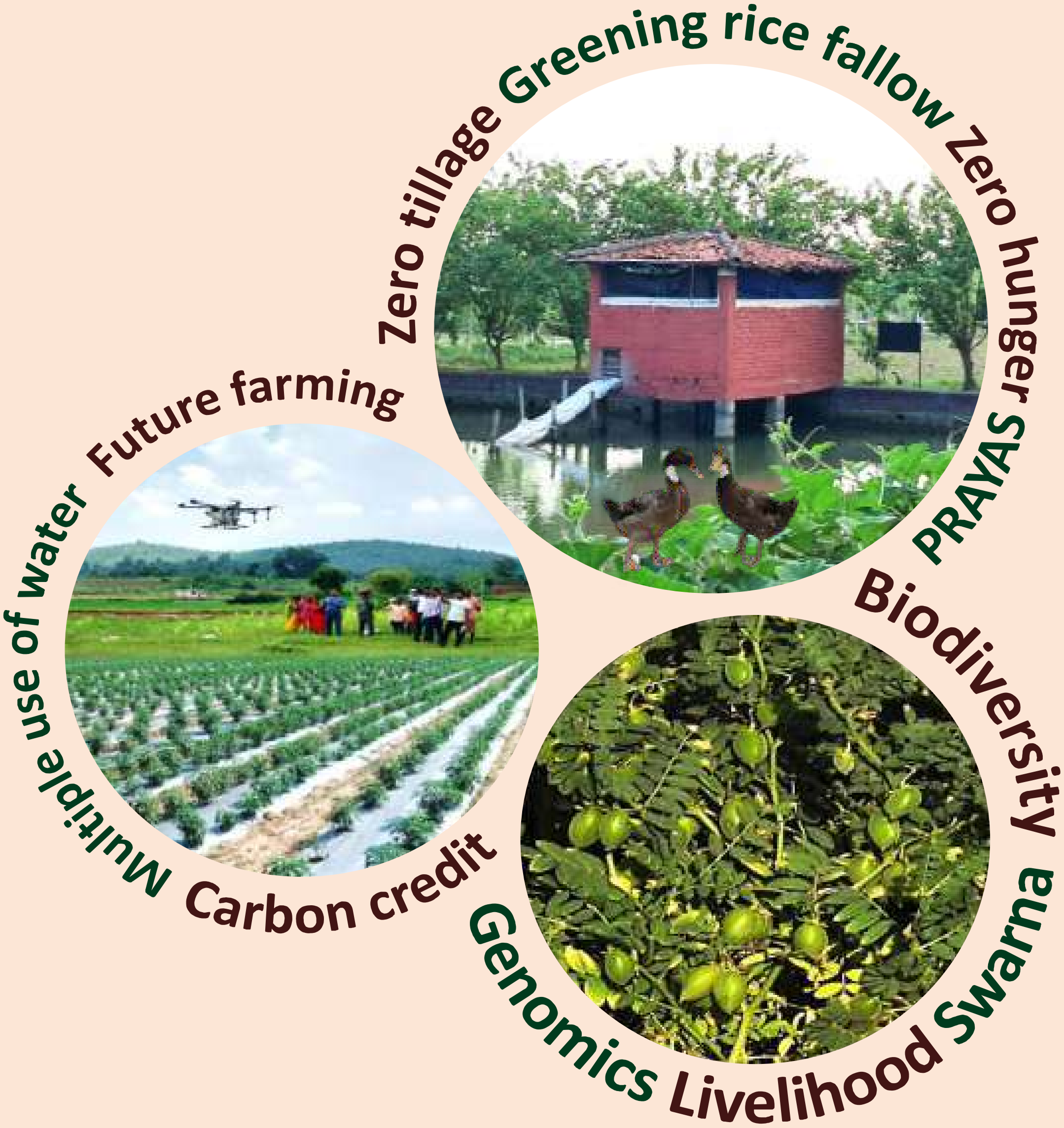

वार्षिक प्रतिवेदन
ANNUAL REPORT

2024

भारतीय कृषि अनुसंधान परिषद का पूर्वी अनुसंधान परिसर, पटना

ICAR Research Complex for Eastern Region, Patna

Annual Report
2024

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



Annual Report 2024

ICAR Research Complex for Eastern Region,
Patna

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Preface

The eastern India, which comprises Assam, Bihar, Chhattisgarh, Odisha, Eastern UP, West Bengal and Jharkhand, abounds in natural and human resources. However, this region more often encounters vagaries of nature in terms of flood, drought, rising temperature, contraction of cool season, and the like. These factors collectively account for poor realization of farm productivity. The ICAR Research Complex for Eastern Region, Patna with its centre 'Farming System Research Centre for the Hill and Plateau Region' (Ranchi, Jharkhand) and two Krishi Vigyan Kendra (one at Buxar in Bihar, and the second at Ramgarh in Jharkhand), has been striving to develop location-specific cutting-edge technologies to bring about livelihood security in all the seven states. The institute's endeavours include conservation of natural resources, enhancing soil and water productivity, mitigating climate change impacts and greening over 9.5 million ha rice fallow areas spread across all the seven eastern states. There has been a strong focus on the rice fallow management by integrating into the system the short-duration varieties of rice, pulses and oilseeds and conservation agriculture. The institute has done commendable work to bring about sustainable development through productivity and income enhancement through horti-livestock-based integrated farming systems.

During the year, a *multiple use of water* model covering an area of 0.65 ha was developed at the Sabajpura Farm (Patna), which combines water harvesting (2000 m^3 pond storage), groundwater recharge, drip/sprinkler irrigation, fertigation and resource conservation to enhance input-use efficiency, improve soil health and reduce GWP. The institute also undertook systematic research on nano fertilizers, soil microbiome studies in different agro-ecosystems, climate change studies using the insect life cycle modelling, precision irrigation and application of drones in agriculture. Technological options for greening vast rice fallow areas, soil, water and crop management practices for climate resilient agriculture, integrated farming system, agro-forestry models, fruit-based multitier models, rehabilitation of coal mine affected area, holistic GHG emission studies in the CA-based rice-wheat system, drip fertigation in vegetable crops, etc for enhancing productivity, resource use efficiency, income and environmental security were the main focus during the year.

In the reporting year, two high-yielding, multiple stress-tolerant rice varieties 'Swarna Purvi Dhan 4' and 'Swarna Purvi Dhan 5' were released and notified. In addition, 'Swarna Lakshami', a high-yielding, heat-tolerant *Desi* chickpea variety, was also released and notified for cultivation in eastern UP, Bihar, Jharkhand, Assam and West Bengal under timely-sown irrigated conditions. During the year, a total of 20.64 t quality seeds (breeder and truthfully labelled) of institute's 11 rice varieties, and 28.95 t quality seeds (BS, FS, CS and TL) of recently released varieties of pulses (under the two pulse seed hubs) were produced and marketed. In addition, over 3.2 t foundation seeds of three varieties (DBW 187, DBW 222 and DBW 303) of wheat were also produced and sold.

New initiatives of the institute included the evaluation of crop varieties for natural and organic farming, the development of Integrated Natural/Organic Farming System models and diversifying rice-wheat cropping system. The institute also characterized three indigenous populations (Seemanchali sheep, Kodo duck and Mala chicken) and submitted proposals for their registration. Besides, the ecosystem services provided by female *Murrah* graded buffalo during her lifetime was also estimated. For tangible transfer of technology, the PRAYAS (Participatory Research Application for Year-Round Income and Agricultural Sustainability) was implemented as a single-window technology transfer module across the seven eastern states, that fetched attention from various stakeholders.

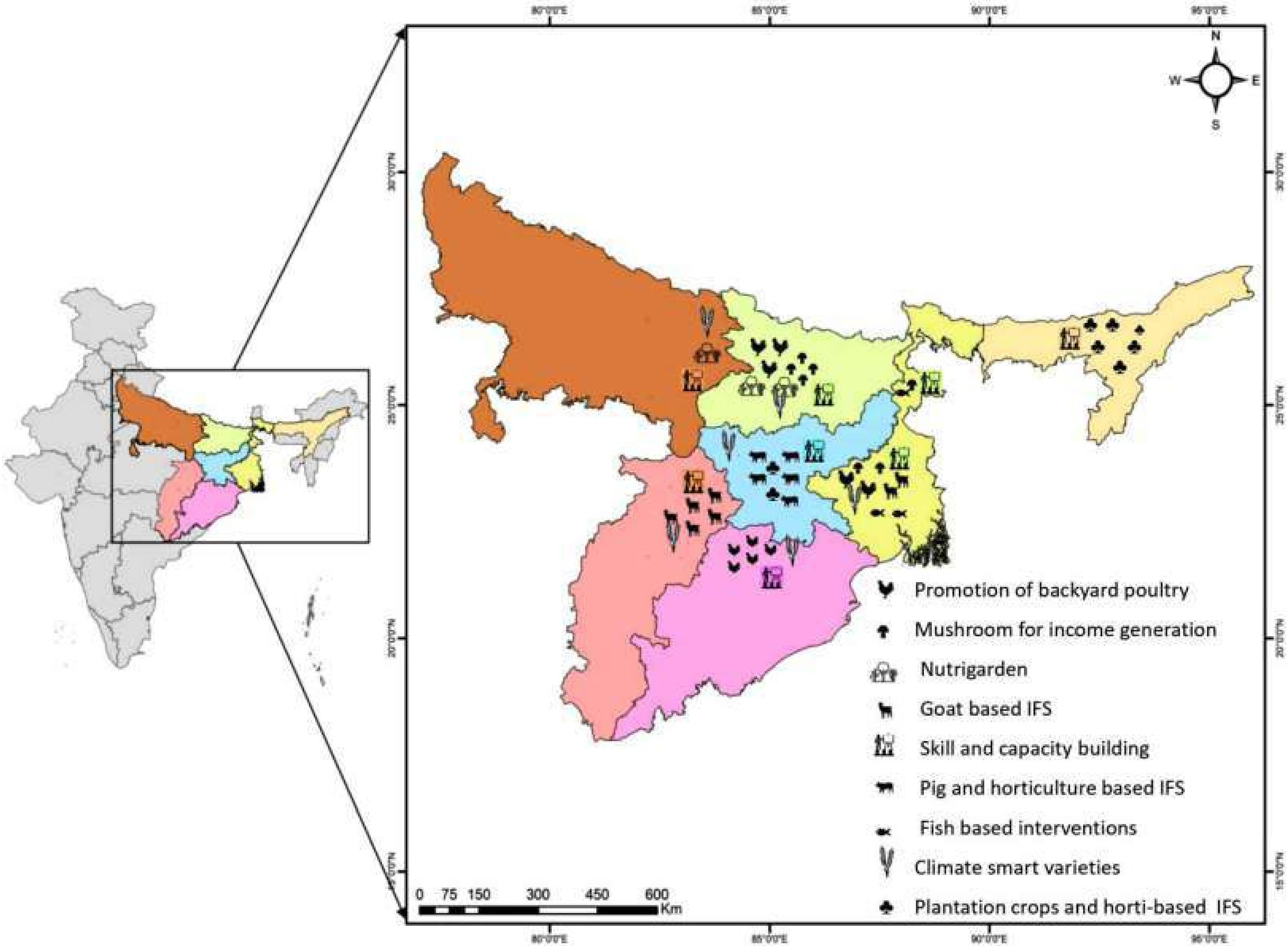
The IARI Patna Hub under ICAR-RCER carried out teaching activities for its 38 *undergraduate* (17 in the first-year, and 21 in the second-year) and five postgraduate (2 *M Tech* and 3 *Ph D*) students. In addition to their academic work, students participated in a wide range of extra-curricular activities, which enriched their educational experience, and aided to their personality development.

Institute's research and academic achievements are too numerous to mention. However, it could have hardly achieved this excellence without guidance and support from ICAR, New Delhi. Sincere gratitude is expressed to Dr Himanshu Pathak (Secretary, DARE & DG, ICAR) for their continued support and valuable guidance. The guidance provided by Dr SK Chaudhari (DDG, NRM) is also deeply appreciated and acknowledged. The institute further acknowledges the valuable suggestions provided by the chairman and members of both RAC and QRT in shaping our research and development strategies. Finally, the dedicated support of each and every staff member of the institute is gratefully acknowledged as we are moving forward with renewed energy and purpose.

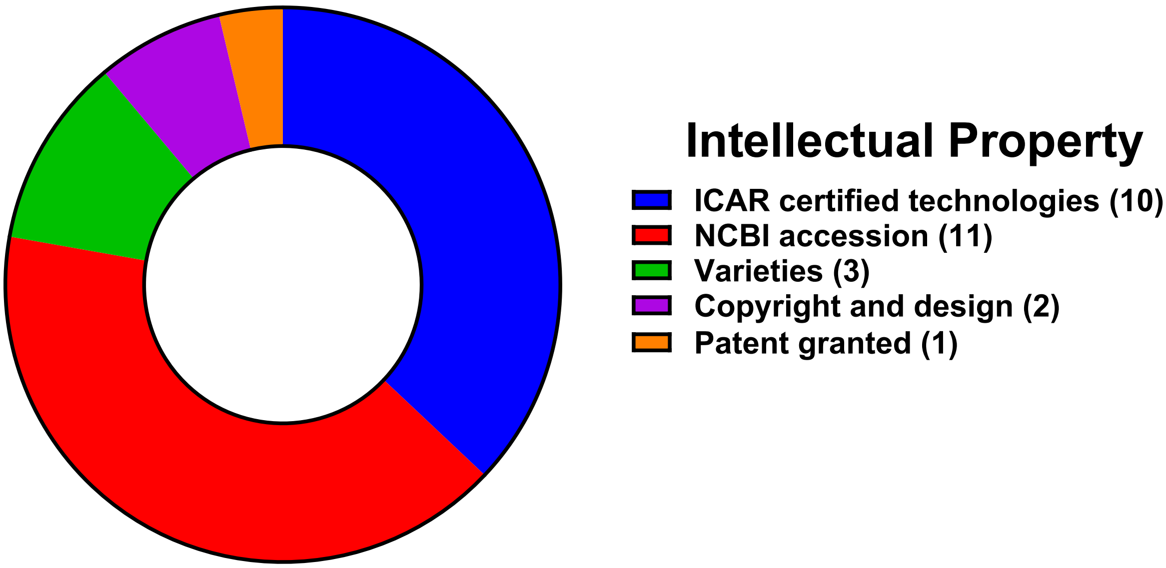
(Anup Das)

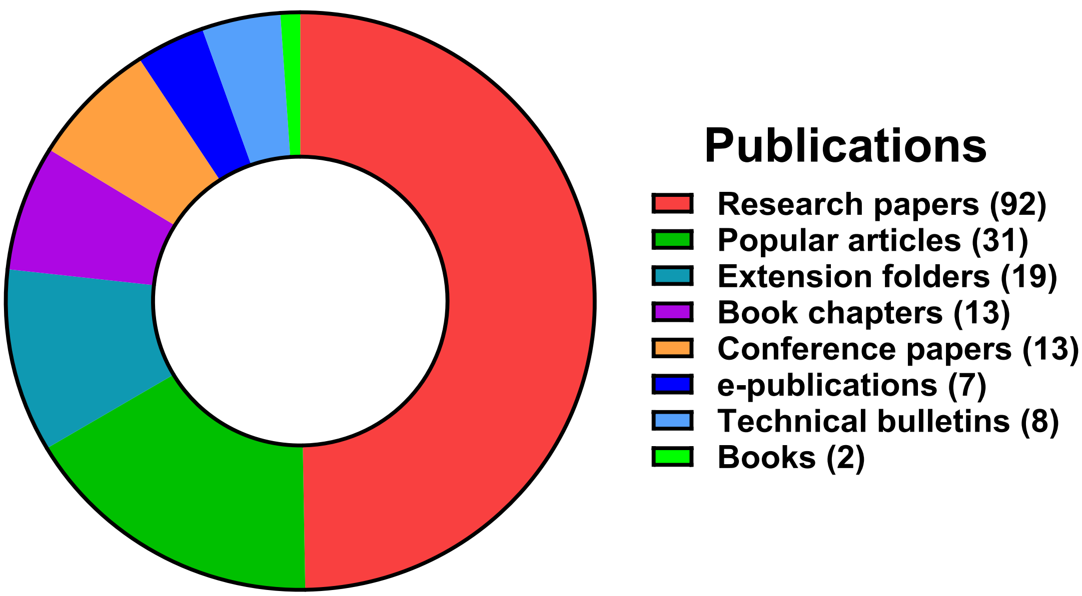
Content

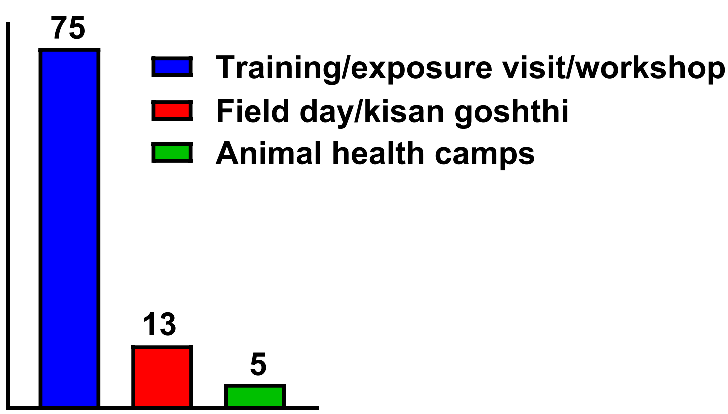
Coverage of ICAR RCER technologies and outreach activities in eastern India



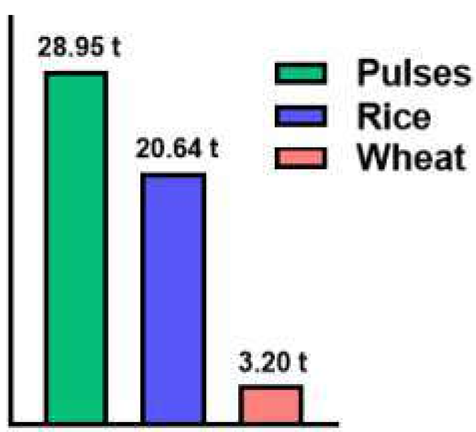
Institute at a Glance







Capacity Building



Quality Seed Production

A Farmer's Journey from Innovation to Entrepreneurship

Raj Kumar Singh, a farmer turned entrepreneur

Mr Raj Kumar Singh, popularly known as *Pappu Singh*, hails from the Vishnupura village, located in Bihta block under the district 'Patna' (Bihar). Motivated by his passion for agricultural innovation, he took a bold step of leaving behind his pharmaceutical business and took to his roots. In 2002, he embarked on his green journey by starting a nursery business "Mother Nature Floriculture" at Bihta Khagaul Road on his parental land of one acre, which he later expanded to a size of five hectares by taking additional land on lease. Mr Singh specializes in ornamental, medicinal, and floriculture plants and attained technical skills from many institutes of national repute, including ICAR-RCER (Patna). His dedication and innovation have earned him over 90 awards. Mr Raj Kumar Singh's journey stands as a shining example of how vision, dedication and continuous learning can transform a simple subsistence farming activity into a thriving and sustainable agribusiness. His work continues to inspire many farmers, especially young ones, to become farm entrepreneurs.

Mother Nature Floriculture setup by Raj Kumar Singh at Bihta (Patna)

Raj Kumar Singh's Journey at a Glance	
Business	B2C Nursery business "Mother Nature Floriculture" at Bihta
Year of establishment	2002
Expertise	Ornamental, medicinal, and floriculture plants
Employment generation	4-5 regular & 25 seasonal workers
Supplier	Horticultural planting material, vermicompost, containers, and nursery equipment
Turnover	Rs 10 million
Net profit	Rs 2.5 million
Upscaling interests	IFS and conservation agriculture (Zero tillage)
Awards	Krishi Shree Award, Udyan Pandit Award and many others

कार्यकारी सारांश

भारतीय कृषि अनुसंधान परिषद का पूर्वी अनुसंधान परिसर, पटना पाँच विशिष्ट विषयगत क्षेत्रों, जैसे कृषि प्रणाली अनुसंधान जिसमें जलवायु अनुकूल कृषि शामिल है, आनुवंशिक संसाधन प्रबंधन एवं उत्पादन प्रौद्योगिकियाँ, भूमि एवं जल उत्पादकता बढ़ाने हेतु प्राकृतिक संसाधन प्रबंधन, पशुधन एवं मत्स्य प्रबंधन तथा सामाजिक-आर्थिक, प्रसार एवं नीतिगत अनुसंधान में, रणनीतिक एवं अनुप्रयुक्त अनुसंधान करता है। प्रतिवेदित वर्ष में, प्राकृतिक खेती, समेकित कृषि प्रणाली, धान-परती भूमि प्रबंधन, प्रजातियों का विकास एवं गुणवत्तायुक्त बीज उत्पादन, जल के बहुआयामी उपयोग, देसी पशुधन का लक्षण निर्धारण एवं पंजीकरण तथा निरंतर आय और कृषि स्थिरता के लिए सहभागी अनुसंधान अनुप्रयोग (प्रयास) संस्थान की कुछ प्रमुख योजनाएं रहीं। प्रतिवेदित वर्ष (2024) में, प्रमुख अनुसंधान उपलब्धियाँ एवं प्रौद्योगिकी हस्तांतरण गतिविधियाँ संक्षेप में इस प्रकार हैं:

- एक एकड़ एवं दो एकड़ समेकित कृषि प्रणाली मॉडलों से क्रमशः ₹ 1,06,350 (लाभ-लागत अनुपात 2.01) एवं ₹ 2,16,628 (लाभ-लागत अनुपात 2.05) वार्षिक शुद्ध आय प्राप्त हुई, जो धान-गेंहूँ प्रणाली की तुलना में लगभग चार गुना अधिक थी।
- कृषि प्रणाली का पहाड़ी एवं पठारी अनुसंधान केंद्र, राँची में एक एकड़ समेकित कृषि प्रणाली मॉडल में ऊर्जा सूचकांक दर्शाते हैं कि प्रक्षेत्र फसलें, चारा, फल एवं जैविक खाद से शुद्ध धनात्मक ऊर्जा लाभ दिखा, जिसमें चारा सर्वाधिक ऊर्जा दक्ष (ऊर्जा दक्षता अनुपात 15.42) रहा। खेतों की फसलें उच्च ऊर्जा दक्षता (ऊर्जा दक्षता अनुपात 2.73, शुद्ध ऊर्जा लाभ: 24.33 गीगा जूल) के साथ प्रदर्शित हुई, जबकि फल और जैविक खाद मध्यम स्तर की दक्षता (ऊर्जा दक्षता अनुपात क्रमशः 1.87 और 1.38) के साथ दर्ज किए गए। सब्जियों और दुग्ध उत्पादों में ऋणात्मक ऊर्जा संतुलन पाया गया, जो इन क्षेत्रों में अनुकूलन की आवश्यकता को दर्शाता है।
- प्राकृतिक खेती से भूमि उपयोग दक्षता (63% तक) एवं सकल उत्पादकता (35.35 किग्रा/हे./दिन तक) बढ़ी, साथ ही मृदा पीएच (6.13 बनाम 5.84), जैविक कार्बन एवं जैविक सक्रियता (डीएचए: 129.4 μg टीपीएफ/ग्रा/डी; एसएमबीसी: 354 μg/ग्रा) में भी सुधार हुआ; ये परिणाम कृषि प्रणाली का पहाड़ी एवं पठारी अनुसंधान केंद्र, रांची में प्राप्त हुए हैं, जो पहाड़ी एवं पठारी क्षेत्रों की निम्न लागत वाली परिस्थितियों में टिकाऊ फसल उत्पादन हेतु प्राकृतिक खेती की संभावनाओं को दर्शाते हैं।
- गया (बिहार) जिले में 350 चयनित किसानों के माध्यम से 160 हे. से अधिक क्षेत्र में धान-परती भूमि प्रबंधन हेतु किस्म आधारित (उच्च गुणवत्ता वाले अरहर किस्म 'आईपीए 203' तथा रबी मौसम की अल्पावधि वाली दाल एवं तिलहन फसलों की किस्मों की आपूर्ति के माध्यम से) एवं समेकित फसल प्रबंधन सहित संरक्षण कृषि पर आधारित तकनीकों को सम्मिलित करते हुए एक एकीकृत पद्धति का प्रदर्शन किया गया।
- धान-परती भूमि प्रबंधन परीक्षण में (9वें वर्ष के बाद), ट्रांसप्लांटेड पडल्ड धान (टीपीआर) द्वारा धान उत्पादकता (5.27 टन/हे.), शून्य जुताई विधि द्वारा धान की सीधी बुआई (जेडटीडीएसआर) (3.34 टन/हे.) एवं संरक्षण जुताई विधि द्वारा धान की सीधी बुआई (सीटीडीएसआर; 3.83 टन/हे.) की तुलना में अधिक रही। हालांकि, समय के साथ टीपीआर का वर्षा पश्चात उगाई जाने वाली सभी दलहनी एवं तिलहनी फसलों के प्रदर्शन पर प्रतिकूल प्रभाव पड़ा।
- एक दीर्घकालीन अध्ययन में, संरक्षण कृषि आधारित धान-गेंहूँ प्रणाली के 16वें वर्ष के पश्चात अधिकतम धान उपज पारंपरिक रोपण विधि के तहत 6.24 टन/हेक्टेयर दर्ज की गई, जो कि सीटीएमटीआर द्वारा प्राप्त उपज 6.08 टन/हेक्टेयर के बराबर थी। हालांकि, सीटीएमटीआर -जेडटी गेंहूँ - जेडटी मूंग प्रणाली से 17.37 टन/हेक्टेयर का चावल समतुल्य उपज उत्पादन प्राप्त हुआ, जबकि पारंपरिक धान-गेहूं प्रणाली के अंतर्गत यह (चावल समतुल्य उपज) मात्र 12.73 टन/हेक्टेयर थी।

- उच्च उत्पादकता वाली, बहु तनाव सहिष्णु एवं शीघ्र पकने वाली (115-120 दिन) धान की दो किस्में 'स्वर्ण पूर्वी धान 4' (4.5-5.0 टन/हे.) एवं 'स्वर्ण पूर्वी धान 5' (4.0-4.5 टन/हे.) को सीमित जल उपलब्धता वाले सूखा प्रभावित वर्षाश्रित क्षेत्रों में सीधी बुआई के लिए जारी एवं अधिसूचित किया गया।
- कई उन्नत प्रजनन पंक्तियाँ जैसे आईआर 16एल 1499, आईआर 17एल 1060, आईआर 14 एल 157, आईआर 107891-बी-बी -1253-1-1, आईआर 14 एल 36, आईआर 95781-15-1-1-4, आईआर 97030-7-2-2-2, आईआर 95817-5-1-1-2 एवं आईआर 18आर 1179 तथा कुछ जारी की गई किस्में 'स्वर्ण पूर्वी धान 2', 'स्वर्ण समृद्धि धान' एवं 'स्वर्ण श्रेया' (4.60-5.36 टन/हे.) प्राकृतिक खेती के लिए आशाजनक पाई गईं।
- उच्च उपज देने वाली (1.75 टन/हे.), जैव-संवर्धित (जिंक की मात्रा: 45 पीपीएम), रोग प्रतिरोधी (फ्यूज़ेरियम विल्ट) एवं उष्णता सहिष्णु देसी चना की किस्म 'स्वर्ण लक्ष्मी' को उत्तर प्रदेश, बिहार, झारखंड, असम एवं पश्चिम बंगाल राज्यों में खेती हेतु जारी एवं अधिसूचित किया गया।
- झाड़ीदार सेम की दो आशाजनित उन्नत प्रजनन पंक्तियाँ 'आरसीपीडी 1' और 'आरसीपीडी 16' को एकल पौधा चयन विधि के माध्यम से विकसित किया गया, जो पूर्वी भारत की जलवायु परिस्थितियों के अनुकूल हैं। ये दोनों प्रजातियाँ प्रकाश-असंवेदी, रोग-रोधी एवं पोषक तत्वों से भरपूर हैं, जो विशेष रूप से लघु एवं सीमांत किसानों में व्याप्त सूक्ष्म पोषण की कमी की समस्या को दूर करने में सहायक सिद्ध हो सकती हैं।
- बिहार एवं पश्चिम बंगाल की मिट्टियों से पाँच प्रभावशाली आर्सेनिक-प्रतिरोधी पीजीपीआर उपभेदों की पहचान एवं विशेषताओं का निर्धारण किया गया, जिनमें उच्च स्तर की आर्सेनिक सहिष्णुता तथा फॉस्फोरस, पोटाश और जिंक जैसे बहुपोषक तत्वों को घुलनशील बनाने की क्षमता पाई गई । इन उपभेदों में बी007 और एस10पी2 ने धान में आर्सेनिक न्यूनीकरण के लिए बेहतर प्रदर्शन किया।
- यार्डलॉन्ग बीन में येलो मोज़ेक वायरस की तीव्रता का पूर्वानुमान लगाने हेतु मशीन लर्निंग तकनीकों का उपयोग किया गया। रैंडम फॉरेस्ट, क्यूबिस्ट, एक्सजीबूस्ट, के-निकटतम पड़ोसी और ग्रेडिएंट बूस्टिंग मशीन दृश्य सूचकांकों का उपयोग करके वाईएमडी गंभीरता की भविष्यवाणी करने के लिए पांच शीर्ष प्रदर्शन करने वाले मॉडल के रूप में उभरे।
- शरीफ़ा जर्मप्लाज्म का स्थलिक गुणधर्म वर्णन करने पर पाया गया कि 'सीसीए03' जीनोटाइप में सबसे अधिक गूदा प्रतिशत तथा सबसे कम छिलका प्रतिशत पाया गया।
- 11 लीची जीनोटाइप्स की फील्ड स्क्रीनिंग में 'स्वर्ण मधु' को कोनोपोमोर्फा प्रजाति के संक्रमण के प्रति अत्यधिक प्रतिरोधी (केवल 2.5% संक्रमण) पाया गया। इसके छिलके (पेरिकार्प) और बीज में फिनॉलिक यौगिकों तथा टैनिन की मात्रा अधिक पाई गई, जिनका फल संक्रमण के साथ प्रबल ऋणात्मक सहसंबंध ($r = -0.72$ से -0.98) देखा गया।
- 34 सब्जी सोयाबीन जीनोटाइप्स के मूल्यांकन में 'स्वर्ण सुगंधा' को एक संभावनाशील, सुगंधित एवं उच्च उपज देने वाली किस्म के रूप में चिन्हित किया गया, जिसमें 63 दिनों में हरे फली की तुड़ाई संभव है तथा इसके बीज मोटे होते हैं (75 ग्राम/100 हरे बीज)। यह किस्म व्यावसायिक खेती के लिए उपयुक्त पाई गई है।
- लौकी में विल्ट जटिलता (विल्ट कंपलेक्स) का आणविक गुणधर्म वर्णन करने पर यह पाया गया कि गढ़वा से एकत्रित जे2 एवं जे4 आइसोलेट्स फ्यूज़ेरियम ऑक्सीस्पोरम प्रजाति के हैं, जबकि डालटनगंज से प्राप्त जे5 आइसोलेट फ्यूज़ेरियम सोलानी तथा रांची से प्राप्त जे7 आइसोलेट फ्यूज़ेरियम क्लेमाइडोस्पोर प्रजाति का पाया गया।

- संस्थान द्वारा विकसित धान की किस्मों के कुल 20.64 टन उच्च गुणवत्ता युक्त बीज (प्रजनक एवं सत्यांकित) का उत्पादन किया गया। दो दलहन बीज केंद्र के अंतर्गत हाल ही में जारी की गई दलहन किस्मों के 28.95 टन उच्च गुणवत्ता युक्त बीज (प्रजनक बीज, आधार बीज, प्रमाणित बीज एवं सत्यांकित बीज) का उत्पादन एवं विपणन किया गया। इसके अतिरिक्त, गेंहूँ की तीन किस्मों (डीबीडब्ल्यू 187, डीबीडब्ल्यू 222 एवं डीबीडब्ल्यू 303) के 3.2 टन से अधिक आधार बीज का भी उत्पादन एवं विक्रय किया गया।
- अम्लीय मिट्टी में फास्फोरस के संचालन हेतु जैविक संशोधन पर किए गए प्रयोग में पाया गया कि वर्मी कम्पोस्ट (7 टन/हेक्टेयर) एवं पीएसबी (5 किलोग्राम/हेक्टेयर) के प्रयोग से सूक्ष्मजीवीय क्रियाशीलता में उल्लेखनीय वृद्धि हुई। इनमें सर्वाधिक बैक्टीरिया की संख्या (40.1×10^6 सीएफयू/ग्राम) एवं डिहाइड्रोजनेज एंजाइम सक्रियता (1.20 माइक्रोग्राम टीपीएफ/ग्राम/घंटा) दर्ज की गई, जिससे फास्फोरस घुलनशीलता में सुधार हुआ।
- सबजपुरा प्रक्षेत्र (पटना) में 0.65 हेक्टेयर क्षेत्रफल में जल के बहु आयामी उपयोग मॉडल का विकास किया गया, जिसमें जल संचयन (2000 घन मीटर की तालाब भंडारण क्षमता), भूजल पुनर्भरण, टपक/स्प्रिंकलर सिंचाई, फर्टिगेशन तथा संसाधन संरक्षण को सम्मिलित किया गया। यह मॉडल आदान उपयोग दक्षता बढ़ाने, मृदा स्वास्थ्य सुधारने तथा भूमंडलीय ऊष्मीकरण क्षमता (जीडब्ल्यूपी) को घटाने में सहायक सिद्ध होता है।
- नैनो डीएपी उर्वरक के साथ उपचार [50% पारंपरिक डीएपी तथा 100% नाइट्रोजन एवं पोटाश + बीज उपचार (5 मि.ली./किग्रा बीज), पहली पर्णीय स्प्रे (4 मि.ली./लीटर जल) 20–25 दिनों पर तथा दूसरी स्प्रे अंकुरण/रोपाई के 45 दिन बाद] से धान-गेहूं प्रणाली में मृदा सूक्ष्मजीव गतिविधि, पोषक तत्व चक्रण एवं फसल उत्पादकता बढ़ी। इस उपचार से नाइट्रोजन स्थिरीकरण एवं गंधक के ऑक्सीकरण बढ़ावा मिला, जिससे पोषक तत्वों की उपलब्धता में सुधार हुआ।
- तीन देसी पशु प्रजातियों – सीमांचली भेड़, कोडो बतख एवं माला मुर्गी – के लक्षण निर्धारण के उपरांत, इन्हें नई नस्लों के रूप में पंजीकरण हेतु प्रस्ताव भेजे गए।
- संस्थान के पशुधन प्रक्षेत्र एवं किसानों के खेतों से चयनित 248 गायों एवं भैंसों की उप-नैदानिक मस्टाइटिस की जांच कैलिफोर्निया मास्टाइटिस टेस्ट के माध्यम से की गई। कुल 2677 भिन्न रूप से व्यक्त जीनों में से 2336 जीनों में महत्वपूर्ण स्तर पर अभिव्यक्ति में वृद्धि (अप-रेगुलेशन) तथा 341 जीनों में महत्वपूर्ण रूप से अभिव्यक्ति में कमी (डाउन-रेगुलेशन) दर्ज की गई, जो उप-नैदानिक मास्टाइटिस से ग्रस्त पशुओं में देखी गई।
- मुर्रा ग्रेड की एक मादा भैंस द्वारा अपने जीवनकाल में प्रदान की गई पारिस्थितिकीय सेवाओं का कुल अनुमानित मूल्य ₹ 12,34,675 आंका गया, जिसमें प्रदायक सेवाओं का योगदान ₹ 8,43,214 (68.3%), सहयोगी एवं आवास सेवाओं का ₹ 5,906 (0.5%), विनियामक सेवाओं का ₹ 23,355 (1.9%) तथा सामाजिक-सांस्कृतिक सेवाओं का योगदान ₹ 3,62,200 (29.3%) रहा।
- बायोफ्लॉक पद्धति में पंगासियस मछली के बीज पालन से जुड़े एक प्रयोग में पाया गया कि 200 शिशु मछलियाँ प्रति घन मीटर की घनता पर पालन करने से औसत शरीर भार, विशिष्ट वृद्धि दर (एसजीआर) तथा वजन में प्रतिशत वृद्धि सबसे अधिक रही। वहीं, सबसे अधिक जीवितता (59.07%) उस इकाई में दर्ज की गई जहाँ 150 शिशु मछलियाँ प्रति घन मीटर की दर से डाली गई थीं। इसके विपरीत, सामान्य बाहरी वातावरण में 200 शिशु मछलियों प्रति घन मीटर की घनता पर पालन करने पर सबसे कम जीवितता (32.1%) प्राप्त हुई।
- फार्मर्स फर्स्ट' परियोजना के अंतर्गत फसल, पशुपालन, उद्यमिता एवं कृषि प्रणाली आधारित विभिन्न मॉड्यूलों के माध्यम से प्रभावशाली हस्तक्षेप किए गए, जिनके परिणामस्वरूप उच्च फसल उत्पादकता, किसानों की आय में वृद्धि, पशु उत्पादकता में

सुधार तथा खाद्य एवं पोषण सुरक्षा में उल्लेखनीय बढ़ोतरी देखी गई।

- कृषि व्यवसाय इनक्यूबेशन (एबीआई) परियोजना के अंतर्गत कृषि आधारित उद्यमों में नवाचार हेतु चार उद्यमियों को चुना गया और उन्हें मार्गदर्शन दिया गया। इसके अलावा, पाँच प्रतिभागियों ने भा.कृ.अनु.प. - राष्ट्रीय कृषि अनुसंधान प्रबंधन अकादमी में आयोजित एबीआईजीआरओडब्ल्यू 2.0 प्रशिक्षण कार्यक्रम में सहभागिता की।
- संस्थान द्वारा ग्राफ्टेड टमाटर, बहुस्तरीय फसल प्रणाली, पौध प्रवर्धन एवं फल मक्खी प्रबंधन ट्रैप से संबंधित प्रौद्योगिकियों के हस्तांतरण हेतु कुल 15 समझौता ज्ञापनों पर हस्ताक्षर किए गए, जिनसे लाइसेंस शुल्क एवं रॉयल्टी के माध्यम से राजस्व प्राप्त होने की अपेक्षा है।
- निरंतर आय और कृषि स्थिरता के लिए सहभागी अनुसंधान अनुप्रयोग' (प्रयास) परियोजना का संचालन भारत के सातों पूर्वी राज्यों में किया गया। वर्ष के दौरान कुल 41 प्रशिक्षण कार्यक्रम (36 लघु अवधि एवं 5 दीर्घ अवधि), 14 अग्र पंक्ति प्रदर्शन, 6 जागरूकता कार्यक्रम एवं एक प्रक्षेत्र आधारित प्रशिक्षण आयोजित किए गए, जिनसे कुल 1,724 किसानों को लाभ मिला।
- कृषि विज्ञान केंद्र, बक्सर एवं कृषि विज्ञान केंद्र, रामगढ़ दोनों ने ही प्रक्षेत्र स्तर पर नवीनतम कृषि ज्ञान एवं तकनीकों को सीधे किसानों के खेतों तक पहुँचाने के उद्देश्य से अनेक महत्वपूर्ण गतिविधियाँ सक्रिय रूप से संचालित कीं। प्रमुख हस्तक्षेपों में प्रक्षेत्र आधारित प्रशिक्षण, अग्र पंक्ति प्रदर्शन, समूह अग्र पंक्ति प्रदर्शन, कौशल-वर्धन प्रशिक्षण कार्यक्रम तथा प्रक्षेत्र भ्रमण शामिल रहे, जिनकी सहायता से किसान स्थानीय चुनौतियों को पार कर अपनी कृषि गतिविधियों में ठोस प्रगति कर सके।
- भारतीय कृषि अनुसंधान परिषद का पूर्वी अनुसंधान परिसर, पटना में संचालित आईएआरआई पटना हब में 38 स्नातक छात्र (17 प्रथम वर्ष और 21 द्वितीय वर्ष) एवं 5 स्नातकोत्तर छात्र (2 एम.टेक और 3 पीएच.डी.) के लिए शिक्षण से जुड़ी गतिविधियाँ संचालित की गईं। शैक्षणिक कार्यों के साथ-साथ छात्रों ने कई सह-पाठ्यक्रम गतिविधियों में भी सक्रिय भागीदारी की, जिससे न केवल उनकी सीखने की प्रक्रिया समृद्ध हुई, बल्कि उनके व्यक्तित्व के सर्वांगीण विकास को भी प्रोत्साहन मिला।
- प्रतिवेदित वर्ष के दौरान हमारे वैज्ञानिकों द्वारा प्रतिष्ठित राष्ट्रीय एवं अंतरराष्ट्रीय शोध पत्रिकाओं में 92 शोध/समीक्षा लेख प्रकाशित किए गए।
- वर्ष के दौरान कुल 13 पुरस्कार/फेलोशिप/सम्मान भारतीय कृषि अनुसंधान परिषद द्वारा मान्यता प्राप्त व्यावसायिक समितियों, अखिल भारतीय समन्वित अनुसंधान परियोजनाओं एवं अन्य संस्थाओं से प्राप्त हुईं। इसके अतिरिक्त, 08 वैज्ञानिकों को राष्ट्रीय/अंतर्राष्ट्रीय संगोष्ठियों/सम्मेलनों के दौरान सर्वश्रेष्ठ शोध पत्र प्रस्तुति के लिए प्रमाण पत्र/ प्रशस्ति पत्र प्रदान किए गए।

1 Executive Summary

The ICAR Research Complex for Eastern Region, Patna conducts strategic and applied research across five distinct thematic areas: Farming System Research including Climate Resilient Agriculture, Genetic Resource Management and Production Technologies, Natural Resource Management for Enhancing Land and Water Productivity, Livestock and Fisheries Management and Socio-Economics, Extension and Policy Research. Natural farming, integrated farming system (IFS), rice fallow management, varietal development and quality seed production, multiple uses of water, characterization and registration of indigenous livestock and participatory research application for year-round income and agricultural sustainability (PRAYAS) were a few major flagship programmes of the institute during the reporting year. Key research achievements and technology transfer activities for the reported year (2024) are given below briefly.

- One-acre and two-acre IFS models provided an annual net income of Rs 1,06,350 (BC ratio of 2.01) and Rs 2,16,628 (BC ratio of 2.05), respectively, about four times higher than that of rice-wheat cropping system.
- Energy indices of one-acre IFS model at FSRCHPR, Ranchi revealed that field crops, fodder, fruits and compost showed net positive energy gains, with fodder being the most energy-efficient (EER: 15.42). Field crops showed high energy efficiency (EER: 2.73, NEG: 24.33 GJ), whereas fruits and compost were moderately efficient (EER: 1.87 and 1.38). Vegetables and dairy recorded negative energy balances, indicating the need for optimization.
- Natural farming enhanced land use efficiency (up to 63%) and system productivity (up to 35.35 kg/ha/day) besides improving soil pH (6.13 vs 5.84), organic carbon and biological activity (DHA: 129.4 µg TPF/g/d; SMBC: 354 µg/g) at FSRCHPR, Ranchi, demonstrating its potential for sustainable crop production under low input conditions of hill and plateau region.
- An integrated approach comprising varietal (through supply of quality seeds of red gram variety 'IPA 203' and short-duration varieties of Rabi pulse/oilseed crops) and integrated crop management including conservation agriculture based interventions to rice fallow management was demonstrated in the district 'Gaya' (Bihar) on over 160 ha area of 350 selected farmers.
- In rice-fallow management trial (after 9th year), rice productivity was higher for transplanted puddled rice (TPR; 5.27 t/ha) than obtained for zero-till direct seeded rice (ZTDSR; 3.34 t/ha) and conventional-till direct seeded rice (CTDSR; 3.83 t/ha). However, TPR system adversely impacted the performance of all post-rainy pulses/oilseed crops over time.
- In a long term study on CA-based rice-wheat system, after 16th year maximum rice yield was recorded with TPR (6.24 t/ha), which was at par with CTMTR (6.08 t/ha). However, CTMTR-ZT wheat-ZT mungbean system provided a REY of 17.37 t/ha as against 12.73 t/ha under conventional rice-wheat system.
- Two high yielding, multiple stress tolerant and early maturing (115-120 days) rice varieties 'Swarna Purvi Dhan 4' (4.5-5.0 t/ha) and 'Swarna Purvi Dhan 5' (4.0-4.5 t/ha) were released and notified for direct seeding in water-limiting drought-prone rainfed areas.
- Several advance breeding lines, *viz.*, IR16L1499, IR17L1060, IR 14L157, IR 107891-B-B-1253-1-1, IR 14 L36, IR 95781-15-1-1-4, IR 97030-7-2-2-2, IR 95817-5-1-1-2 and IR18R1179, and a few released varieties 'Swarna Purvi Dhan 2', 'Swarna Samriddhi Dhan' and 'Swarna Shreya' of rice were found promising

(4.60-5.36 t/ha) for cultivation under natural farming condition.

- A new high-yielding (1.75 t/ha), biofortified (Zn content: 45 ppm), disease resistant (Fusarium wilt) and heat tolerant variety of *Desi* chickpea 'Swarna Lakshami' was released and notified for cultivation in the states of UP, Bihar, Jharkhand, Assam and WB.
- Two improved bush-type lablab bean genotypes 'RCPD 1' and 'RCPD 16' were developed through single-plant selection, tailored for eastern India's agro-climatic conditions. Both genotypes are photo-insensitive, disease-resistant and nutrient-rich, enabling them to address the problem of micro-malnutrition prevalent especially in smallholder farming community.
- Five potent arsenic-resistant PGPR strains were characterized from Bihar/West Bengal soils, demonstrating high arsenic tolerance and multi-nutrient solubilization (P, K and Zn). *Strain B007* and *S10P2* showed superior performance for mitigating arsenic in paddy.
- Machine learning was applied to predict yellow mosaic virus severity in yardlong bean. Random forest, Cubist, XGBoost, K-nearest neighbors and gradient boosting machine emerged as the five top-performing models for predicting YMD severity using visible indices.
- In-situ characterization of custard apple germplasm showed that the genotype 'CCA03' had the highest and lowest percentage of pulp and peel, respectively.
- Field screening of 11 litchi genotypes identified 'Swarna Madhu' as highly resistant (2.5% infestation) to *Conopomorpha* spp with high phenolics and tannins in pericarp and seed, showing strong negative correlations (r = -0.72 to -0.98) with fruit infestation.
- Evaluation of 34 vegetable soybean genotypes revealed 'Swarna Sugandha' as a promising high-yielding aromatic variety with early green pod harvest at 63 DAS and bold seeds (75 g/100 green seeds), supporting its potential for commercial cultivation.
- Molecular characterization of bottle gourd wilt complex identified isolates *J2* and *J4* (Garhwa) as *Fusarium oxysporum, and* isolates *J5* (Daltenganj) and *J7* (Ranchi) as *Fusarium solani* and *Fusarium Chlamydospore*, respectively.
- A total of 20.64 t quality seeds (breeder and truthfully labelled) of our own rice varieties were produced. Under the two pulse seed hubs, 28.95 t quality seeds (BS, FS, CS and TL) of recently released varieties of pulses were produced and marketed. In addition, over 3.2 t foundation seeds of three varieties (DBW 187, DBW 222 and DBW 303) of wheat were also produced and sold.
- Experiment on organic amendments for phosphorus mobilization in acidic soils showed that vermicompost (7 t/ha) and PSB (5 kg/ha) significantly enhanced microbial activity, with the highest bacterial count (40.1 $\times 10^6$ CFU/g) and dehydrogenase activity (1.20 µg TPF/g/h), leading to improved phosphorus solubilisation.
- A *multiple use of water* model covering an area of 0.65 ha was developed at the Sabajpura Farm (Patna), which combines water harvesting (2000 m^3 pond storage), groundwater recharge, drip/sprinkler irrigation, fertigation and resource conservation to enhance input-use efficiency, improve soil health and reduce GWP.
- Treatment with nano DAP fertilizer [50% DAP (conventional) and 100% N and K + seed treatment with nano DAP @ 5 mL/kg seed, first foliar spray @ 4 mL/L water at 20-25 DAT and second spray at 45 days after germination/transplanting] enhanced soil microbial activity, nutrient cycling and crop productivity in a rice-wheat system. The treatment promoted nitrogen fixation and sulphur oxidation, improving nutrient availability.
- After characterization of three indigenous populations, *viz.*, Seemanchali sheep, Kodo duck

and Mala chicken, proposals were submitted for their registration as new breeds.

- 248 cows and buffaloes, selected from the institute livestock farm and farmers' fields, were screened for subclinical mastitis by California mastitis test (CMT). Out of a total of 2677 differentially expressed genes, 2336 genes showed significant upregulation and 341 genes exhibited significant downregulation in animals suffering from subclinical mastitis.
- The total estimated value of ecosystem services provided by female Murrah graded buffalo during her lifetime was Rs 12,34,675, with provisioning services contributing Rs 8,43,214 (68.3%), supporting and habitat services Rs 5,906 (0.5%), regulating services Rs 23,355 (1.9%) and socio-cultural services Rs 3,62,200 (29.3%).
- In an experiment on seed rearing of Pangasius in biofloc system of culture, maximum average body weight, SGR (%) and percentage weight gain were achieved in the biofloc unit with 200 numbers/m^3 of fry treatment. On the other hand, maximum survival (59.07%) was achieved in the biofloc system with a stocking density of 150/m^3 of fry and minimum (32.1%) was in normal outdoor conditions with 200/m^3 of fry.
- Under the Farmers FIRST project, impactful interventions through various modules based on crops, livestock, enterprise and farming system resulted in significant gains such as higher crop yields, increased farmer incomes, improved animal productivity and enhanced food and nutritional security.
- Under the ABI project, four entrepreneurs were incubated for innovations in agri-based enterprises, while five incubatees participated in ABIGROW 2.0 training at ICAR-NAARM.
- The institute signed altogether 15 MoUs for technology transfer on grafted tomato, multi-tier cropping, planting material propagation and fruit fly traps, with expectation to generate revenue through license fees and royalties.
- The *participatory research application for year-round income and agricultural sustainability* (PRAYAS) project, which focuses on year-round income and agricultural sustainability, was implemented across all the seven eastern states of India. During the year, 41 training programs (36 short-term and 5 long-term), 14 FLDs, 6 awareness camps and one OFT were organized, benefiting 1,724 farmers of the seven eastern states.
- Both KVK Buxar and KVK Ramgarh actively implemented a wide range of field-level initiatives designed to transfer cutting-edge agricultural knowledge and technologies directly to farmers' fields. Key interventions included OFTs, FLDs, CFLDs, skill-enhancing training programs and exposure visits, enabling farmers to overcome local challenges and make measurable strides in their agricultural ventures.
- The IARI Patna Hub under ICAR-RCER carried out teaching activities for its 38 *undergraduate* (17 in the first-year, and 21 in the second-year) and five postgraduate (2 *M Tech* and 3 *Ph D*) students. In addition to their academic work, students participated in a wide range extra-curricular activities, which enriched their educational experience and aided to their personality development.
- In the reporting year, our scientists published 92 research/review papers in reputed national and internations journals.
- During the year, a total of 13 awards / fellowships / recognition were received from ICAR-recognized professional societies / AICRP / other organizations. In addition, 08 scientists also received certificate / appreciation for best paper presentation(s) during national / international conferences/symposia.

❖❖❖

2 Introduction

The eastern region of India comprises the fertile plains of Assam, Bihar, Chhattisgarh, Eastern Uttar Pradesh, Jharkhand, Odisha and West Bengal. This region accounts for 21.85% of the country's geographical area, and supports 33.62% of its population. Despite being endowed with rich natural resources such as fertile soil, abundant water and solar energy, the region continues to have low agricultural productivity and limited per capita income among farmers. Contributing factors include erratic climatic conditions, rapid population growth, land degradation, fragmented land holdings, inadequate access to quality seeds and planting materials and weak extension services. Nonetheless, the eastern region holds high potential for spearheading a *second green revolution*. This can be achieved through integrated and sustainable management of land, water, crops, horticulture, biomass, livestock, fisheries and human resources.

To harness the hidden potential, the ICAR Research Complex for Eastern Region (ICAR RCER) was established on 22nd of February, 2001 in Patna. The institute currently operates through four major divisions at its headquarters in Patna: the Division of Crop Research (DCR), the Division of Land and Water Management (DLWM), the Division of Livestock and Fishery Management (DLFM) and the Division of Socio-Economics and Extension (DSEE). In addition to these, the institute includes the Farming System Research Centre for Hill and Plateau Region (FSRCHPR) located at Plandu, Ranchi. Furthermore, the institute manages two Krishi Vigyan Kendras (KVKs), one situated at Buxar in Bihar, and the second at Ramgarh in Jharkhand. The institute addresses multifaceted challenges related to land and water resource management, crop production, horticulture, agroforestry, aquatics, fisheries, livestock and poultry, agro-processing, and socio-economic development. It aims to strengthen research capacities, and provides strategic support to enhance agricultural productivity and sustainability across the region. Geographically, the institute is located at 25°35′30″ N latitude and 85°05′03″ E longitude, at an elevation of 52 m above mean sea level.

Fig 2.1 Institute building at ICAR RCER, Patna

Mandate

- Performing strategic and adaptive research for efficient integrated management of natural resources to enhance productivity of agricultural production systems in eastern region.
- Transforming low productivity-high potential eastern region into high productivity region for food, nutritional and livelihood security.
- Utilizing seasonally waterlogged and perennial water bodies for multiple uses of water.
- Promoting network and consortia research in the eastern region.

Vision

To pre-position the institute with desired competitiveness for developing the kind of technologies needed to address the multiple vulnerabilities confronting agriculture and allied fields today and likely to confront tomorrow and thereby contribute towards production, profitability and sustainability in agriculture, particularly in view of Look East Policy of Govt. of India, for ensuring food security in the country.

The institute is committed to innovating and developing low-cost, efficient and sustainable technologies tailored to the specific requirements of agricultural development in the eastern region. Recognizing the diverse challenges faced by farmers, the institute channels its research efforts toward creating practical solutions that are accessible, affordable and environmentally friendly. The institute is dedicated to transforming this potential yet low-productive area, comprising six distinct Agri-ecological Economic Zones (AEZ), into highly productive zone. Through its research, development and extension initiatives, the institute has concentrated its major focus:

- To facilitate and promote coordination and dissemination of appropriate agricultural technologies through network / consortia approach involving ICAR institutes, Central / 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 as well as 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, and
- To perform socio-economic evaluation and impact assessment of agricultural technologies.

Finance

A summary of budget allocation and expenditure during the financial year 2024-25 of the complex is given below (Table 2.1).

Table 2.1 Financial allocation and expenditure during the year 2024-25 (Rs in lakh)

Head of Accounts	Revised Estimates				Actual Expenditure			
	Main	SCSP	TSP	NEH	Main	SCSP	TSP	NEH
Establishment Charges	2971.50	0.00	0.00	0.00	2971.50	0.00	0.00	0.00
TA	25.69	0.80	0.92	0.75	25.69	0.80	0.92	0.75
HRD	2.41	0.00	0.00	0.00	2.41	0.00	0.00	0.00
Capital	204.00	0.00	0.00	0.00	204.00	0.00	0.00	0.00
Other Charges	621.45	63.71	37.08	19.25	621.45	63.71	37.08	19.25
Total	**3825.05**	**64.51**	**38.00**	**20.00**	**3825.05**	**64.51**	**38.00**	**20.00**

Table 2.2 Staff position as on December 31, 2024

Category	Position	
	Sanctioned	Filled-in
Scientific*	79	60
Technical	61	43
Administrative	46	30
Skilled supporting staff	61	25

*including the Director

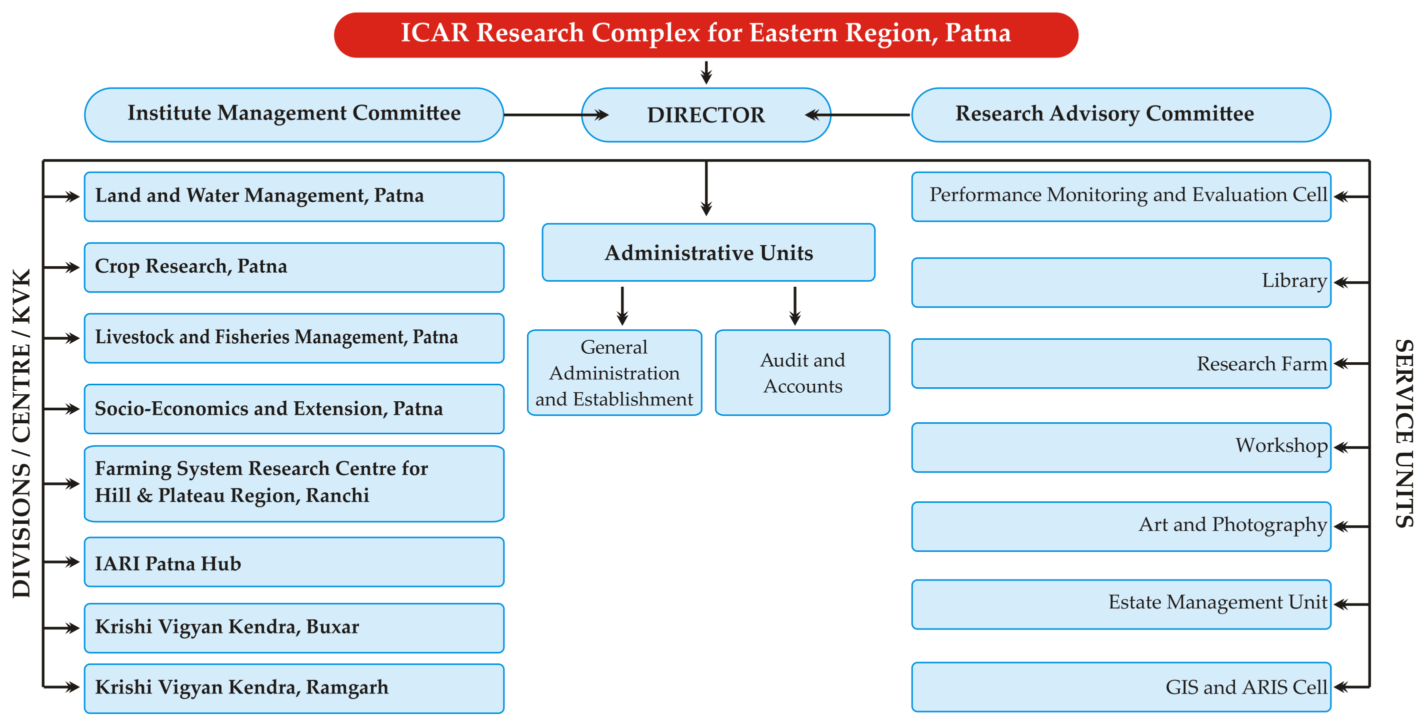


Fig 2.2 Organogram of ICAR Research Complex for Eastern Region, Patna

Research Facilities

At present, the Complex has well-equipped laboratories for plant, soil and water analysis, natural resource management and a livestock and fisheries laboratory. Details of different instruments under these laboratories are listed in the Table 2.3.

Table 2.3 List of instruments available with ICAR RCER

S. No.	Facilities	Instruments/Equipments
ICAR RCER, Patna		
1	Soil and water analysis laboratory	Atomic absorption spectrometer, Kjeldahl distillation and digestion unit, spectrophotometer, flame photometer, pH meter, EC meter, TOC analyzer and pressure plate apparatus
2	Pressurized irrigation laboratory	Solar pump, electrical pump, sand filters, screen filters, multi parameter water quality meter, sprinklers and rain-gun
3	Institute workshop	Portable arc welding machine, electric welding machine, pipe bending machine, hammer drill, bench grinder, air compressor, tachometer, digital vernier caliper, load cell, hand grinder and cut off machine
4	Plant science laboratory	UV-VIS spectrophotometer, centrifuge, deep freezer, multiparameter pH, EC meter, IR Thermometer and water purification system
5	GHG analysis laboratory	Gas chromatograph for greenhouse gas analysis
6	Conservation agriculture laboratory	Cone penetrometer, soil moisture probe, vacuum desiccator and incubator shaker
7	Fisheries laboratory	Soil water digester, water bath, trinocular research microscope with digital photographic system, hot air oven, spectrophotometer and centrifuge
8	Animal health laboratory	ELISA plate reader, laminar flow hood, refrigerated centrifuge, microtome, BOD incubator, autoclave, microscope and distillation unit
9	Livestock production and reproduction laboratory	Thermal cycler, real time PCR, BOD incubator, Gel documentation system, Gel electrophoresis centrifuge and -20°C deep freezer
10	Fisheries wet laboratory	Biofloc and eco-hatchery
11	Feed analytical & biochemical laboratory	Refrigerated centrifuge, thermal cycler, spectrophotometer, nitrogen analyzer, milk analyzer, sonicator, fat analyzer, double distillation unit, fiber analyzer and bomb calorimeter
12	Library	3211 books covering various areas of agriculture and allied sectors, 41 Indian and 51 foreign journals and periodicals, electronic scientific reference databases like CAB abstracts, Agricola, etc and online facility to access e-journals through CeRA
FSRCHPR, Ranchi		
13	Pathology laboratory	Wood microtome, phase contrast stereoscopic binocular microscope, incubators and spore trapper; a laboratory for preparation of uncontaminated mushroom spawn of different species is also available
14	Post harvest laboratory	Tray dryer, pulper, shrink wrapping machines, refractometer and centrifugal juice
15	Soil science laboratory	Lypholyzer, nitrogen analyzer, flame photometer, atomic absorption spectrophotometer and time domain reflectometry
16	Quality analysis laboratory	Infra-red gas analyzer, UV-Vis spectrophotometer, pH meter, canopy analyzer and leaf area meter
17	Molecular laboratory	Refrigerated centrifuge, thermo cycler, electrophoresis apparatus, gel documentation unit and micro-centrifuge

Allied facilities

Besides the laboratory infrastructure, the institute also has smart classes for UG and PG students, a modern auditorium and a seminar room to facilitate scientific meetings and group discussions. The farmers' hostel at Patna is well-equipped with various facilities designed to accommodate farmers, scientists and other visitors. It includes three dormitories, three air-conditioned double rooms, one air-conditioned triple room and three VIP suites.

The institute continues to offer viable, location-specific solutions to farmers through several flagship programs such as rice fallow management, development of integrated farming system (IFS) models for small and marginal farmers in irrigated, rainfed, flood-prone and plateau regions, multiple use of water to enhance agricultural productivity in eastern India, climate-resilient agriculture, ecosystem services through indigenous livestock species and the Diara farming system. Institute's major new initiatives include implementation of the Zero Hunger and Zero Technology Gap programs, the establishment of the IARI Patna Hub, the creation of an Innovation Cell and the organization of fortnightly seminars. Thirteen technologies developed by the institute have been certified by the Indian Council of Agricultural Research (ICAR), New Delhi. During the year 2024, a total of 97 research papers were published, with over 65% appearing in journals having a NAAS rating above 6.0. Against this backdrop, the Annual Report 2024 has been prepared to reflect the institute's vision and mandate. It comprises 27 chapters that collectively highlight various research and extension activities, and document the significant achievements made during the year.

3 Weather

The weather at ICAR-RCER, Patna

Weather parameters, including air temperature, humidity, rainfall, sunshine hours and pan evaporation, were collected from Agri-Met Centre, Patna. The Long Period Average (LPA) of the annual total rainfall of Patna is 1127.30 mm. However, the year 2024 experienced a significant rainfall deficit of 62.71%, with an annual total precipitation of only 707.00 mm. The annual total precipitation (707.00 mm) was distributed among 43 meteorological rainy days. The monsoon season recorded a total of 634.4 mm of rainfall, considerably lower than the normal precipitation of 951.90 mm. The month September (201.90 mm) received the highest monthly rainfall, whereas June received the lowest (74.70 mm) during monsoon season. Notably, a single-day extreme rainfall event of 89.90 mm was recorded on 6th of September.

Temperature variations throughout the year followed a seasonal pattern. The mean monthly maximum temperature ranged from 19°C in January to 39.5°C in June, making June the warmest month of the year. Similarly, the mean monthly minimum temperature varied from 9.8°C (January) to 29.15°C (June). Relative humidity showed significant fluctuations, with the lowest and the highest monthly average recorded during April (17%) and January (97%), respectively. The monthly variations in temperature and rainfall trends are illustrated in Fig 3.1. A detailed summary of the meteorological data for 2024 is presented in Table 3.1.

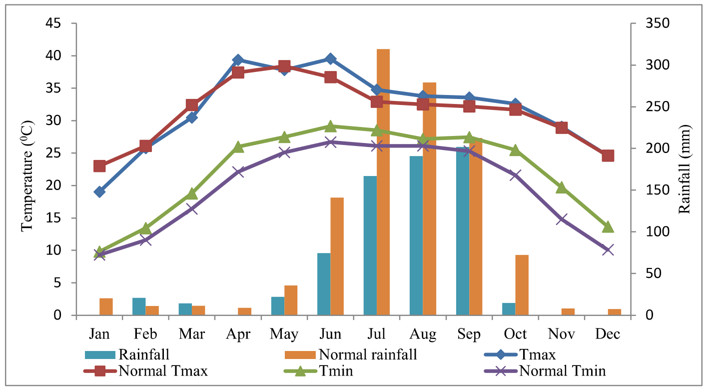


Fig 3.1 Monthly variation of temperature and rainfall during the year 2024

Table 3.1 Mean monthly weather parameters during the year 2024

Month	Temperature (°C)				Mean RH (%)	Total rainfall (mm)		Rainy days (no.)
	Max	Normal	Min	Normal		Observed	Normal	
January	19.0	23.1	9.8	9.3	88	0.4	20.4	0
February	25.8	26.1	13.4	11.6	70	21	11.1	2
March	30.4	32.4	18.8	16.4	59	14.3	11.4	2
April	39.4	37.4	26.0	22.1	31	0	9.0	0
May	37.8	38.4	27.5	25.1	54	22.2	35.6	1
June	39.5	36.7	29.2	26.7	63	74.7	141.1	3
July	34.8	32.9	28.5	26.1	79	167	319.2	11
August	33.8	32.5	27.2	26.1	81	190.8	279.0	13
September	33.6	32.2	27.5	25.3	81	201.9	212.6	9
October	32.6	31.7	25.5	21.6	78	14.7	72.3	2
November	29.1	28.9	19.7	14.8	76	0	8.2	0
December	24.6	24.6	13.6	10.1	73	0	7.4	0
Annual	31.7	31.4	22.2	19.6	69	707	1127.3	43

Source: IMD, Met Centre, Patna; Max: maximum, Min: minimum, RH: average relative humidity

Extreme weather observations recorded in 2024

Extremes in weather variables for the year 2024 have been reported in Table 3.2. The warmest and coldest days in the entire year were obtained based on daily mean temperature data, and it was found that the 9th of June was recorded as the hottest day of the year (43.5°C), while the 22nd of January was reported as the coldest day of the year (5.5°C). The maximum amount of rainfall in a day was recorded on 6th of September (89.9 mm), whereas the highest and lowest relative humidity was observed on 24th of January (97%) and on 28th of April (17%), respectively.

Climate condition at FSRCHPR, Ranchi

The mean monthly temperature data indicates seasonal variations, with morning temperatures ranging from 7.4°C in January to 23.2°C in June, while afternoon temperatures peaking at 36.3°C in June (Fig 3.2). Summer months (April-June) recorded the highest temperatures, whereas monsoon months (July-September) showed a cooling effect. Post-monsoon, temperatures gradually declined, reaching their lowest in the winter (December-January).

During the monsoon season, rainfall was the highest during August (588.1 mm) followed by July (377.8 mm) and September (363 mm) (Fig 3.3). Pre-monsoon months (February-May) show moderate rainfall, while the post-monsoon months (October-December) witness a decline, with November being the driest month. The mean relative humidity (RH) varied throughout the year, ranging from 68% in January to around 89% in June and July, indicating peak monsoon moisture (Fig 3.4).

Rainfall during the year (2024) exhibited significant variations compared to the expected normal levels. The monsoon months (July-September) received above-normal rainfall, with August recording the highest (588.1 mm vs. 319.1 mm normal) and 19 rainy days (Table 3.3). However, June had significantly low rainfall (83.1 mm vs. 249.4 mm normal), indicating a delayed or weak monsoon onset. Post-monsoon rainfall during October (104.7 mm) exceeded normal levels, while November remained completely dry. Pre-monsoon months (February–May) showed fluctuations, with March (68.9 mm) and February (55.9 mm) receiving higher-than-normal rainfall. The total number of rainy days was the highest in July and August (19 each), contributing significantly to the annual precipitation.

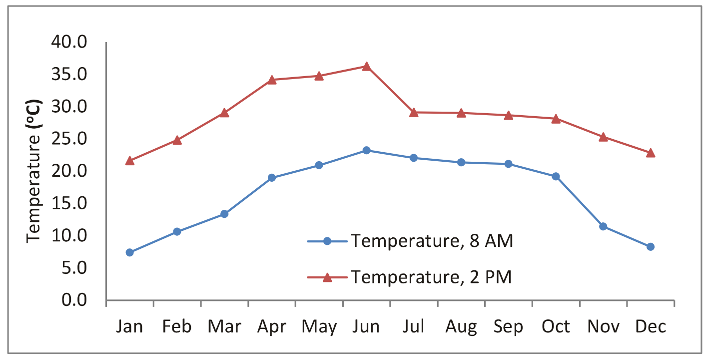


Fig 3.2 Variations in mean monthly air temperature at Ranchi

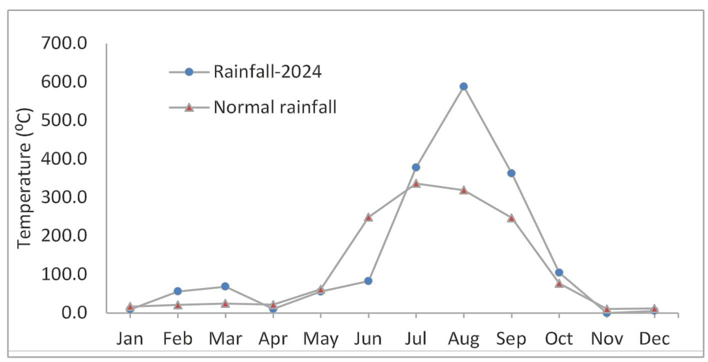


Fig 3.3 Monthly normal vs. observed rainfall for the year 2024

Table 3.2 Extreme weather events recorded during the year 2024

Weather events	Value	Date
Warmest day	T_{max}: 43.5°C	June 09, 2024
Coldest day	T_{min}: 5.5°C	January 22, 2024
Most humid day	RH: 97%	January 24, 2024
Least humid day	RH: 17%	April 28, 2024
Most rainy day	Rainfall: 89.9 mm	September 06, 2024

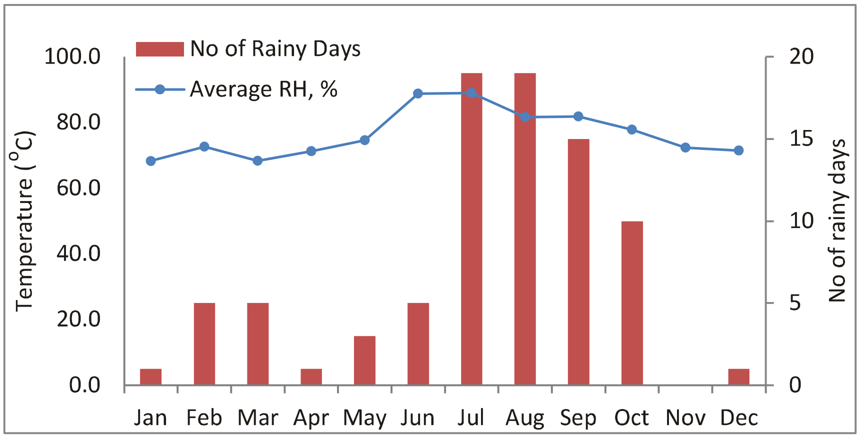


Fig 3.4 Variations in relative humidity and rainy days at Ranchi

Table 3.3 Mean monthly weather parameters recorded at Ranchi during 2024

Month	Temperature* (8 AM)	Temperature (2 PM)	Humidity# (8 AM)	Humidity (2 PM)	Rainfall (mm)	No. of rainy days
January	7.4	21.6	76.2	60.4	9.4	1
February	10.6	24.8	77.6	67.6	55.9	5
March	13.3	29.1	72.7	64.0	68.9	5
April	19.0	34.2	73.0	69.5	10.5	1
May	20.9	34.8	77.1	72.3	55.3	3
June	23.2	36.3	79.2	98.5	83.1	5
July	22.1	29.1	89.4	88.6	377.8	19
August	21.4	29.0	85.3	77.9	588.1	19
September	21.1	28.6	84.1	79.4	363.0	15
October	19.2	28.1	80.3	75.4	104.7	10
November	11.4	25.3	75.9	68.6	0.0	0
December	8.3	22.8	76.6	66.4	5.7	1

*: Temperature in degree Celsius, #: humidity in percentage

4 Climate Resilient Agriculture

Rice-fallow management through climate resilient agricultural practices

The Institute initiated a flagship program entitled "Rice-fallow management through climate resilient agricultural practices" in June 2023 to address the issues of rice fallow areas through an integrated multidisciplinary approach. The programme has been implemented at *Guleriyachak* and *Tekari* villages of Gaya district in Bihar. The project has the following objectives:

- ❖ Assessing and characterizing rice fallow areas for possible interventions, and their management based on soil, climate, soil moisture, natural resources and spatiotemporal variations
- ❖ Understanding the socioeconomic constraints and farmers' perception of the rice fallow system, and
- ❖ Developing location - specific rice fallow management strategies through an inter-disciplinary approach.

In the first year, the target area was selected, and basic information was collected from the farming community of rice fallow areas. Lack of irrigation facilities during *Rabi* season was identified by the farmers as the primary reason for keeping the land fallow after harvest of rice. A multidisciplinary team of scientists/experts in collaboration with KVK, Gaya under administrative control of BAU, Sabour (Bhagalpur) has been collectively implementing the programme, intending to green rice fallow areas through suitable RCTs, integrated crop management (ICM) and conservation agricultural (CA) management practices in a participatory approach with farmers and central/state departments' functionaries. Following interventions were carried out at the project site for greening rice fallow areas:

- ❖ Introduction of HYV of Arhar (IPA 203) to diversify the existing rice production system. Pigeonpea was promoted especially in the field bunds for additional income and climate resilience.
- ❖ Introduction of climate resilient crop varieties (Rice: Swarna Shreya; Arhar: IPA 203; Lentil: IPL 220; Chickpea: GNG 2299; Mustard: DRMR 150-35; Safflower: PBNS 12).
- ❖ Introduction of farm machinery (ZT/Happy seeder/Custom hiring centre).
- ❖ Promotion of ZT along with residue retention for Rabi crops (Oilseeds: Mustard; Pulses: Lentil and Chickpea).
- ❖ Adoption of CA / RCTs-based crop establishment and residue management practices.
- ❖ Foliar application of nutrients (2% Urea; N-P- K:: 15-15-15) at flowering/podding stage.
- ❖ Seed priming for all crops/cultivars (rice / pulses /oilseeds).
- ❖ Weed management through suitable herbicides.
- ❖ Collaborative research with other ICAR Institutes on FLDs (ICAR-DRMR/ICAR -IISS).
- ❖ Awareness program on soil moisture conservations and climate resilient practices.
- ❖ Capacity buildings and gender sensitization.
- ❖ Linkages with climate resilient agriculture (CRA) programme of govt of Bihar (GoB).

During *Kharif* season, a large area remains fallow in Gaya (25000 ha) due to inadequate rainfall and its poor distribution during the monsoon season. To address these issues, 18 farmers were selected for the demonstration of pigeonpea (arhar, cv. IPA 203) in *Kharif* 2023. Selected farmers were provided need-based training and awareness about pigeonpea production technology. This intervention was adopted by farming community in their upland and raised field bunds. The performance of arhar in rainfed conditions was good, and farmers were encouraged to cultivate this high-value crop. Similarly, short-duration pulse/oilseed crops were demonstrated during *Rabi* season to 350 farming communities for greening rice fallow areas covering over 255 acres through ICM and CA-based practices (Table 4.1). In ICM, need-based standard agronomic management practices like seed priming (soaking seed in water overnight) before sowing, seed treatment with suitable rhizobium, crop nutrition management through foliar application of 2% urea, management of pests/diseases through suitable agro-chemicals were practiced. The details of critical inputs provided to participating farmers for demonstration in rice-fallow areas are given below.

Demonstrations results showed that yields of rice (Swarna Shreya), arhar (IPA 203), lentil (IPL 220), chickpea (GNG 2299) and mustard (DRMR 150-35) were respectively 4.5-4.8 t/ha, 1.77 t/ha, 1.14 t/ha, 1.57 t/ha and 1.08-1.14 t/ha on residual soil moistures (Fig 4.1) following improved agronomic management practices at farmers' fields of project site Guleriyachak and Simuara (Tekari block) under Gaya district of Bihar (Table 4.2).

Climate driven risk and distribution of oriental fruit fly under CMIP6 projections

The Oriental fruit fly (*Bactrocera dorsalis*), an important pest of horticultural crops, was studied at seven ecologically pertinent constant temperatures (15, 18, 22, 25, 29, 32 and 35 degree Celsius) under a photoperiod of 12:12 h L:D with a relative humidity of 60 ± 10% to establish its temperature-based development. Using the *insect life cycle modelling*

Table 4.1 Crop inputs provided for greening rice fallow area at Gaya project site during 2023-25

S.N.	Crop	Variety	Quantity (kg)	Farmers (no.)	Area (acre)
2023-24 & 2024-25: *Rabi* season					
1.	Arhar (CT)	IPA 203	300	50	40
2.	Lentil (ZT)	IPL 220	800	75	50
3.	Chickpea (ZT)	GNG 2299	1600	60	50
4.	Mustard (ZT)	DRMR 150-35	100	50	50
5.	Mustard (FLD*)	DRMR 150-35	30	15	15
***Kharif* 2024**					
1.	Rice	Swarna Shreya	50	75	50
Total			**2880**	**350**	**255**

*FLD: Frontline demonstrations in collaboration with ICAR-DRMR, Bharatpur (Rajasthan)

Table 4.2 Crop yields under demonstrated plots of rice fallows at project sites under Gaya district of Bihar

Crops	Varieties	Sowing date	Harvesting date	Duration (day)	Seed yield (t/ha)	REY (t/ha)
Rice	Swarna Shreya	25-30 June	25-30 Oct	120-125	4.50-4.80	4.65
Arhar	IPA 203	22-29 July	15-26 Apr	270-275	1.77	5.68
Lentil	IPL 220	8-17 Nov	7-17 Mar	115-120	1.14	3.12
Chickpea	GNG 2299	14-24 Nov	15-26 Mar	120-125	1.57	3.82
Mustard	DRMR 150-35	6-18 Nov	28 Jan-16 Feb	115-120	1.08	2.74
Mustard*	DRMR 150-35	4-10 Nov	27 Feb-23 Mar	115-120	1.14	2.96

*FLD: Frontline demonstrations in collaboration with ICAR-DRMR, Bharatpur (Rajasthan)

Fig 4.1 Winter crops under the residual soil moisture at Guleriyachak, Gaya (Bihar)

software, *B. dorsalis* process-based phenophases models were linked with three global climate models (GCMs) and two climate change scenarios (SSP1-2.6 and SSP5-8.5). The results revealed that the lowest temperature threshold (LTT) for the development of the egg, larva, pupa, male and female of *B. dorsalis* were 9.8, 6.9, 9.7, 14.2, and 14.3°C, respectively. The temperatures between range of 26-29°C was found optimum for *B. dorsalis* survival, growth and multiplications, leading to less generation time and increased population potential. The distribution and abundance indices projected for near current climate (1970–2000) successfully fitted the identified dispersal areas of *B. dorsalis* in India (Fig 4.2). The projections under the changing climates in India indicated that the increase in temperature in future climate for *B. dorsalis* will be less suitable (~65%) for very high establishments (0.8-1.0 establishment risk index), but an increase in abundance and damage potential (16.48 to 71.39 %) is expected based on increased activity and generation risk indices. The predicted abundance and damage potential suggest that *B. dorsalis* in India will pose a considerable risk to horticultural crops in future climate scenarios.

Climate change impact studies through crop simulation models at selected locations in Bihar

Climate change has introduced a significant layer of uncertainty to agricultural productivity in India, and Bihar is no exception. This analysis, based on simulations from the DSSAT v4.6 model, evaluates the potential impact of projected climate change on

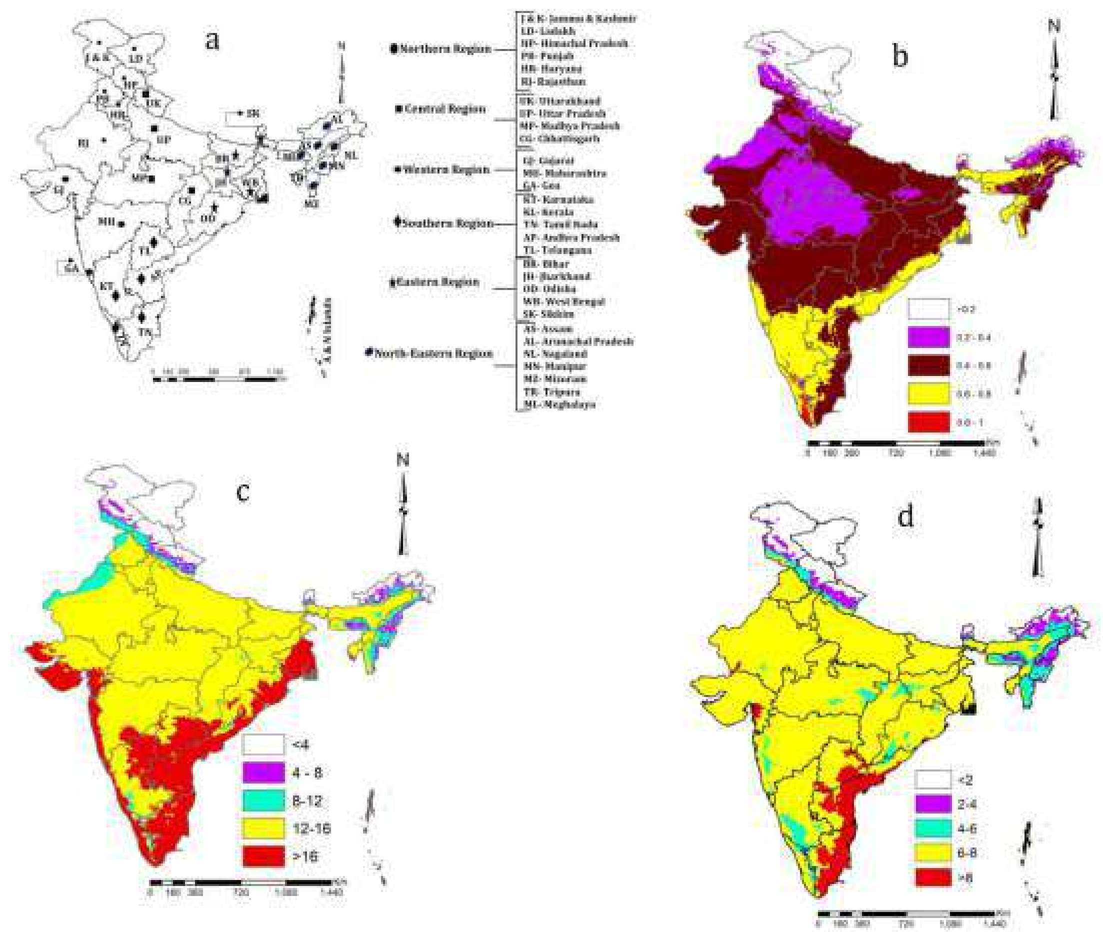


Fig 4.2 Geographical regions of India (a), showing risk for establishment (b), activity (c), and generations (d) from less suitable to highly suitable condition for projected development of oriental fruit fly based on current climatic conditions (1970-2000)

maize and chickpea yields at three representative agro-ecological locations in Bihar (Patna, Samastipur, and Sabour). Simulations were conducted under two Representative Concentration Pathways: RCP 4.5, representing a moderate emissions trajectory, and RCP 8.5, a high emissions scenario, for two time horizons—2030s and 2050s. Figure 4.3 illustrates the percent change in yield for maize and chickpea under these climate change scenarios. For maize, results indicate a consistent decline in yield across all three locations under both RCPs. In the 2030s, maize yields decline by 5-10% under RCP 4.5 and up to 13% under RCP 8.5. By the 2050s, the projected yield loss intensifies, reaching -14% to -19%, particularly under RCP 8.5 in Patna and Sabour. These declines are primarily driven by increased temperature stress, erratic rainfall, and a higher frequency of extreme events during the monsoon, factors to which maize is highly sensitive. In contrast, chickpea (rabi season pulse)-shows a more mixed response.

Under RCP 4.5 in the 2030s, yields are projected to increase slightly, particularly in Samastipur and Patna, likely due to CO_2 fertilization and moderately warmer winters that favor chickpea development. However, under RCP 8.5, chickpea yields decline modestly in most locations by the 2030s. By the 2050s, chickpea still shows some yield gain under RCP 4.5 at Samastipur, but yields decrease across all locations under RCP 8.5-most notably in Sabour, with reductions approaching 6%. This reflects the crop's growing vulnerability to terminal heat stress and shortened crop durations as warming accelerates. Overall, the study highlights that maize is more vulnerable to climate change impacts than chickpea in Bihar, particularly under high-emission pathways. Locations such as Sabour appear more sensitive, likely due to inherent agro-climatic conditions. These findings underscore the urgency for adaptation strategies, including crop diversification, climate-resilient varieties, altered sowing windows, and improved agronomic practices, to mitigate the negative effects of climate change on staple and pulse crops in the region.

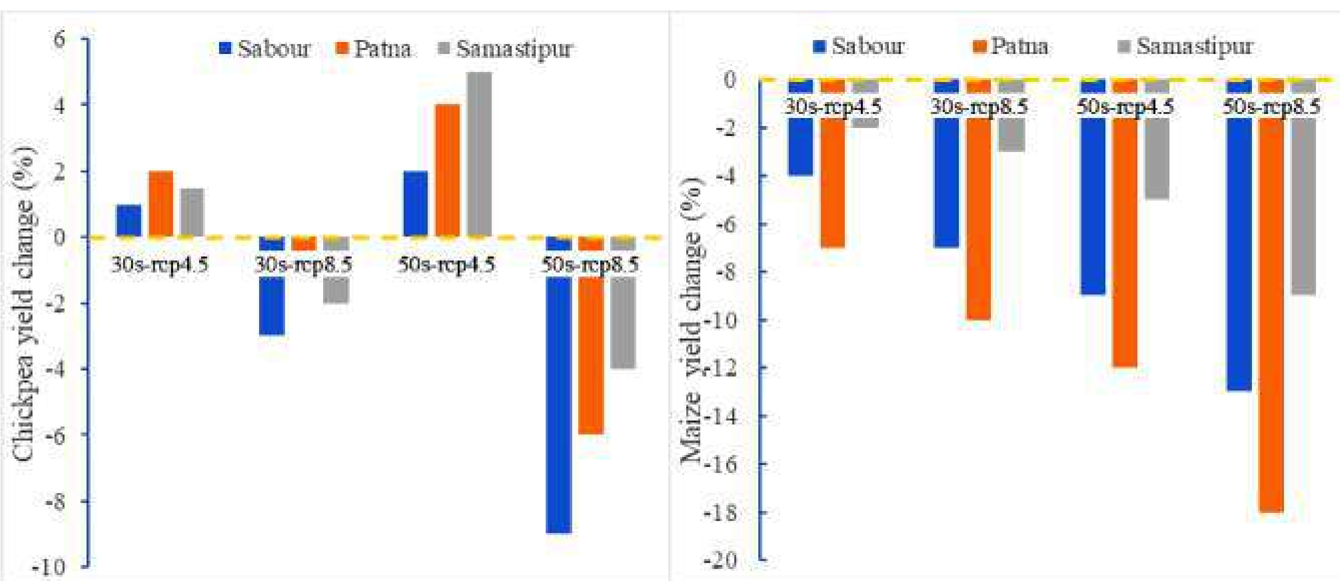


Fig 4.3 Projected percent change in the yield of maize and chickpea at three locations in Bihar (Sabour, Patna, and Samastipur) under different climate change scenarios. The scenarios include: 2030 under RCP 4.5 (30s-RCP4.5), 2030 under RCP 8.5 (30s-RCP8.5), 2050 under RCP 4.5 (50s-RCP4.5), and 2050 under RCP 8.5 (50s-RCP8.5)

5 Cereals

RICE

Release and notification of rice varieties

Two high yielding multiple stress tolerant rice varieties 'Swarna Purvi Dhan 4' (IET 29405) and 'Swarna Purvi Dhan 5' (IET 29036) have 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. 4388 (E) dated 8th of October 2024].

Swarna Purvi Dhan 4

The rice variety 'Swarna Purvi Dhan 4' has been released and notified for cultivation under direct-seeded aerobic condition in water limiting irrigated as well as a drought-prone rainfed areas of Bihar, Jharkhand, Haryana and Gujarat (Fig 5.1). This rice variety is of early duration (115-120 days), semi-dwarf, high yielding (4.5-5.0 t/ha), multiple stress (drought, disease, and insect pests) tolerant with desirable cooking quality traits It has shown desirable quality parameters like high head rice recovery (61.9%), intermediate amylose content (23.2%), and a soft gel consistency (38.7 mm). This variety has shown resistance to neck blast, and moderate resistance to leaf blast, brown spot, sheath blight, bacterial leaf blight, sheath rot and glume discoloration diseases. It is also moderately resistant to major rice pests like stem borer, leaf folder, gall midge (biotype 4M), whorl maggot and caseworm under natural condition.

Swarna Purvi Dhan 5

The rice variety 'Swarna Purvi Dhan 5' has been released and notified for cultivation under direct-seeded condition in drought prone rainfed midland to upland ecosystems of Bihar, Jharkhand, and West Bengal. This is semi-dwarf, high yielding (4.0-4.5 t/ha), early maturing (110-115 days), and multiple stress (drought, diseases, and insect pests) tolerant (Fig 5.2). It has desirable cooking quality traits, and high micronutrients, *i.e.*, zinc (25.5 ppm) and iron (13.1 ppm) contents. This variety is also suitable for direct-seeded aerobic condition. It has shown desirable quality parameters like high head rice recovery (59.7%), intermediate amylose content (21.7), alkali spreading value (ASV=5.0), and a soft GC (49.3 mm). It is resistant to neck blast and stem rot, and has moderate resistance to leaf blast, brown spot, and sheath rot diseases. It has also shown moderate resistance to major pests like stem borer, leaf folder, gall midge, and rice thrips under natural condition.

Fig 5.1 Swarna Purvi Dhan 4

Fig 5.2 Swarna Purvi Dhan 5

Nomination and promotion of rice entries and trials conducted under AICRIP programme

On the basis of performance under on-station trials, four promising advance breeding lines (RCPR 99, RCPR 102, RCPR 107, and RCPR 108) of rice were nominated (under different trials/ecology) to national AICRP trials for multi-locational evaluation during *Kharif* 2024. Moreover, three rice genotypes 'RCPR 95' (IET 30674), 'RCPR 101' (IET 31519), and 'RCPR 104' (IET 32100) were promoted from IVT to AVT-1 after first year testing during *Kharif* 2023 under national AICRP on rice programme. One rice genotype 'RCPR 84' (IET 30330) was recommended for further evaluation in AVT 2-E-DS trial (rainfed upland trial) after third year of testing during *Kharif* 2023. In addition, one rice genotype 'RCPR 94' ((IET 30651) was promoted from AVT-1 (ETP) to AVT-2 (ETP) trial after second year testing.

During *Kharif* 2024, four AICRP rice trials (AVT-2 and 1-E-TP, IVT-aerobic, AVT-2 and 1-aerobic, and AVT-2 and1-NIL and GEL) comprising 145 rice genotypes (consisting of advanced breeding lines and check varieties) were conducted at ICAR RCER, Patna (Fig 5.3). These AICRP trials were monitored by scientific representatives from ICAR-NRRI, Cuttack. The generated data will be shared with Coordinator looking after AICRP on rice.

Fig 5.3 AICRP trials on rice genotypes conducted at ICAR RCER Patna

Evaluation of rice genotypes under dry direct seeded rainfed conditions

Compared to the conventional puddled transplanted rice (PTR) method, dry DSR offers water saving by eliminating puddling and continuous ponding, reducing irrigation frequency, saving labour, and reducing emissions of greenhouse gases (methane emissions) that contribute to climate change. Keeping this in view, a field evaluation was done during *kharif* 2024 with an aim to identify drought tolerant rice genotypes suitable for dry DSR conditions in middle Indo-Gangetic Plains. One hundred seventy-three (stage-1 trial) and fifty (stage-2 trial) rice genotypes (comprising advanced breeding lines developed at IRRI, partners breeding lines, global checks, and local checks) of early maturity group were evaluated under rainfed dry DSR condition (Fig 5.4). Under Stage-1 trial, grain yield of rice genotypes ranged from 0.027-4.20 t/ha, with a mean grain yield of 1.039 t/ha. 10 genotypes (DRRH 4, IR 147501-B-B-218-B, IR 147506-B-B-44-B, IR 147506-B-B-6-B, Swarna Shreya, IR 147506-B-B-121-B, RCP 12-2, RCP 10-5, RCP 12-4 and RCPR 99) with the productivity range of 2.22-3.42 t/ha compared to check variety DRR Dhan 42 (1.24 t/ha) and IRRI 154 (1.26 t/ha) were identified as promising under stage-1 breeding trials. Under stage-2 trial, 10 other genotypes (Arize 6453 ST, RCPR 68, RCPR 70, Swarna Sukha Dhan, Swarna Shreya, IR22EL1245, RCPR 104, IR22EL1466, IR22EL1571 and IR22EL1247) with productivity range of 3.13-5.21 t/ha compared to check variety Sahbhagi Dhan (2.87t/ha) were found promising for rainfed dry DSR condition. Identified promising genotypes showed better seedling emergence, early vegetative vigour, weed suppressing /competitive ability, phenotypic acceptability and drought stress tolerance as compared to most of the check varieties.

Fig 5.4 Evaluation of rice genotypes under dry DSR rainfed condition

Evaluation of rice genotypes under direct-seeded rainfed conditions

Fifty rice genotypes (comprising advanced breeding lines and check varieties) were evaluated under dry direct-seeded rainfed condition during *kharif* 2024 (Fig 5.5). The mean and range for grain yield were 1.02 t/ha and 0.092-3.667 t/ha, respectively. Among rice genotypes, IR18R 1068 (3.66 t/ha), IR18R 1179 (3.52 t/ha), Swarna Shreya (2.34 t/ha), RCP 12-1 (2.31 t/ha), IR18R 1123 (2.24 t/ha), RCPR 68 (2.22 t/ha), RCPR 84 (2.03 t/ha), IR 97197-93-3-1-1 (2.01 t/ha), IR 107891-B-B-1216-1-1 (1.93 t/ha), IR 95781-15-1-1-4 (1.84 t/ha), RCP 10-1 (1.83 t/ha), RCPR 100 (1.70 t/ha) and Swarna Sukha dhan (1.56 t/ha) were found promising for dry direct-seeded rainfed condition, and showed better drought tolerance than the check varieties 'Sahbhagi Dhan' (1.19 t/ha), IR 64 (0.244) and 'Vandana' (0.683 t/ha). Identified promising genotypes showed better seedling emergence, early vegetative vigour, weed suppressing /competitive ability, phenotypic acceptability and drought stress tolerance than most of the check varieties.

Evaluation and identification of rice genotypes for multi-stage drought tolerance

Multi-stage drought tolerant rice genotypes are required to improve rice productivity in drought prone areas to achieve food self-sufficiency at the regional as well as national level. Under the present study, 36 rice genotypes were evaluated under multi-stage drought (MSD) in rainout shelter and non-stress (irrigated) conditions during *Kharif* 2024 (Fig 5.6). In MSD experimental field, water was provided only once on the day immediately after sowing so that the seeds could properly germinate. The non-stress experiments were maintained by applying irrigation as and when required. Grain yield of different genotypes varied from 0.412 to 2.053 t/ha, and 3.525 to 5.532 t/ha under MSD and non-stress conditions, respectively. Results of the study revealed that irrespective of genotypes, there was a

Fig 5.5 Evaluation of rice genotypes under dry direct seeded rainfed condition

significant reduction (70.73%) in mean grain yield under MSD condition. Among rice genotypes, IR18R 1068 (2.05 t/ha), RCPR 68 (2.01 t/ha), Swarna Shreya (1.96 t/ha), IR18R 1179 (1.84 t/ha), IR83929-B-B-291-3-1-1 (1.81 t/ha), IR 95781-15-1-1-4 (1.80 t/ha), IR 97046-39-2-1-2 (1.75 t/ha), IR84899-B-182-3-1-1-2 (1.73 t/ha), IR 84899-B-185-8-1-1-1 (1.68 t/ha), IR14L 613 (1.67 t/ha), RCPR 84 (1.61 t/ha) and IR18R 1123 (1.56 t/ha) were identified as promising ones for MSD tolerance.

Evaluation and identification of rice genotypes for multi-stage drought tolerance

Eight rice genotypes were evaluated under control (non-stress), vegetative stage drought (VSD), multi-stage drought (VSD+RSD), submergence, multiple submergence and combine stress (submergence + drought) conditions during *Kharif* 2024. The average grain yields of 6.24, 2.85, 1.38, 0.963, 0.731 and 0.662 t/ha were recorded under non-stress, VSD, MSD, submergence, multiple submergence and combine stress conditions, respectively. Results of the present study revealed that irrespective of the genotypes, there was a significant reduction in grain yield of rice under VSD (54.3%), MSD (77.8%), submergence (84.5%), multiple submergence (88.3%) and combine stress (89.4%) as compared to non-stress condition. Four rice genotypes (IR 96321-315-323-B-3-1-3, IR 96321-315-294-B-1-1-1, IR 96321-1447-521-B-2-1-2 and IR 96321-558-563-B-2-1-1) were found promising for different stresses either under individual or combine stresses as compared to the check variety 'Swarna Sub 1' and 'Swarna'.

Cultivar evaluation for direct - seeded rice cultivation in the eastern Indo - Gangetic Plains (DSR cultivar cafeteria)

A field experiment was conducted during *kharif* 2024 to assess the performance of 39 inbred/hybrid rice cultivars (early: 24; medium: 12; late: 3) under conventional-till direct dry-seeded conditions (DSR cultivar cafeteria). Initial status of soil (0-15 cm depth) of the experimental field was silty-clay loam (10.8% sand, 53.2% silt and 36.1% clay) in nature, low in organic carbon (0.48%) and available N (236 kg N/ha), high in available P (25.5 kg P/ha), medium in available K (277 kg K/ha) and neutral in soil reaction (pH 7.73). The experiment was laid out in a randomized complete block design with three replications. Inbred varieties 'Swarna Samriddhi Dhan' and 'MTU-7029' (Swarna) were used as Check I and II. The crop was sown on 12^{th} of June 2024 in CT direct dry-seeded (CT-DSS) condition following standard agronomic management practices (Fig 5.7, 5.8 and 5.9). The crop was planted using a seed rate of 25 kg/ha through Limit Crop Planter. At the grain filling stage, cypermethrin powder @ 2.5 kg/ha is applied to manage the infestation of Gandhi bug in short/medium duration cultivars. Data on crop yields was recorded at crop maturity. A gross plot area (24 m^2) was harvested separately for the estimation of grain and straw yields. After threshing, yields were recorded, and then it was adjusted at 12% moisture content. The salient findings are given below:

- ❖ Among the 24 tested short duration inbreds/hybrids, 'Swarna Unnat Dhan' (5.28 t/ha), followed by 'DRR 42' (5.27 t/ha) and 'Swarna

Fig 5.6 Evaluation of rice genotypes under multi-stage drought condition

Shreya' (5.09 t/ha) had significantly higher grain yield than other tested inbred ultivars. Amongst tested hybrids, 'Arize 6129' recorded maximum grain yield (4.92 t/ha).

- Hybrids (from private firms) of medium maturity duration performed better than the short duration inbreds / hybrids. Amongst the 12 medium duration inbreds / hybrids, '28P68' (6.22 t/ha) and '28P66' (6.13 t/ha) had significant high yield as compared to the remaining inbreds / hybrids within the group.
- Among the long-duration cultivars, 'MTU-7029' (Swarna: 5.57 t/ha) yielded better than 'Sabour Sampanna Dhan' (4.90 t/ha) and 'BPT 5204' (5.38 t/ha).
- The present study showed that the cultivation of medium duration inbred / hybrids like '28 P 68' (6.22 t/ha) and '28 P 66' (6.13 t/ha) having crop duration of 125-130 days could be desirable to get higher productivity and profitability than the short/long duration rice inbreds / hybrids.

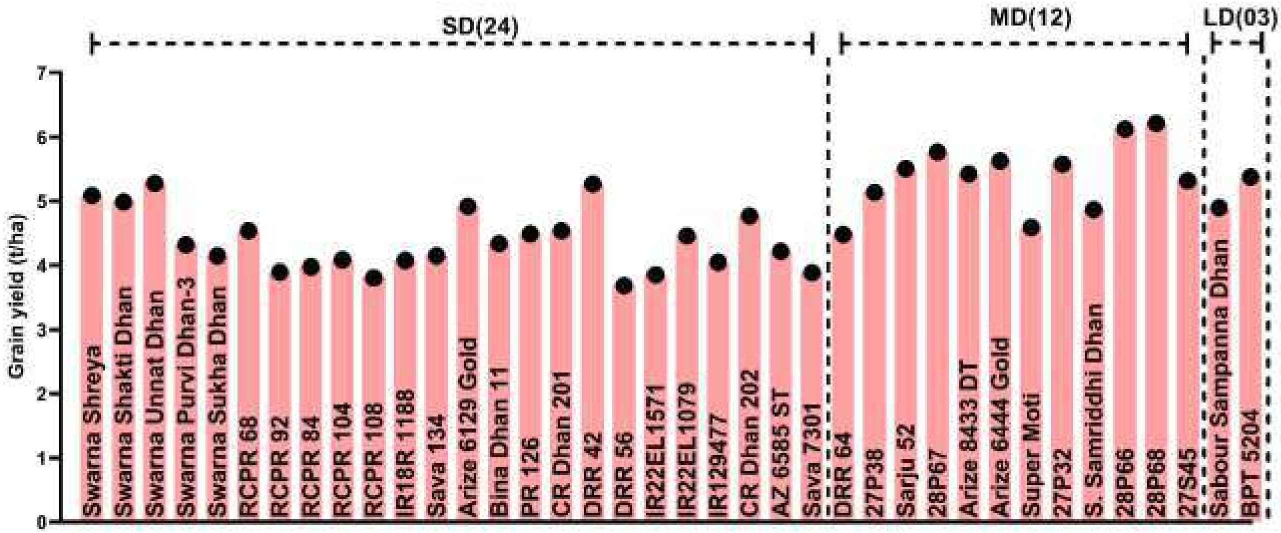


Fig 5.7 Crop yield of inbred/hybrid rice cultivars under dry-direct seeded condition in irrigated agro-ecosystem of Bihar (mean data of *Kharif* 2024, *Check 1: Swarna Samriddhi Dhan, **Check II: MTU 7029)

Fig 5.8 Inbred/hybrid rice cultivars under conventional-till direct dry-seeded condition

Fig 5.9 Field view of experimental crop at ICAR-RCER Patna

Evaluation of rice genotypes under natural farming condition

The objective of this experiment was to identify rice genotypes suitable for natural farming. In this experiment, sixty rice genotypes including advanced breeding lines and high yielding varieties were evaluated under natural farming condition during *Kharif* 2024 (Fig 5.10). The mean and range for grain yield were 4.38 t/ha and 2.51-5.36 t/ha, respectively. Among rice genotypes, IR16L1499 (5.36 t/ha), IR17L1060 (5.32 t/ha), IR 14L157 (5.25 t/ha), IR 107891-B-B-1253-1-1 (4.99 t/ha), IR 14 L362 (4.95 t/ha), IR 95781-15-1-1-4 (4.93 t/ha), IR 95885-31-2-1-2 (4.89 t/ha), IR 97030-7-2-2-2 (4.87 t/ha), Swarna Purvi Dhan 2 (4.85 t/ha), IR14L360 (4.81 t/ha), Swarna Samriddhi Dhan (4.78 t/ha), IR 95817-5-1-1-2 (4.75 t/ha), IR18R1179 (4.73 t/ha) and Swarna Shreya (4.60 t/ha) were found promising under natural farming condition.

Fig 5.10 Evaluation of rice genotypes under natural farming condition

Frontline demonstrations of rice varieties

The frontline demonstrations (FLDs) of nine rice varieties (Swarna Shreya, Swarna Shakti Dhan, Swarna Samriddhi Dhan, Swarna Sukha Dhan, Swarna Unnat Dhan, Swarna Shusk Dhan, Swarna Purvi Dhan 1, Swarna Purvi Dhan 2 and Swarna Purvi Dhan 3) were conducted during *Kharif* 2024 at 43 beneficiary farmers' (including 08 women farmers) fields covering an area of 15.4 ha in four districts (Patna, Nawada, Nalanda and Gaya) of Bihar and Ramgarh district of Jharkhand (Fig 5.11).The performance of the demonstrated rice varieties was found superior to the respective check varieties. At the farmer's field, these rice varieties recorded grain yield of 3.98-5.44 t/ha grain yield, showing 11.3-24.2% yield advantage over respective local check varieties. The feedback of the farmers revealed that they needed rice varieties which should be early/medium maturing and high yielding having tolerance to drought, diseases and insect pests and good grain qualities.

Breeder seed production of rice varieties

Breeder seeds of rice varieties 'Swarna Shreya' (17.4 q), 'Swarna Shakti Dhan' (25.2 q), 'Swarna Samriddhi Dhan' (42.3 q), 'Swarna Unnat Dhan' (30.3 q), 'Swarna Sukha Dhan' (2.00 q), 'Swarna Shusk Dhan' (4.50 q), 'Swarna Purvi Dhan 1' (2.40 q), 'Swarna Purvi Dhan 2' (4.2 q) and 'Swarna Purvi Dhan 3' (31.1 q) were produced at ICAR RCER, Patna during *Kharif* 2024. The representatives of National Seed Corporation (Patna, Bihar), Bihar State Seed and Organic Certification Agency (Patna), and scientific staff of ICAR RCER, Patna participated in the monitoring of breeder seed production of aforesaid rice varieties (Fig 5.12). Besides, small quantity of nucleus seeds (3.20 q) of two rice varieties (Swarna Purvi Dhan 4 and Swarna Purvi Dhan 5) was also produced during *Kharif* 2024. In addition, truthfully labelled (TL) seeds of rice varieties, such as 'Swarna Shreya' (13.0 q), 'Swarna Shakti Dhan' (2.00 q), 'Swarna Samriddhi Dhan' (15.0 q), 'Swarna Unnat Dhan' (2.0 q), 'Swarna Sukha Dhan' (2.00 q), 'Swarna Shusk Dhan' (5.0 q), 'Swarna Purvi Dhan 1' (2.0 q), 'Swarna Purvi Dhan 2' (2.0 q) and 'Swarna Purvi Dhan 3' (1.5 q), were also produced during *Kharif* 2024.

Fig 5.11 Frontline demonstrations of rice varieties in different districts of Bihar and Jharkhand

Fig 5.12 Breeder seed production of rice varieties and their monitoring

Seed distribution of rice varieties

More than 5 quintals quality seeds of climate resilient rice varieties 'Swarna Shreya', 'Swarna Shakti Dhan', 'Swarna Samriddhi Dhan', 'Swarna Sukha Dhan', 'Swarna Unnat Dhan', 'Swarna Shusk Dhan', 'Swarna Purvi Dhan 1', 'Swarna Purvi Dhan 2' and 'Swarna Purvi Dhan 3' were distributed to more than 300 farmers belonging to different districts of Bihar and Jharkhand for on-farm demonstrations or on-farm testing during *Kharif* 2024 (Fig 5.13).

Fig 5.13 Seed distribution of rice varieties

Maintenance and generation advancement of breeding materials

131 rice genotypes comprising advance breeding lines and released varieties of different durations were grown, purified, and maintained in rice cafeteria during *Kharif* 2024. Besides, 52 advanced rice breeding materials belonging to different generations (F_2-F_7) along with their parents were also raised. Uniform plants or lines of early and medium early duration were selected based on the plant type, panicle length, effective tiller numbers, grain features, lodging resistance, and tolerance to diseases and insect pests. The seeds of rice breeding materials were retained for further evaluation and generation advancement.

Evaluation of traditional rice germplasm for flood prone ecosystem

72 traditional rainfed lowland rice germplasm were evaluated for grain yield and other agro-morphological characters during *Kharif* 2024 under stress free normal condition. 'Jal Dubi-1' (6.6 t/ha), 'Tilbora-2' (6.2 t/ha), 'Bodbi' (6.0 t/ha) 'Balidhan' (5.7 t/ha) and 'Panjhali' (5.6 t/ha) were found to be top yielding genotypes. These genotypes were of long duration (155-160 days), tall in growth habit, and susceptible to lodging at reproductive stage. However, they appeared to possess field tolerance to insect pests and diseases. These genotypes may be promising for natural farming condition.

Thirty four accessions of traditional short-grain aromatic rice germplasm collections from eastern India were also evaluated along with two improved varieties as checks for grain yield and agro-morphological characters. 'Rajendra Kasturi' (3.95 t/ha) produced the highest grain yield, followed by 'Bhabeli Joha' (3.94 t/ha), 'Satria Malbhog' (3.65 t/ha), 'Tulsiphul-2' (3.61 t/ha) and 'Boga Joha' (3.60 t/ha).

Screening for submergence tolerance

36 elite flood tolerant rice genotypes along with submergence tolerant check 'Swarna sub-1' and susceptible check 'Swarna' were subjected to complete submergence (Fig 5.14) for 18 days at active tillering stage (10 days after transplanting of 30 days old seedlings). It was observed that all the elite genotypes showed better survival percent (>75%) than the check variety *Swarna sub-1* (68%). The susceptible check 'Swarna' showed survival percent of only 30.9.

Crop view after withdrawal of submergence

Crop condition at maturity

Fig 5.14 Screening for submergence tolerance at active tillering stage

Ecosystem Services

A significant initial step towards the quantification of ecosystem services in rice practices prevalent in MIGP's was done to develop effective responses in collaboration with the key players from government, and other organizations. The study found that ZTDSR (9583 US$ /ha/yr) followed by conventional till DSR (9398 US$ /ha/yr) had the highest ES value compared to PTR systems (8767 US$ /ha/yr) (Fig 5.15). The cumulative ecosystem value of different rice establishment methods ranged from US$ 8767 to 9583 per ha/yr. Results revealed the benefits of DSR cultivation and ZT and its significance in developing sustainable agriculture in ecologically fragile areas. The findings can help policymakers to formulate payment for ecosystem services, and appropriately incentivize the farmers to adopt sustainable agriculture practices.

Arsenic amelioration in paddy through arsenic-resistant PGPR

Phosphate solubilizing, potassium solubilizing and zinc solubilizing bacteria were isolated from soil samples of Bihar and West Bengal. These isolates were further screened down based on arsenic resistance [various doses of As(III) as $NaAsO_2$ (0-40 mM) and As(V) as $Na_2HAsO4{\cdot}7H_2O$ (0-500 mM)], their PGPR properties and colony characteristics, and five were selected for further study (Table 5.1).

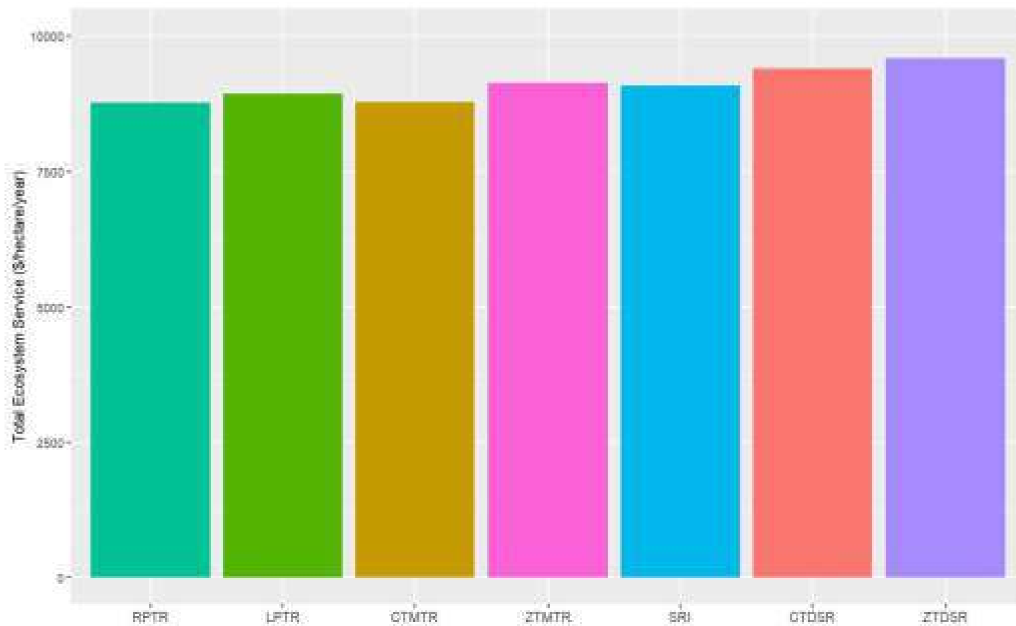


Fig 5.15 Total ecosystem services (US$ /ha/yr) under different rice establishment methods

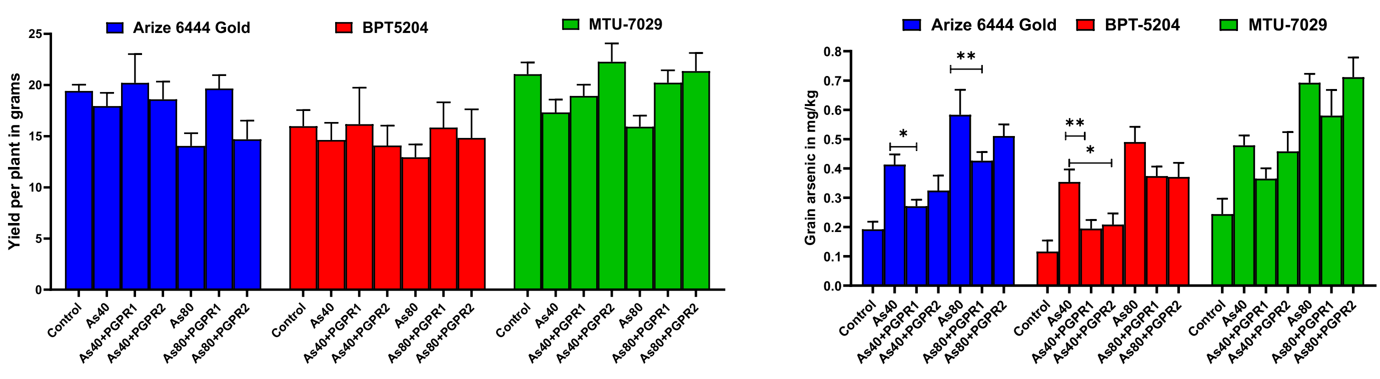
Table 5.1 Characteristics of selected arsenic-resistant PGPR

Isolates	P	K	Zn	As(III) MIC	As(V) MIC	Taxonomy
B007	+++++	+++	++	30	400	*Burkholderia sp.*
B14P1	++	+++	+ + + +	8	175	*Enterobacter sp.*
S10P2	++	++	++	10	200	*Pseudomonas anuradhapurensis*
A28P12	+	+	+++	8	450	*Enterobacter sp.*
T6NA4	++	++	++	5	200	*Staphylococcus sp.*

The pot experiment was conducted using three rice cultivars 'Arize 6444 Gold', 'BPT-5204' and 'MTU-7029' with two different soil arsenic concentrations (40 mg/kg and 80 mg/kg). Soil arsenic content has a significant impact on paddy grain yield and PGPR 1 (B007) can significantly enhance the paddy grain yield under arsenic stress. In control soil, the per plant yield was 18.82 ± 2.47 g, while under 40 mg/kg and 80 mg/kg *As* concentrations, it was 16.63 ± 1.96 g and 14.31 ± 1.67 g, respectively (Fig 5.16a). The yield decrease over control was 11.63% (statistically nonsignificant) under 40 mg/kg concentration, and 23.96% ($p < 0.05$) under 80 mg/kg soil arsenic concentration. The current study showed that soil arsenic had a negative impact on paddy yield especially under high soil arsenic levels.

Total arsenic concentration in husked rice (brown rice) was estimated under different arsenic and PGPR treatments in all the three paddy varieties. Arsenic quantification in rice grain revealed that 'BPT-5204' accumulated less arsenic in rice grain followed by 'Arize 6444 Gold' and 'MTU-7029' under different soil arsenic concentrations (Fig 5.16b). Grain arsenic content in all the three varieties was above 0.35 mg/kg (Codex Alimentarius Commission limit in husked rice) at soil arsenic concentrations of 40 mg/kg and 80 mg/kg; however, the accumulation potential was found comparatively less in 'BPT-5204'. PGPR inoculation was found to have a variety of dependent variable impacts on arsenic accumulation in rice grain under 40 mg/kg and 80 mg/kg *As* concentrations. In 'BPT-5204', PGPR1 and PGPR2 both significantly reduced the grain arsenic content below 0.35 mg/kg over the control (As40) when soil arsenic was 40 mg/kg. Whereas only PGPR1 significantly reduced the grain arsenic content below 0.35 mg/kg over control (As40) in 'Arize gold 6444'. Moreover, only PGPR 1 was found to significantly reduce soil arsenic content under 80 mg/kg soil arsenic content in 'Arize 6444 Gold'. Therefore, this study showed that the PGPR-mediated amelioration of arsenic in rice grain depends both on the paddy variety and PGPR strains.

GHGs (CH_4 and N_2O) were estimated in control and arsenic-amended pots with three different paddy varieties at different time intervals. The overall results (without considering the varietal response) indicated that the paddy in the control group (without arsenic amendment) had the highest methane emission (in kg/ha) at a concentration of 26.2 kg/ha, while the lowest methane emission was found under the 80 mg/kg arsenic amendment. This showed that total arsenic concentration in soil decreases the methane emission in paddy. At the variety level, 'MTU-7029' had the highest emission under control followed by 'Arize 6444 Gold' and 'BPT-5204'. When it came to nitrous oxide emissions,



(a) **(b)**

Fig 5.16 (a) Per plant yield of different paddy varieties under arsenic and PGPR treatments**; (b)** Grain total arsenic concentration in husked rice (brown rice) in different paddy varieties under arsenic and PGPR treatments the control condition (without arsenic amendment) had the highest emission, whereas the 40 mg/kg treatment had the lowest emission (Table 5.2). The observed trend of N_2O emission was: control > 80 mg/kg > 40 mg/kg. 'MTU-7029' had the highest global warming potential (GWP) followed by 'Arize 6444 Gold' and 'BPT-5204' under existing soil arsenic levels (Table 5.3). It was interesting to notice that GWP of these varieties decreased with increasing soil arsenic concentration.

Evaluation of nano DAP fertilizer on the performance and yield of rice and wheat crops

A field experiment was conducted from 2021 to 2024 to assess the impact of nano DAP fertilizer on the growth, grain yield and soil health under rice-wheat cropping system. After three years, soil samples were analyzed to evaluate microbial diversity under different phosphorus-treated plots. The experiment comprised ten treatments, ranging from *no* phosphorus application to *varying* combinations of conventional and nano DAP treatments. For metagenomic analysis, four treatments were selected, and designated as follows: C: 0% P and 0% Basal N (no basal DAP), 100% N and K (control); T1: 100% NPK (recommended dose of fertilizer); T2: 50% DAP (conventional) and 100% N and K; T3: 50% DAP (conventional) and 100% N and K + seed treatment with nano DAP @ 5 ml/kg seed, first foliar spray @ 4 ml/L water at 20-25 DAT, and second spray at 45 days after germination/transplanting. The initial soil had a silty loam texture with a pH of 7.34, Walkley-Black carbon of 0.53%, available N of 170 kg/ha, available P of 64.36 kg/ha, available K of 168 kg/ha, bulk density of 1.61 Mg/m^3, and DTPA-extractable Fe and Zn concentrations of 31.7 mg/kg and 0.86 mg/kg, respectively. All the treatments (including control) were replicated three times following a randomized complete block design.

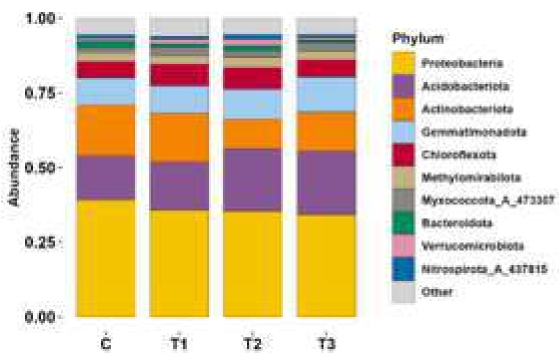
Microbial community analysis revealed that Proteobacteria, Acidobacteriota and Actinobacteriota were the dominant phyla across all phosphorus treatments, followed by Gemmatimonadota, Chloroflexota and other minor bacterial groups (Fig 5.17a). Proteobacteria, the most dominant phylum, plays a crucial role in nutrient cycling, organic matter decomposition, and plant growth promotion. Its stable abundance across treatments suggests microbial resilience to phosphorus inputs and nano DAP applications. Functional predictions of the bacterial community, conducted using FAPROTAX (Fig 5.17b), further highlighted treatment-specific variations in microbial processes. The control (C), which received no basal phosphorus (DAP), exhibited low functional gene abundance related to denitrification, nitrification and organic matter degradation compared to the fertilized treatments. T1 (100% NPK) favoured denitrification and nitrate reduction, which may increase nitrogen loss through gaseous emissions. Notably, treatments that received 50% basal DAP (T2 and T3) promoted nitrogen fixation and sulphur oxidation, potentially enhancing nutrient cycling. Application of nano DAP showed no negative impact on most other important processes.

Table 5.2 Methane and Nitrous oxide emission at different *As* levels (kg/ha)

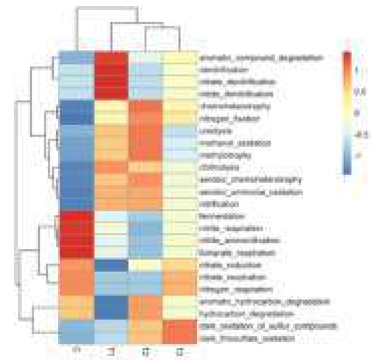
Treatments	BPT-5204		Arize 6444 Gold		MTU-7029	
	CH_4	N_2O	CH_4	N_2O	CH_4	N_2O
Control	24.86	0.74	25.57	0.96	28.06	0.93
40 mg/kg	23.94	0.44	22.13	0.65	23.20	0.63
80 mg/kg	21.71	0.69	20.25	0.72	20.63	0.84

Table 5.3 Global warming potential (kg CO_2e) of varieties under different Arsenic levels

Treatment	BPT-5204	Arize 6444 Gold	MTU-7029
Control	892.43	971.27	1032.50
40 mg/kg	785.71	792.79	815.76
80 mg/kg	792.02	732.41	800.71



(a)



(b)

Fig 5.17 Histogram of relative abundance of dominant bacteria, **(a)** at phylum level, and **(b)** bacterial community functional predictions using FAPROTAX across treatments

WHEAT

Evaluation of wheat genotypes under natural farming condition

The objective of this experiment was to identify wheat genotypes to fit into rice-wheat cropping system for cultivation under natural farming condition. A total of 27 wheat genotypes were evaluated under natural farming condition during 2023-2024 (Fig 5.18). The range of genotypes for grain yield varied from 1.351 to 3.192 t/ha with the mean value of 2.087 t/ha. Among wheat genotypes, 'HD 2046' (3.19 t/ha), 'PBW 826' (2.83 t/ha), 'HD 3386' (2.81 t/ha), 'DBW 222' (2.69 t/ha), 'DBW 17' (2.61 t/ha), 'HD 2987' (2.61 t/ha), 'HD 3086' (2.50 t/ha) and 'HD 3226' (2.49 t/ha) were identified as promising for natural farming condition.

Fig 5.18 Evaluation of wheat genotypes for natural farming condition

Quality seed production in wheat

Over 3.2 t foundation seeds of three varieties (DBW 187, DBW 222 and DBW 303) of wheat were produced at our own farm. These seeds were sold to important stakeholders including farmers.

MAIZE

Rearing diets for growth and reproduction of *fall armyworm*

Larval, pupal and adult development period, survival rate, parameters of life table and nutritional indices of fall armyworm (*Spodoptera frugiperda*) were assessed on maize-artificial diet (maize up to 3rd instar, and artificial diet there after), artificial diet, maize and castor leaves under laboratory conditions. Egg to adult preoviposition development time on maize-artificial diet (27.78 ± 0.31 days) was significantly lower than that on other diets (Fig 5.19). Furthermore, its (fall armyworm) fecundity on maize-artificial diet was significantly higher than on the artificial diet, maize and castor leaves. The values of finite rate of increase (λ) and intrinsic rate of increase (r) were highest on the maize-artificial diet at 0.176 per day and 1.193 per day, respectively as compared to others. The values of nutritional indices such as *relative growth rate* (RGR) and *relative consumption rate* (RCR) were substantially superior for the armyworm fed on maize-artificial diet, artificial diet and maize leaves than for larvae fed on castor leaves. Growth and reproduction parameters values showed that the larvae reared after successive feeding on maize-artificial diet were the most suitable.

FINGER MILLET

Evaluation, characterization and identification of high yielding finger millet genotypes for eastern India

A preliminary evaluation of 138 finger millet germplasm accessions of eastern India received from ICRISAT, Hyderabad was conducted under direct seeding along with four improved varieties as local check, *viz.*, RAU-3, RAU-8, BR-407 and Rajendra Madua-1. The germplasm accessions with early duration and high seed yield were identified (Table 5.4). These accessions will be further evaluated to ascertain their real worth.

AICRP trials

Durng the year, ICAR-RCER, Patna was included as a *voluntary centre* under AICRP on finger millet. One *initial variety trial* (IVT) with 26 genotypes and one *released variety trial* (RVT) with 44 genotypes of finger millet were conducted during *Kharif* 2024; the trial data were submitted to IIMR, Hyderabad. In the RVT, the performance of top 10 entries is presented in Table 5.5

Screening of finger millet germplasm against diseases

Seventy genotypes of finger millet were planted at the main research farm during July 2024, and were screened for resistance to diseases. Four diseases, *i.e.*, foot rot, sheath rot, leaf spot and smut, were found to be predominant at the maturity stage (Fig 5.20). The incidence of foot rot and leaf spot was significantly higher than the remaining two diseases. Incidence of foot rot varied from 0 to 60%.

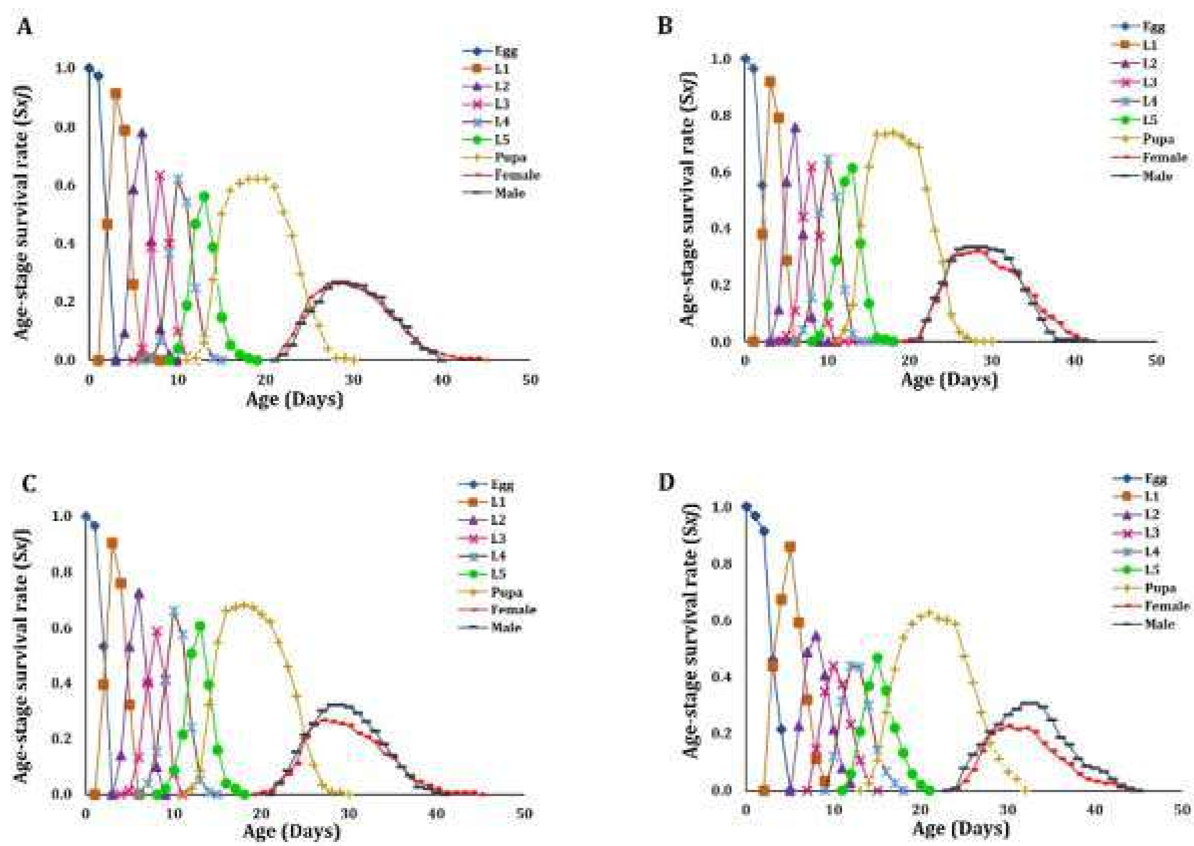


Fig 5.19 Age-stage specific survival rate (S_{xj}) of fall armyworm reared on (A) artificial diet, (B) maize-artificial diet, (C) maize leaves, and (D) castor leaves

Table 5.4 Performance of promising finger millet germplasm accessions during *Kharif* 2024

Genotypes	Days to 50% flowering	Plant height (cm)	No. of ear bearing tillers	1000 seed weight (g)	Harvest index (%)	Seed yield (q/ha)
Early maturing germplasm accessions						
IE-169	60	82.6	7.8	2.24	22.6	15.6
IE-175	61	74.0	3.8	2.20	29.8	16.9
IE-224	63	105.0	4.8	2.42	20.9	27.9
IE-184	66	73.6	4.4	2.32	25.6	18.9
IE-509	68	89.2	5.2	2.32	14.2	17.3
Germplasm accessions with high grain yield						
IE-546	93	119.4	8.0	2.30	19.0	33.3
IE-510	85	127.8	8.0	1.98	7.4	26.7
IE-678	94	110.8	8.0	2.74	8.5	25.8
IE-3121	89	127.0	9.6	2.06	9.7	24.9
IE-680	102	114.6	5.2	2.20	9.9	24.3
Improved varieties as check						
RAU-3	69	106.8	6.7	2.15	18.4	12.5
RAU-8	85	108.0	6.8	2.09	14.9	20.7
BR-407	87	110.5	7.8	2.22	15.6	11.9
Rajendra Madua-1	84	113.2	7.5	2.13	10.8	25.3

Table 5.5 Performance of top ten entries in RVT of AICRP on finger millet (*Kharif* 2024)

Genotypes	Days to 50% flowering	Plant height (cm)	No. of ear bearing tillers	No. of ears/plot	1000 seed weight (g)	Harvest index (%)	Seed yield (q/ha)
R-23-3035	91	116.8	4.0	242	3.29	28.24	30.6
R-23-3054	88	113.0	3.8	228	2.92	24.31	25.0
R-23-3052	95	111.8	4.4	148	2.80	22.97	21.2
R-23-3044	83	110.9	4.6	246	2.79	24.56	20.4
R-23-3064	79	114.1	5.5	335	2.38	18.59	19.7
R-23-3948	68	98.0	4.3	279	2.61	22.61	19.0
R-23-3136	86	103.3	4.3	228	2.78	15.80	18.3
R-23-3055	90	129.5	4.8	196	2.79	14.93	18.1
R-23-3135	75	111.6	5.4	255	2.35	23.22	17.9
R-23-3028	88	111.4	6.3	214	2.60	20.71	17.6

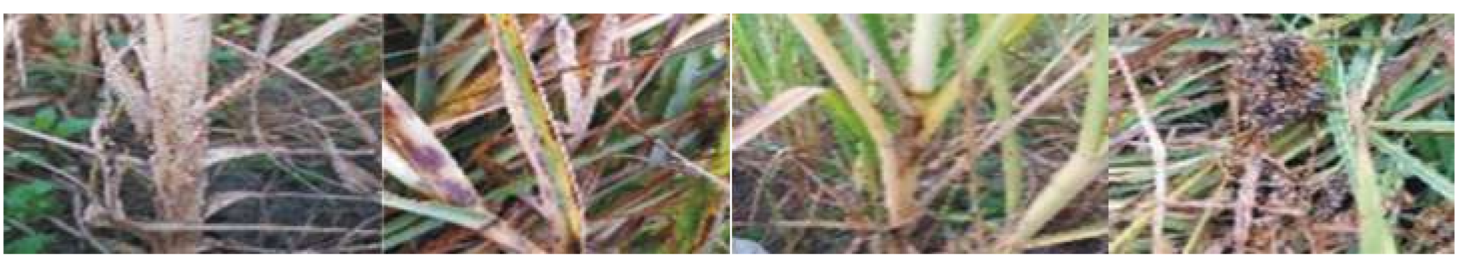


Fig 5.20 Diseases of Finger millet observed at the main farm; (a) foot rot, (b) leaf spot, (c) sheath rot, and (d) Smut

6 Pulses

Notification and release of 'Swarna Lakshami

'Swarna Lakshami' (DBGC 3), a *Desi* chickpea variety derived from a cross 'ICC 13124' × 'WR 315', was notified [S.O. 1560 (E), dated: March 26, 2024] and released for cultivation in the north-east plain zone (NEPZ; eastern UP, Bihar, Jharkhand, Assam and WB) for timely sown irrigated condition. The variety recorded an overall mean yield of 1750 kg/ha weighted over 15 locations in the national AICRP trials under timely sown irrigated conditions of the NEPZ. However, under well managed condition, the variety has yielded over 2800 kg/ha in the demonstration plots at this institute (Fig 6.1). Besides, under late sown condition, it also maintained satisfactory yield level (> 1500 kg/ha) owing to heat stress tolerance. It has an excellent grain color, size and shape, having an average 100-seed weight of 21.27 g and high '*Dal recovery ratio*' (> 0.78). Seeds of the variety are rich in protein (20.86%), Zn (46.25 ppm) and Fe (53.6 ppm) contents. The variety is resistant to Fusarium wilt, and moderately resistant to dry root rot as well as collar rot. The presence of waxy-like substances on the upper leaf surface and double pod/peduncle are the main diagnostic characteristics of this variety. The variety is well suited to rice-chickpea cropping sequence of the north-east plains.

Performance of advance breeding lines in the state varietal trial (SVT)

- The genotype 'DBGC 1' (Pusa 256 × WR 315) of chickpea excelled all other genotypes, and was promoted for the next stage of testing during 2024-25.
- Another chickpea entry 'RCEC 6003' also performed well in the first year of testing, and was recommended for further evaluation during 2024-25.
- In lentil, the performance of a genotype 'DBGL 105' was rated good, and recommended for the next stage of evaluation during 2024-25.

Fig 6.1 'Swarna Lakshami' (DBGC 3) - a double podded variety of *desi* chickpea

- In chickpea, a new entry 'RCEC 3' (Pusa 256×ICC 4958) was contributed to the SVT for evaluation during 2024-25.

Station trial

Pigeonpea: A pigeonpea trial under the institute funded project "*Development of high moisture tolerant pigeonpea and its agronomic practices for eastern India*" was conducted during 2023-24 to assess the yield potential of newly developed moisture tolerant pigeonpea lines. These three test lines (ICARPP 01, ICARPP 02 and ICARPP 03) were grown in a randomized complete block design (RCBD) in three replications along with an early (UPAS 120), three medium duration (NDT 1, NDT 5 and NDT 6) and three long-duration (Bahar, MAL 13 and MA 6) checks. It was interesting to note that the maturity duration of the test lines was matching with the long-duration check varieties. However, none of the test lines yielded even at par with the best yielding check variety (MA 6). Details of the trial are mentioned in the Table 6.1.

Table 6.1 Performance of moisture tolerant lines in the station trial during the year 2023-24

Genotypes	Yield (t/ha)	100 seed wt (g)	Maturity duration (day)
ICARPP 01	1.39	8.97	253
ICARPP 02	0.79	7.75	255
ICARPP 03	1.57	8.22	254
UPAS 120 (EC)	1.00	8.45	170
NDT 1 (MC)	1.60	8.20	253
NDT 5 (MC)	1.38	9.40	254
NDT 6 (MC)	0.62	7.40	255
Bahar (LC)	1.96	10.94	253
MAL 13 (LC)	1.29	9.59	253
MA 6 (LC)	2.11	11.18	253
LSD (P=0.05)	0.15	0.20	3.10

EC: early check, MC: medium duration check, LC: long-duration check

***Lentil*:** A station trial was conducted to assess 10 breeding lines, which were selected from breeding materials procured from ICARDA. These lines were grown in RCBD along with two checks (HUL 57 and IPL 220). Each entry in a block was grown in six rows (row length of 4 m) with an inter row spacing of 30 cm. Yield data revealed that none of the test entries excelled the best check 'HUL 57' (1.84 t/ha); however, one entry (74004) yield at par with the second check 'IPL 220' (1.55 t/ha). Details are mentioned in the Table 6.2.

Under the NFSM funded project "*Building lentil growing community resilience by the development of climate smart lentil varieties through farmers' participatory interventions*", a trial comprising 100 advance breeding lines was conducted in four blocks with three checks (IPL 220, IPL 314 and IPL 534) following augmented design. Each line was grown in a plot of three rows (row length of 3 m) at an inter row spacing of 20 cm. In block-1, only one test line out-yielded the best check 'IPL 316' (2.5 t/ha). In block-2, none of the test entries excelled the best check (IPL

Table 6.2 Performance of selected breeding lines of lentil in the station trial (2023-24)

Genotypes	Yield (t/ha)	100 seed wt (g)	Maturity duration (day)
70004	1.13	2.22	122
70032	0.94	2.53	117
70039	1.18	2.34	122
70043	0.87	4.63	119
70053	0.92	2.29	123
70059	1.08	2.90	115
70060	0.75	2.93	119
70061	0.93	2.85	120
74004	1.46	2.23	120
74005	1.10	2.49	125
HUL 57	1.84	2.03	115
IPL 220	1.55	1.96	118
LSD (P=0.05)	0.10	0.15	2.90

316; 2.5 t/ha). In block-3, two checks (IPL 316 and IPL 220) recorded the same yield level (2.22 t/ha), and only one test entry significantly yielded better than these two checks. A total of two test entry out-yielded the best check (IPL 220; 2.28 t/ha) in the fourth block. Out of the 100 test entries, a total of six lines showed susceptible reaction to *Stemphylium blight* under field condition. The results of preliminary yield trials indicated limited scope of genetic enhancement for yield in the existing set of breeding materials.

***Grass pea*: A station trial comprising nine treatments including two checks (Ratan and Mahateora) was conducted following RCBD at recommended plant spacing. The seven test lines were selected from advance breeding materials developed for low ODAP content at ICARDA. Each entry was replicated thrice, and was grown in six rows (row length of 4 m) in each block with an inter row spacing of 30 cm. Yield data revealed that all the test entries except '75022' significantly excelled the best check 'Ratan' (1.91 t/ha). Details are mentioned in the Table 6.3.

***Chickpea*: A state varietal trial of chickpea was conducted during the year 2023-24. A total of 13 coded entries were received from the state coordinator, BAU, Sabour. The trial was conducted in the RCBD at the specified spacing and replication. The yield of entries varied from 2.54 t/ha (SVT 2 & SVT 13) to 3.40 t/ha (SVT 10). 100-seed wt showed wider variation than that of yield and maturity duration. Details are mentioned in the Table 6.4.

Maintenance of promising genotypes of cool season pulses

A number of promising genotypes of *Desi* (DBGC 1, DBGC 2, DBGC 3 and DBGC 4) as well as *Kabuli* (RCECK 17-2 & RCECK 17-4) chickpeas, lentil (DBGL 62, DBGL 105, DBGL 135 and RCEL 19-1) and grass pea (RCEGP 17-2) were multiplied during the crop season 2023-24 for further use in the forthcoming season.

Demonstration

Demonstration of seven chickpea varieties, namely 'Swarna Lakshami', 'Sabour Chana 1', 'Pusa 3043', 'GNG 2207', 'GCP 105', 'PBG 9' and 'KPG 59', was conducted at the main farm, each in about 120 m^2 area. Yield of the varieties varied from 1975 kg (PBG 9) to 2983 kg (Swarna Lakshami). 'Swarna Lakshami', which was released for cultivation in the north-east plains during March 2024, showed decisive superiority over all the previously released chickpea varieties for yield and other consumers' preferred traits.

Table 6.3 Performance of selected breeding lines of grass pea in the station trial (2023-24)

Genotypes	Yield (t/ha)	100 seed wt (g)	Maturity duration (day)
75016	2.49	7.87	133
75017	2.64	7.58	132
75022	1.91	8.80	133
75024	2.24	8.02	132
75040	2.34	8.34	133
75046	2.28	7.28	132
75049	2.43	7.93	131
Ratan	1.91	7.82	132
Mahateora	1.68	7.35	127
LSD (P=0.05)	0.25	0.81	1.2

Pulse seed hub

Under the aegis of NFSM funded mega project on "Creation of seed hubs for increasing indigenous production of pulses in India", breeder seed production (BSP) of pigeonpea (IPA 203) and chickpea (Pusa 3043 and GNG 2207) was taken up at ICAR RCER, Patna during the year 2023-24. BSP of the aforementioned varieties was monitored by a team comprising the sponsoring breeder, scientists from RPCAU, Pusa, and representatives from NSC and BSSOCA, Patna (Fig 6.2). The "Nucleus" seed of a newly released chickpea variety 'Swarna Lakshami' was also produced in sufficient quantity. In lentil, breeder and certified seeds of a biofortified variety 'IPL 220' was produced. In addition, quality seeds (F/S and T/L) of mungbean (Virat, Shikha, IPM 2-3, IPM 2-14 and Samrat) were also taken up at ICAR RCER, Patna. At KVK, Buxar, quality seed production of red gram (IPA 203), chickpea (GNG 2299 and GNG 2207) and lentil (IPL 220) was taken up in the participatory mode. Details of the quality seeds produced are mentioned in the Table 6.5.

Table 6.4 Performance of chickpea breeding lines in the state varietal trial (2023-24)

Genotypes	Yield (t/ha)	100 seed wt (g)	Maturity duration (day)
SVT 01	2.90	27.96	135
SVT 02	2.54	28.91	135
SVT 03	2.82	21.41	134
SVT 04	3.19	29.34	130
SVT 05	3.25	14.96	137
SVT 06	3.07	28.38	135
SVT 07	3.23	24.14	134
SVT 08	3.15	25.87	131
SVT 09	2.52	19.67	134
SVT 10	3.40	27.98	130
SVT 11	3.30	21.04	137
SVT 12	2.76	27.58	135
SVT 13	2.54	30.18	130
LSD (P=0.05)	0.13	1.80	2.11

Fig 6.2 BSP monitoring of chickpea (GNG 2209) and pigeonpea (IPA 203) varieties

Table 6.5 Quality seeds of pulses produced under pulse seed hubs (2023-24)

Crop	Variety	Class of Seed	Seed production (q)
Mungbean	Virat	F/S	08
	IPM 2-14	F/S	03
	Shikha	F/S T/L	05 2.5*
	Samrat	T/L	06
Chickpea	Pusa 3043	B/S	10
	GNG 2299	T/L C/S	1.0 29.0*
	GNG 2207	B/S, F/S F/S, C/S	08 29.0*
	Swarna Lakshami	Nucleus	10
Lentil	IPL 220	B/S F/S, C/S & T/L	20 90*
	PL 8	TL	05
Pigeonpea	IPA 203	B/S F/S, T/L	25 35*
	IPA 206	T/L	03
		Total	289.50

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

Morpho-biochemical and molecular characterization of segregating litchi population

A collection of 40 litchi seedlings, raised at FSRCHPR, Ranchi, was analysed using distinctness, uniformity and stability (DUS) guidelines to identify and validate genome-wide SSRs markers and characterize the segregating litchi population based on morphological, biochemical and genome-wide SSRs. The results showed a significant variation for leaflet length and width, rachis length, petiole length, seed shape, seed length, seed width, inflorescence length and width, fruit length and width, fruit pulp content (%), fruit weight, shape of fruit shoulder, shape of fruit tip, TSS, titratable acidity (%), ascorbic acid content, antioxidant activity, total phenolic content, reducing sugar, non-reducing and total sugar content (%).

A total of 150 SSR primers was selected from the whole genome sequence of litchi using *Krait software* from which 50 single-band amplified primers were selected for characterization. Among these, 26 primers exhibited polymorphism. SSR profiling showed an average number of 3.31 alleles per locus, with PIC values ranging from 0.16 to 0.57. Cluster analysis grouped the litchi germplasm into two major clusters; cluster-1 contained ICAR-RCER-LS-19/7 and 6/4 while the rest fell under Cluster-2 (Fig 7.1). Principal component analysis (PCA) indicated that PC1, PC2, and PC3 accounted for 31.80 % of the variation, while the top 10 PCs explained 71.08 % of the total variation. This new set of SSR markers proved highly informative, serving as a valuable DNA marker resource for future molecular research in litchi.

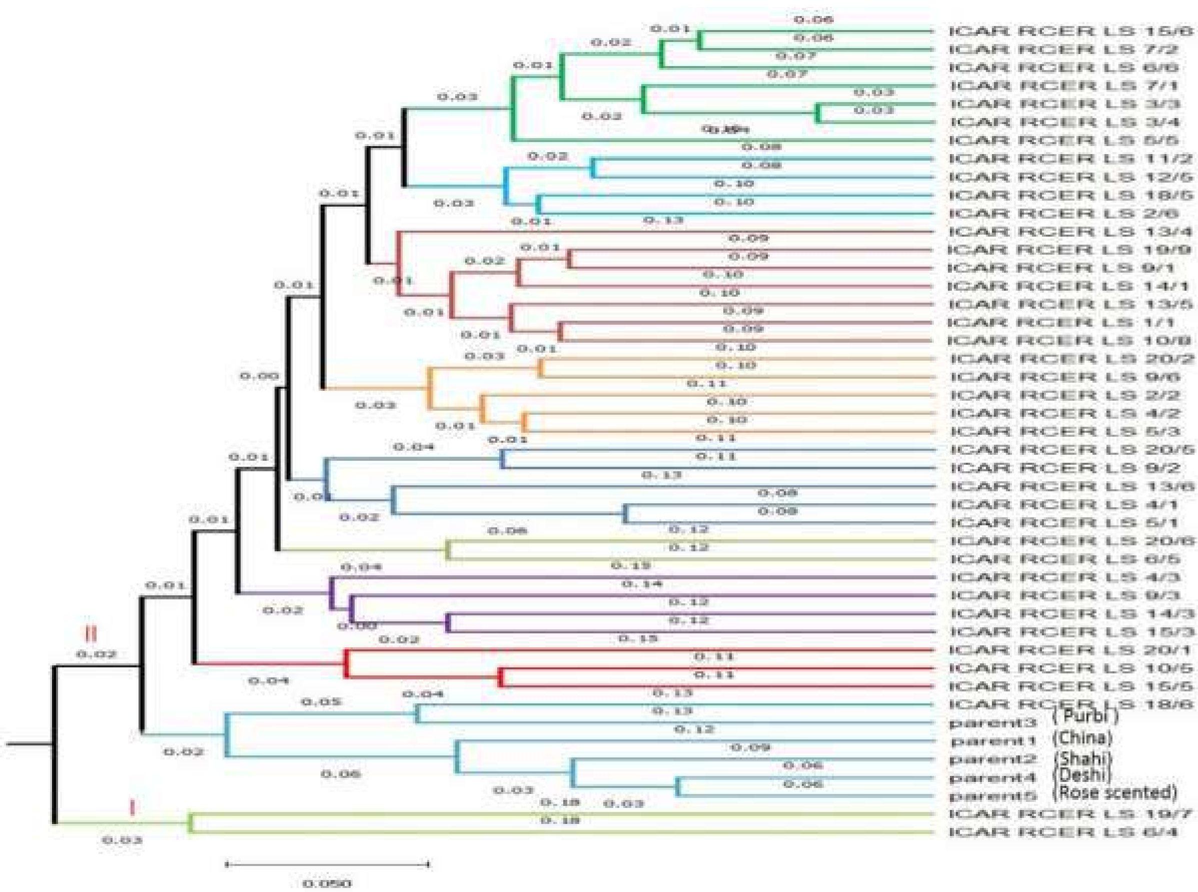


Fig 7.1 Dendrogram based on Nei 1983 genetic distance

In-situ characterization of custard apple germplasm

The survey, DUS testing and data collection were conducted in three districts of Jharkhand [Chaibasa (West Singhbhum), Khunti and Ranchi] to characterize and analyze genetic diversity. The study evaluated 69 genotypes along with 'Arka Sahan' as a reference variety. Significant variability was observed in morphological traits of fruit, seeds, leaves and plant types. A spreading plant habit with ovate leaves, acute leaf apex, green leaf colour and crimson-green petiole colour was predominant among the 70 genotypes. Plant height ranged from 2.10 to 6.90 m, with plant girth varying between 16.78 and 50.65 cm. Fruits exhibited a green exocarp, cordate shape, impressed surface, depressed peduncle end, overlapping segmentation and creamy white pulp. Fruit length ranged from 4.95 to 7.04 cm, fruit diameter from 5.24 to 7.59 cm, and fruit weight from 70.70 to 216 g. Seeds/fruit varied from 5 to 36, with 100-seed weight, seed length, seed width and seed weight respectively ranging from 16.30 to 46.34 g, 1.03 to 1.57 cm, 0.60 to 0.83 cm and 2.28 to 7.93 g. Pulp weight ranged from 29.53 to 150.07 g, with pulp percentage between 41.14 and 77.48 percent and a pulp/seed ratio of 7.60 to 38.52. Biochemical analysis showed a wide variation, with a high gallic acid level in 15 genotypes, averaging 37.74 mg/100 g. The 70 custard apple genotypes were classified into five clusters, with Clusters II and III containing the most genotypes (Fig 7.2). The PCA identified eight PCs with eigen values above 1, accounting for 77.38% of the total variation. Among the genotypes, 'KCA03' emerged as the most promising, exhibiting the highest fruit diameter, fruit weight and pulp weight. The genotype 'CCA03' had the highest pulp percentage and lowest peel percentage; 'KCA21' showed a high pulp percentage, and 'CCA04' recorded high TSS content, whereas 'RCA14' demonstrated the lowest seed percentage with the highest TAC. This study provides valuable insights into genetic variability, and is likely to support future breeding programme for custard apple improvement.

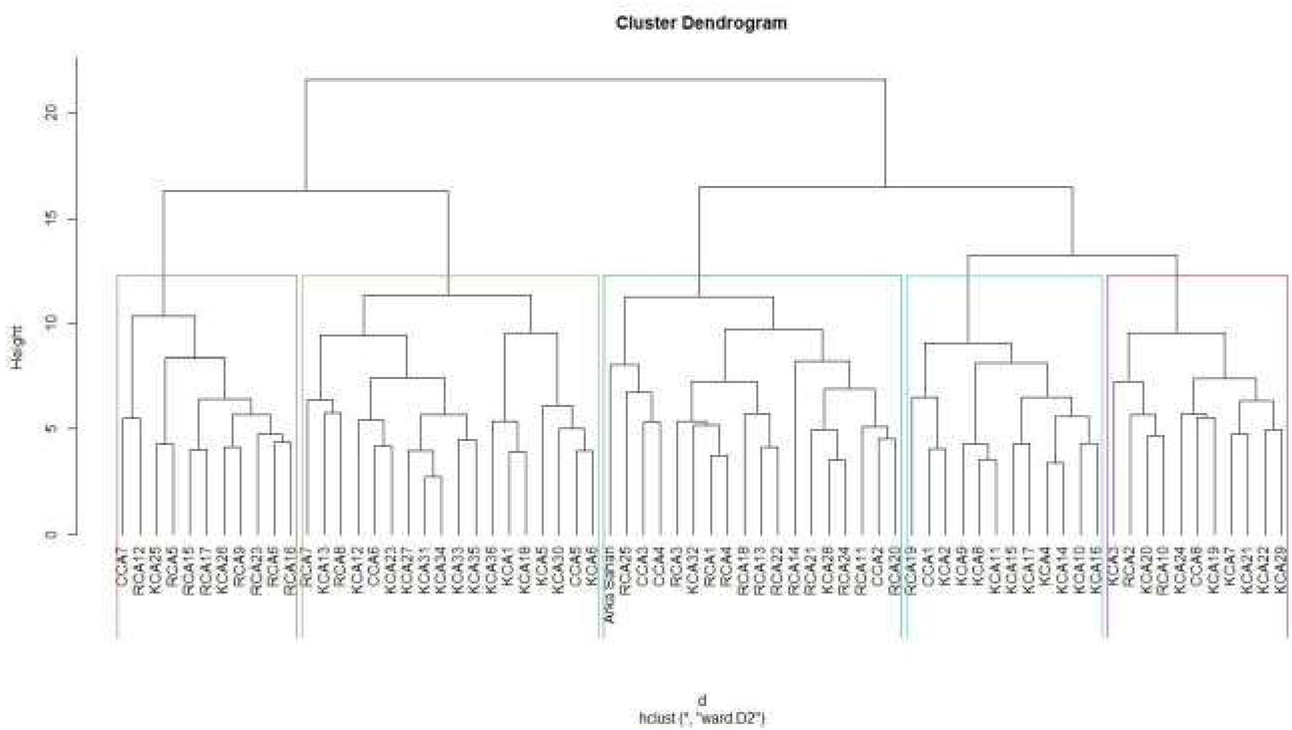


Fig 7.2 Dendrogram of 70 custard apple genotypes based on cluster analysis of 27 morphological and biochemical traits

Performance of custard apple varieties

The custard apple genotypes were screened under natural field conditions for resistance to wilt disease. Screening was based on mortality percentage after two years of plantation. Among the seven varieties of custard apple, 'NMK-4' exhibited the highest mortality under field conditions (Table 7.1), while 'Balanagar' and 'NMK-1' showed lowest mortality compared to other genotypes. After two years of planting, the 'Balanagar' variety did not show significant difference in performance parameters across different production systems (Table 7.2).

Enhancing productivity of high - density litchi orchards through optimal water management

Litchi is one of India's major fruit crops. Its high-density plantations are gaining ground owing to higher productivity. Efficient soil moisture management through advanced irrigation techniques like drip irrigation combined with mulching can aid in moisture conservation, and significantly improve yield. This study, conducted from 2018 to 2023, evaluated the effect of different drip irrigation levels combined with mulching on fruit yield and quality at Ranchi and Pantnagar (Fig 7.3). The experiment was laid out in RCBD with seven treatments and four replications. Each treatment comprised two trees per replication. Pooled data analysis showed that at both locations, the highest fruit yield was recorded under T3 (100% ER + plastic mulch). Individual fruit weight was the highest under T2 (75% ER + plastic mulch) at Pantnagar, and T3 (100% ER + plastic mulch) at Ranchi (Table 7.3). The highest *water use efficiency* was observed in T1 (50% ER + M) at both locations. TSS (total soluble solids) was also highest under T2 (75% ER + plastic mulch). The B:C ratio was highest under T3 (100% ER + M) at both the locations. Drip irrigation combined with mulching significantly enhanced plant growth compared to drip irrigation alone or control treatments at both locations. Based on long-term findings, black polythene mulch combined with drip irrigation at 75% ER from fruit set to pre-harvest (March to May) is recommended for litchi cultivation in Uttarakhand and Jharkhand to enhance 16% and 56% yield at Ranchi and Pantnagar, respectively.

Table 7.1 Plant height (m) and mortality (%) in different custard apple varieties

S.No.	Varieties/Genotypes	Plant height (m)	Mortality (%)
1.	Arka Sahan	1.43	15
2.	Balanagar	1.41	10
3.	Annona-2	1.67	13
4.	NMK-1	1.54	11
5.	NMK-2	1.32	28
6.	NMK-4	1.03	37
7.	Pink Mammoth	1.52	24

Table 7.2 Performance of custard apple under different production systems

S.No.	Production systems	Plant height (m)	Stem diameter (mm)
1.	Polythene mulched + raised bed + drip	1.34	25.3
2.	Paddy straw mulched + raised bed + drip	1.31	23.4
3.	*Tephrosia* mulched + raised bed + drip	1.35	24.3
4.	No mulch + raised bed + drip	1.30	21.8

Fig 7.3 Performance of high-density litchi under drip irrigation and plastic mulch

Table 7.3 Effect of irrigation treatments and mulching on fruit yield and weight of litchi at different centres (pooled 2018 to 2023)

Treatments	Yield (kg/tree)		Yield (t/ha)		Fruits weight (g)	
	Pantnagar	Ranchi	Pantnagar	Ranchi	Pantnagar	Ranchi
T_1 (50% ER + M)	18.51	29.37	7.40	10.47	22.23	21.41
T_2 (75% ER + M)	29.27	33.08	11.72	11.97	23.87	22.49
T_3 (100% ER + M)	31.43	37.12	12.60	13.15	22.76	23.69
T_4 (50% ER - M)	15.22	27.18	6.09	10.76	19.54	20.12
T_5 (75% ER - M)	24.96	27.88	9.99	10.15	21.03	20.33
T_6 (100% ER - M)	26.50	30.93	10.60	11.59	21.98	21.10
T_7 (control)	18.77	26.49	7.50	10.29	20.33	19.43
CD (P=0.05)	3.10	2.95	1.27	1.04	1.66	1.36
SEm (±)	1.08	1.02	0.43	0.30	0.56	0.45
CV (%)	10.26	8.25	10.30	9.49	5.84	5.45

Screening of litchi genotypes for resistance to litchi seed borer

A total of 11 litchi (*Litchi chinensis*) genotypes/cultivars were screened under field conditions for resistance to *Conopomorpha* spp. complex based on antixenotic and allelochemical fruit traits. 'Swarna Madhu' (CHL-8) was was found to be highly resistant (2.50% fruit infestation) among all genotypes. In contrast, 'Rose Scented' was found as susceptible (39.17% fruit infestation) against fruit/seed borer complex (Fig 7.4). Seed size, fruit size and number of protuberances showed positive correlations, whereas fruit weight and pericarp thickness showed negative correlations with the percent fruit infestation by *C. sinensis*. The resistant and susceptible genotypes recorded respectively the highest and lowest contents of total phenol, total flavonoid and total tannin contents. The correlation coefficients revealed that the total phenol content in the pericarp (r = -0.82) and seed (r = -0.85) of litchi genotypes had a significant negative relationship with the percent fruit infestation. The total tannin content in litchi fruit peels also showed a significant negative correlation (r = -0.72) with the percent fruit infestation by *C. sinensis* (Fig 7.5). Phenolic fractions like gallic acid (r = -0.97), protocatechuic acid (r = -0.98), 4-HBA, vanillic acid (r = -0.86) and ferulic acid (r = -0.85) in the seeds of litchi genotypes showed significant negative correlations. The classified resistant genotypes 'Swarna Madhu' and 'Bedana' with aforementioned marker traits could be used in future breeding programmes as resistant sources against *C. sinensis*.

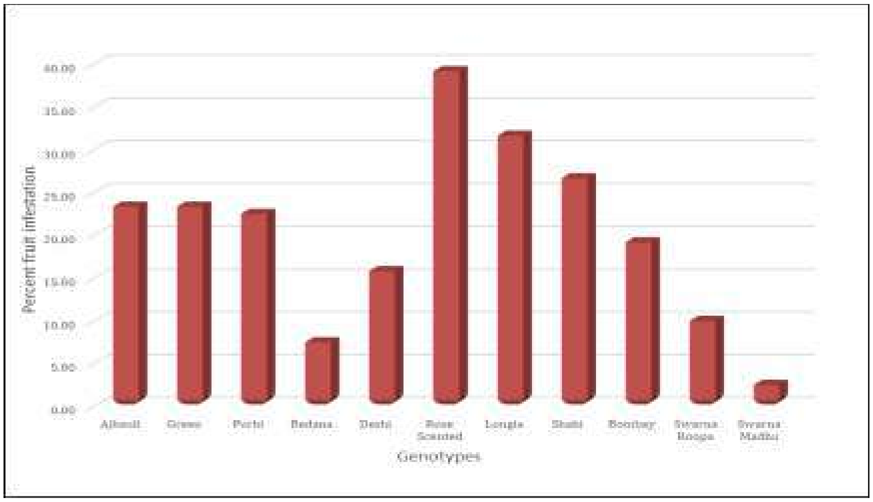


Fig 7.4 Graphical representation showing percent fruit infestation in different litchi genotypes

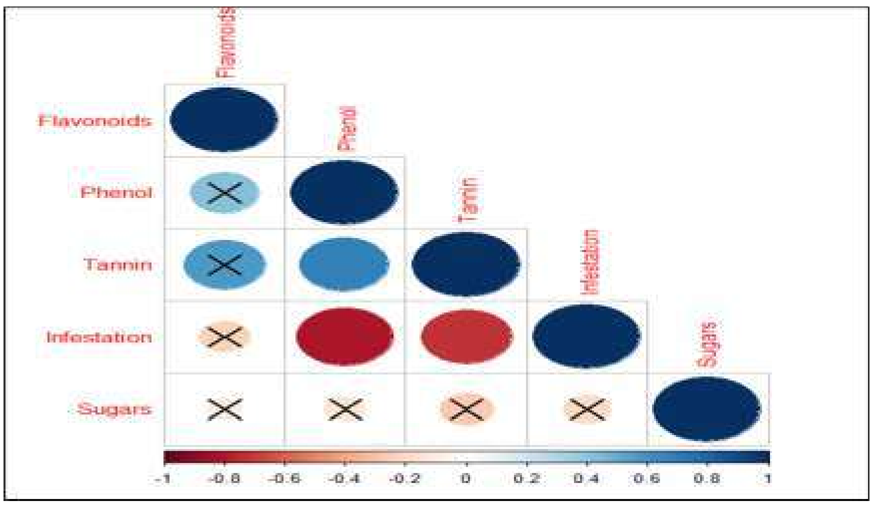


Fig 7.5 Correlation of percent fruit infestation with biochemicals in litchi pericarp of litchi genotypes

Utilization of major fruit seeds and underutilised fruits for the development of functional food product

Fifteen underutilised fruits were collected from two different locations (Guwahati and Shivsagar) of Assam (Fig 7.6), and evaluated for their phenolics and flavonoid contents and antioxidant activity. The underutilized fruits were kordoi (*Averrhoa carambola*), chiniakol (*Musa x paradisiaca*), kajratenga (*Carissa carandas*), kuwabhaturi (*Citrullus colocynthis*), leteku (*Baccaurea motleyana*), heiribo (*Citrus latipes*), amora (*Spondias pinnata*), mitha amora (*Spondias dulcis*), outenga (*Dillenia indica*), kaji nimu (*Citrus limon*), golnimu (*Citrus x jambhiri*), kuji thekera (*Garcinia morella*), bad thekera (*Garcinia pedunculata*) and nagalitchi (*Dimocarpus longan*). Total phenolics and total flavonoids varied from 10 to 946 mg GAE/100g (FWB) and 5 to 706 mg CE/100g, respectively. The fruit *outenga* recorded highest phenolics (321 mg GAE/100g) and flavonoids (706 mg CE/100g) contents. The total antioxidant activity of these fruits varied from 1 to 29 µMol TE/g and 1 to 93 µMol TE/g in the FRAP and CUPRAC method, respectively.

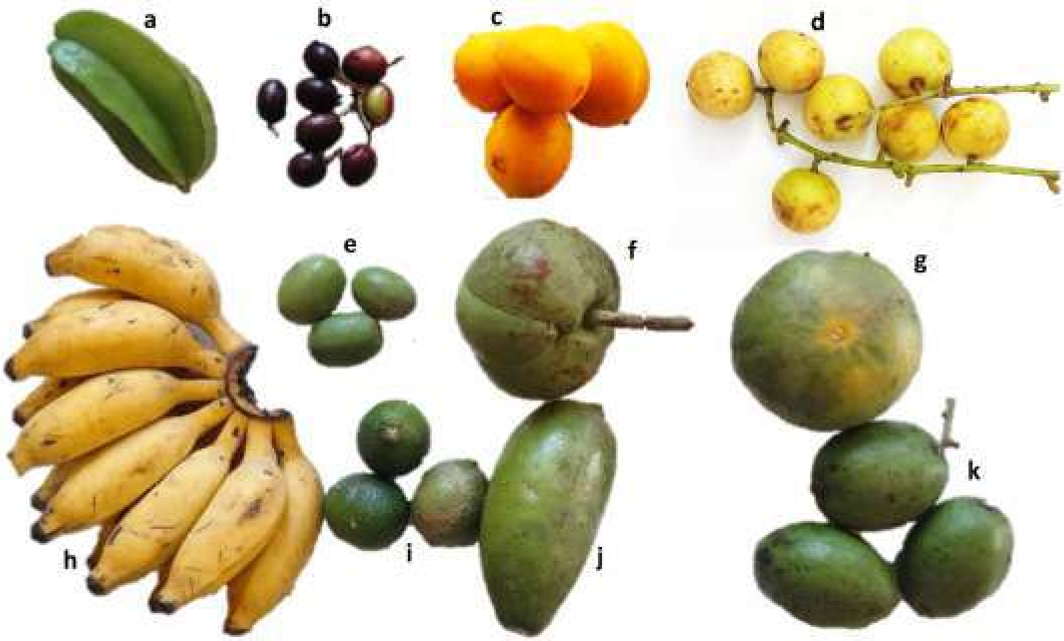


Fig 7.6 Underutilised fruits collected from Assam (a: kordoi, b: kajratenga, c: kuwabhaturi, d: lateku, e: amora, f: outenga, g: heiribo, h: chiniakol, i: golnimu, j: kaji nimu, k: mitha amora)

In addition, sixteen genotypes of monkey jack (*Artocarpus lacucha*) were collected from Ranchi (Jharkhand) and evaluated for their antioxidants content and antioxidant potentiality. Besides, other fruit physical qualities, such as diameter, core diameter, seed weight, fruit weight, no of seeds per fruit and seed weight, were also evaluated. Total phenolics ranged from 19 to 96.4 mg GAE/100g. Total flavonoids content ranged from 14.3 46 mg CE/100g. Antioxidant activity ranged from 2.72 to 7.2 mg TE/g.

Extraction of starch from jackfruit seeds and its characterization

Seeds of jackfruits (*Artocarpus heterophyllus*) were collected from Mokama city. Thereafter collected seeds were thoroughly washed, and peels were removed manually. After lye peeling (KOH 1%), seeds were crushed using a mixer-grinder. After the addition of tap water, pulp was passed through a sieve to remove the fiber. After the removal of fiber, the extracted solution was centrifuged to remove soluble protein and minerals. Sediments were dried to get starch. This starch was evaluated for physico-chemical characteristics. The starch of jackfruit recorded higher swelling and water holding power at 80-90°C; higher solubility was recorded at 95°C. The extracted jackfruit starch contained OH, CH_2 groups, CCH- stretch, and C–O–H bonds.

Fruit based diversified nutri-garden

The *Swarna e-Vatika*, a nutri-garden, has been developed under pre-existing mango and litchi orchard. The open area surrounding the orchard was fortified with minor fruits and vegetables. The understory area of the litchi orchard was fortified with sixty different medicinal and aromatic plants. Similarly, the understory area of the mango orchard was explored for shade-loving tuber crops and spices. Plants were selected based on local consumer requirements and adaptability to local climatic conditions. In addition to this, a poultry and duck unit was established for nutritional security, particularly for the protein. For the recycling of crop litter and manure of birds, a vermicompost unit was also established. A water pool was constructed where aquatic plants and fish would be cultured.

The plot was divided into four distinct blocks. Block I consisted of the mango variety 'Amrapali' surrounded by seasonal vegetable crops. Block II comprised minor and low-chilling temperate fruits with vegetables as intercrops. Block III consisted of the mango variety 'Malda' with tuber crops and spices as intercrops in its understory. The front area of this block was used for production of leafy vegetables. Block IV contained litchi variety 'Shahi' with medicinal and aromatic plants in its understory. The detailed composition of *Vatika* is as follows:

Major fruit plants: Mango (Amrapalli and Malda), litchi (Shahi) and Banana (G-9)

Minor fruits plants: Loquot, lemon, waterapple, custard apple, hog plum and date palm

Spices: Turmeric, ginger and coriander

Vegetables: All cucurbitaceous, cruciferous, solanaceous, leguminous and root vegetables

Tuber: Colocasia, elephant foot-yam, yam, alocasia, arrow root and tapioca

Plantation crops: Cocoa

Medicinal plants: Kalmegh, aloe vera, tulsi, madhunashini and ashwagandha

Aromatic plants: Lemon grass, vetiver, palmarosa and mentha

Livestock: Hen (BV-300) and duck (Khaki Campbel)

Fish: Golden fish and Indian major carp

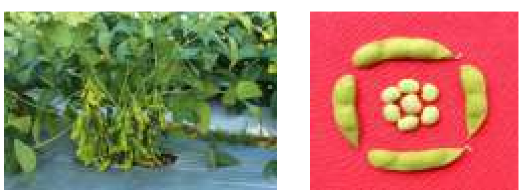
8 Vegetables

Evaluation of vegetable soybean for horticultural and nutritional traits

Thirty-four germplasm lines of vegetable soybean, received from AVRDC-The World Vegetable Centre (Taiwan), were evaluated in the replicated trial during *Kharif* season of 2024. Among these, seven genotypes (AGS-338, AGS-404, Swarna Sugandha, AGS-459, HAVSB-1, AGS-402 and Swarna Vasundhara) excelled all others for yield traits (Table 8.1). Among these top performing genotypes, the high yielding aromatic variety 'Swarna Sugandha' was found very promising for its earliness (first green pod harvest after 63 days of sowing) and bold green seeds (100-green seed wt: 75 g). Days to 1st green pod harvest for the remaining top performing genotypes ranged from 71 days (AGS-459) to 76 days (AGS-338, AGS-404, HAVSB-1, AGS-402 and Swarna Vasundhara). The shelling percentage ranged from 43.66 (AGS-292) to 56.29 (AGS-461). Two-seeded pod weight and length ranged from 1.25 (Harit Soya) to 3.35 g (EC-595824) and from 4.29 (AGS-292) to 6.69 cm (AGS-406), respectively. Three-seeded pod weight and length ranged respectively from 1.82 (GC-84501-32-1) to 3.86 g (AGS-402) and from 5.30 (GC-84501-32-1) to 7.87 cm (AGS-406). Plant height, number of primary branches/plant, days to 50% flowering and crop duration ranged respectively from 19.34 (Karune) to 52.67 cm (HAVSB-1), from 5.13 (AGS-406) to 8.33 (HAVSB-1), from 29.67 (EC-595823 and AGS-461) to 41.33 (AGS-338) and from 65 days (EC-595818) to 89 days (HAVSB-1, AGS-190, AGS-331, AGS-333, AGS-334, AGS-336, AGS-338 and AGS-404) (Fig 8.1).

AGS-338

AGS-404

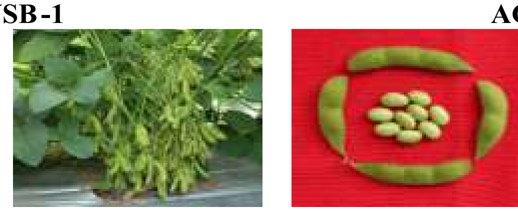


Swarna Sugandha

AGS-459

HAVSB-1

AGS-402



Swarna Vasundhara

Fig 8.1 Plant, pod and shelled seed of promising vegetable soybean varieties

Table 8.1 Performance of selected vegetable soybean germplasm lines

Variety	Graded green pod yield (t/ha)	Green seed yield (t/ha)	100-green seed weight (g)
AGS-338	15.27	7.83	60.47
AGS-404	14.94	7.53	54.00
Swarna Sugandha*	14.44	8.09	75.00
AGS-459	13.67	6.36	59.47
HAVSB-1	13.58	6.23	45.60
AGS-402	13.32	6.17	58.60
Swarna Vasundhara**	12.43	6.29	45.95

*: Aromatic, **: Released variety

Evaluation of F_3 and F_4 segregants of French bean

In this trial, 39 advanced breeding lines (ABLs) of French bean were selected from a total of 285 and evaluated for disease resistance. These lines were developed following pedigree breeding approach, followed by selection for the seventh generation from two crosses (IC632961 × IC525260 and IC632961 × HAFB 74). Seven progeny families (2-2, 2-8, 2-10, 3-2-5, 4-1-23, 69, 70, 245 and 258) were selected for high yield potential and multiple disease resistance/ tolerance and under field condition (Fig 8.2). All these high-yielding progenies possessed consumer-preferred traits, such as earliness, high vigour, green to dark green pods, and round and flat podded. Their yield potential ranged from 50 to 180 q/ha.

Fig 8.2 French bean ABLs validated for high yielding and disease resistance/ tolerance: (a) F7 3-2-5, (b) F7 2-10, (c) F7 69, (d) F7 2-2, (e) F7 4-1-23, and (f) F7 245

Genetic enhancement of selected vegetable legumes for Eastern India

Under this project, 240 genotypes of lablab bean were evaluated to identify promising lines with desirable traits, such as high yield, disease resistance and adaptability. Seven *pole* and two *bush-type* lablab bean lines were identified. Notable among these were 'RCPD-1' (extra-early, dwarf, 105-110 pods/plant, photo-insensitive, and collar rot tolerant), 'RCPD-15' (140-145 pods/plant, pole type, anthocyanin-rich, and collar rot resistant), and 'RCPD-16' (extra-early, suitable for rice-fallow areas, dwarf, photo-insensitive, and 95-110 pods/plant). These promising genotypes were also evaluated across four distinct zones of Bihar. The two lablab bean genotypes were identified and approved by the *Institute Variety Release Committee* for release in the state of Bihar. Detailed description of the two recommended genotypes is given below.

RCPD-1

It is an early-maturing genotype having bush plant-type, developed through single plant selection with a yield potential of 17-18 t/ha (Fig 8.3). It matures early (with 50% flowering in 43 days and a maturity period of 75-85 days). Its pods are long (10.88 cm), light green, slightly curved, and highly nutritious, containing 23.74% protein (dry weight basis) and 460 mg/100 g phosphorus. It is moderately resistant to aphids, pod borer (*Helicoverpa armigera*), and collar rot (with consistent resistance in Patna and East Champaran, Bihar).

RCPD-16

It is a high-yielding bush-type lablab bean (16-17 t/ha) developed through single-plant selection (Fig 8.4). This matures early (50% flowering: 41 days; maturity: 75-80 days), and is suitable for mechanical harvesting. Pods are nutrient-rich, containing 21.64% protein (dry weight), 7.35 mg Fe, and 3.65 mg Zn per 100 g. Small, light green, curved pods have excellent cooking qualities. It is resistant to aphids, pod borer, bruchid, and collar rot. The dwarf growth habit eliminates staking, making it ideal for Bihar farmers.

Fig 8.3 RCPD-1

Fig 8.4 RCPD-16

Additionally, out of 114 yardlong bean genotypes procured from ICAR-NBPGR (New Delhi), 17 diverse lines adapted to Eastern India were selected for further assessment based on traits such as days to 50% flowering, pod length, yield, and nutritional contents. Two genotypes 'IC-52107A' and 'RCPY-1' showed higher foliage production, with latter yielding 512.24 g pods/plant and 15.90% pod-protein. Vegetable-type genotypes 'RCPY-11' (pod yield: 535.03 g/plant) and 'IC-471738' (pod yield: 526.52 g/plant) excelled in pod yield, whereas 'EC-738116' had the longest pods (47 cm). Nutritionally, 'IC-259058', 'IC-630377' and 'EC-738116' had respectively the highest iron (404.50 mg/kg), manganese (14.10 mg/kg) and zinc (58.80 mg/kg) contents. 'CHCP-1' stood out among foliage types with 205.90 mg/kg iron and 15.90% protein, indicating its nutritional significance (Fig 8.5).

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

A new initiative was started to explore the potential of grass pea as a nutritious green leafy vegetable, particularly for drought-prone rice fallow systems (Fig 8.6). The project focuses on two key aspects: first, the characterization of diverse grass pea lines to assess ODAP (β-N-Oxalyl-L-α,β-diaminopropionic acid) content in leaves, for which eighteen lines were sown following RCBD during Rabi 2024-25 (Table 8.2); and the second, a comprehensive nutritional profiling of these to assess their suitability as green leafy vegetables, emphasizing their contribution to food security and sustainability in water-scarce regions.

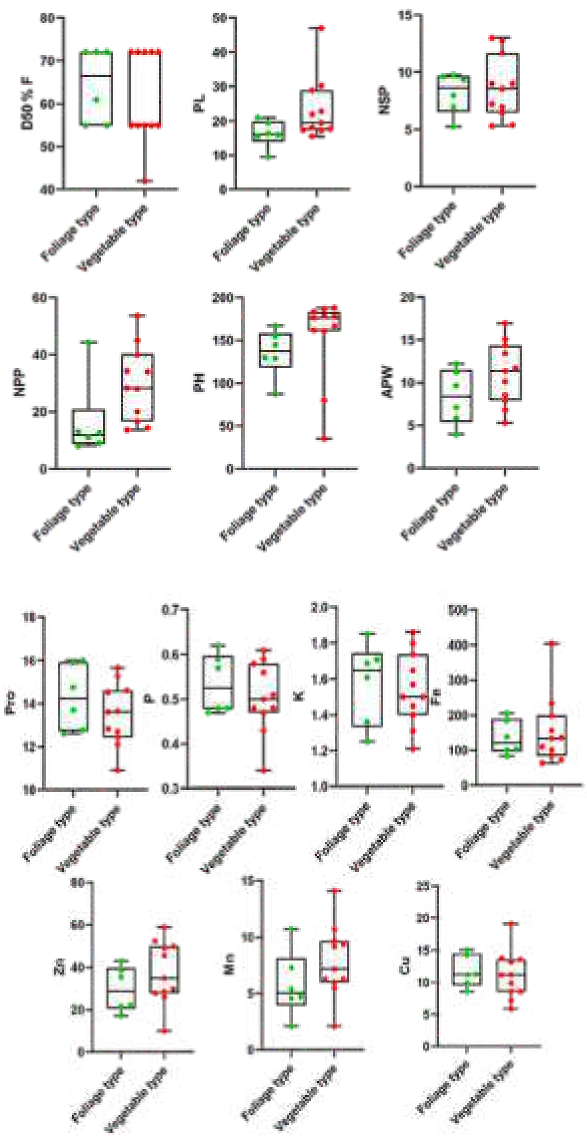


Fig 8.5 Represents the variation in morphology, yield traits and nutritional traits in yardlong bean

Table 8.2 Descriptive statistics of morphological traits of grass pea leaves

Genotypes	Leaf length (cm)	Leaf width (cm)	Stem length/IL	Pod length (cm)	DFF (no.)
75017	5.86	0.76	3.70	4.00	40
RCEGP17-1	5.24	0.82	4.15	2.76	45
75024	5.22	0.92	4.60	3.03	58
75022	6.02	0.94	4.80	2.80	58
Parteek	5.48	0.82	3.75	2.26	58
RCEGP-2	5.74	0.92	4.98	3.10	64
RCEGP-9	5.64	0.58	3.45	3.00	75
RCEGP-7	6.20	0.77	3.47	2.80	70
Mahateora	5.90	0.74	4.50	3.20	45
75016	5.64	0.82	4.37	3.60	55
75049	5.56	0.82	4.25	3.63	45
Ratan	5.92	0.96	4.55	3.30	45
75040	5.50	0.81	3.87	3.26	45
75046	5.34	0.72	3.55	3.06	50
RCEGP-3	6.22	0.64	2.40	3.36	60
RCEGP-4	6.72	0.60	2.75	3.00	65
RCEGP-6	6.82	0.96	2.32	3.00	65
RCEGP17-1	4.80	0.80	4.47	2.90	58
Mean	5.82	0.80	3.85	3.13	55.47
CV (%)	7.98	14.92	20.79	12.66	18.61

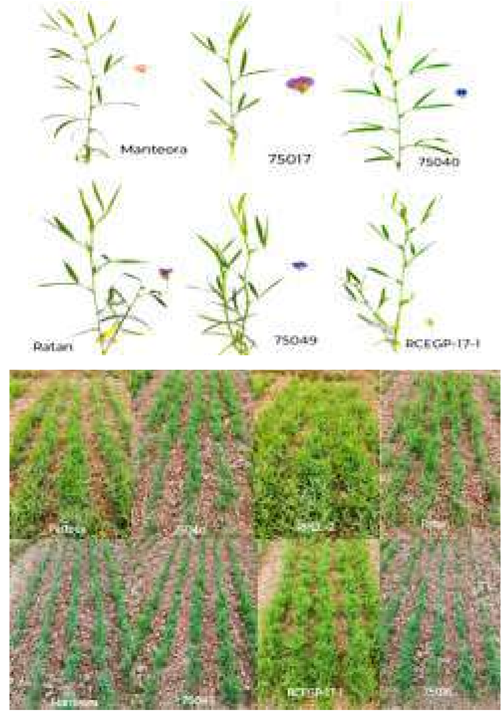


Fig 8.6 Preliminary evaluation of grass pea leaves in field condition

Predicting yellow mosaic virus severity in yardlong bean through machine learning

Field experiments were conducted to understand the correlation and predict the yellow mosaic disease severity in yard-long beans using visible image indices. A total of 45 red green blue (RGB) indices were derived from the RGB images and correlated with disease severity, and were also used as inputs for predicting disease severity using nine machine learning (ML) models. Out of 143 genotypes screened, 3, 18, 18, 17, 34 and 53 genotypes were grouped into immune, resistant, moderately resistant, moderately susceptible, susceptible and highly susceptible categories, respectively. Model performances were evaluated using R^2, d-index, mean bias error, and normalized root mean square error (n-RMSE) metrics. Results revealed that 34 indices exhibited significant correlations ($p<0.01$) with YMD severity, with 23 positively and 12 negatively correlated. Among these, red color composite (RCC) and excessive red (ExR) demonstrated the highest and equal positive correlations (0.87), while green red difference (GRD) exhibited the largest negative correlation (-0.88) with disease severity. The ML models achieved commendable performance, attaining R^2 and d-index values exceeding 0.92 and 0.98, respectively, in calibration, and 0.88 and 0.96 in validation, underscoring their effectiveness in predicting YMD severity using RGB images only. Random forest (RF), Cubist, XGBoost (XGB), K-nearest neighbors (KNN), and gradient boosting machine (GBM) emerged as the five top-performing models for predicting YMD severity using visible indices in yard-long beans.

Nutritional profiling of yardlong bean and edible-podded pea for genetic improvement

Two distinct *coloured* lines of yard long bean (HACP-24: red, and HACP-1: green) were investigated for protein content, anthocyanin composition and amino acid profiling to assess their potential as parental lines for further improvement. The red pods recorded 8.56% protein content (dry weight basis), while green pods exhibited a higher protein content (9.62%). Anthocyanin pigmentation in yardlong bean is primarily attributed to delphinidin, which accounts for 70% (4907.44 μg/g), and cyanidin, contributing 30% (2121.90 μg/g). Additionally, trace amounts of malvidin (1.12 μg/g) and pelargonidin (9.97 μg/g) were also recorded. Amino acid profiling revealed higher concentrations of essential and non-essential amino acids in red pods compared to green pods (except for methionine) (Fig 8.7). The evaluation of segregating pigmented edible podded pea lines under field conditions revealed promising results for various horticultural traits. The advanced breeding line F_{3-82} yielded 453.55 g/plant along with desirable pod characteristics, including pigmentation and sweetness. The stability of these traits across all segregating progenies will be assessed in the succeeding generations.

Standardization of organic farming practices for middle Indo-Gangetic Plains

In *Kharif* 2023, an experiment was initiated at ICAR RCER, Patna (Fig 8.8) with the aim of exploring how organic farming could enhance productivity, sustainability and ecological balance in the region. The experiment involved three vegetable-based cropping systems with varying nutrient management approaches: i) 100% farm yard manure (FYM), ii) 50% FYM + 50% vermicompost (VC), and iii) 50% FYM + 50% VC + biofertilizer (BF) + humic acid (HA) (Fig 8.8). Initial soil properties at 0-15 cm soil depth were determined (available N: 165.89 kg/ha, available P: 40.23 kg/ha, available K: 747.7 kg/ha, and OC: 0.55%). Higher vegetable yield was obained in the T2 (FYM+VC) and T3 (FYM+VC+ BF+ HA) treatment. After the first year of cropping under organic farming, the soil's available potassium level decreased in the range of 19.54 to 39.89%, whereas N, P and OC increased.

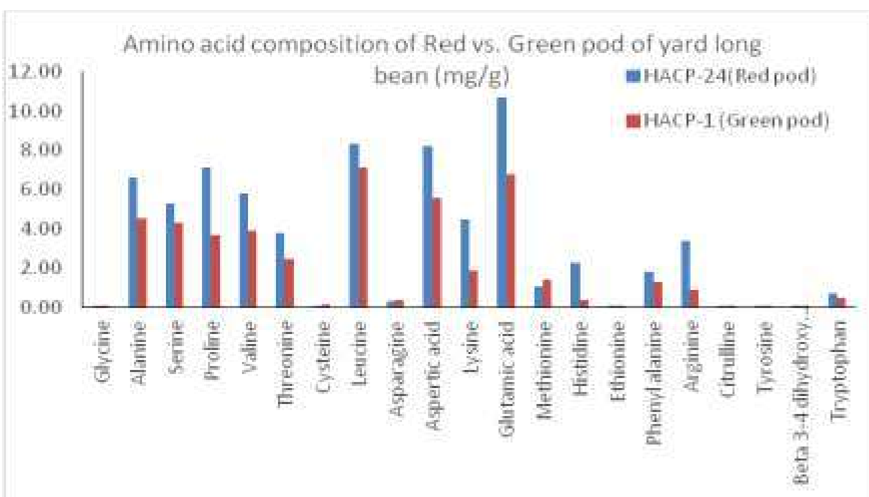


Fig 8.7 Amino acid composition of red vs. green pod of yardlong bean

Fig 8.8 Field view of organic farming experiment

Development of carotenoid-rich tomato and chilli

Breeding was initiated for the development of carotenoid-rich yellow tomato and yellow chillies with wilt resistance, aiming at enhancing bioactive compounds and quality traits. 'RCIDT-314', an oblong yellow tomato with bacterial wilt resistance was identified from the local collection, and was used in reciprocal crosses with five genotypes (Swarna Lalima, CH-3, CH-159, EC-596747 and HAT-296). 'Haldipada', a yellow chilli variety collected from Odisha, was used in reciprocal crossing programme with five varieties (Ujwala, Swarna Apurva, Swarna Praphulya, Swarna Tejaswi and Swarna Arohi). The F_1 seeds obtained from the crossed tomato and chilli fruits would be utilized for further improvement in the breeding programme (Fig 8.9).

***In-silico* identification and characterization of glutathione s-transferase genes involved in anthocyanin development in pea**

The glutathione s-transferase (GST) gene family in plants comprises a diverse group of multifunctional enzymes involved in anthocyanin transport and accumulation in addition to providing protection against biotic and abiotic stresses. In pea (*Pisum sativum*), 44 *PsGST* genes were screened *in-silico*, and characterized based on their structural and functional properties. These genes were categorized into five subfamilies, with Tau (GSTU) and Phi (GSTF) being the predominant groups. *PsGST* genes were distributed across all the seven chromosomes with evidence of duplication events during evolution (Fig 8.10). Subfamily members exhibited similar gene structures and motif distribution patterns. Predictive promoter analysis revealed that *PsGST* genes play a role in developmental signaling, light response, hormonal regulation and other stimuli controlled by transcription factors MYB and WRKY. This comprehensive analysis of the GST gene family in pea provides valuable insights into the molecular and functional mechanisms regulating anthocyanin development in pods, facilitating future genetic and breeding studies.

Fig 8.9 (a) Anthocyanin rich pods of yard long bean 'HACP-24', (b) Anthocyanin rich pods of segregating pea line F_3 82 (c) Carotenoid-rich tomato line 'RCIDT-314', and (d) Carotenoid- rich chilli line 'Haldipada'

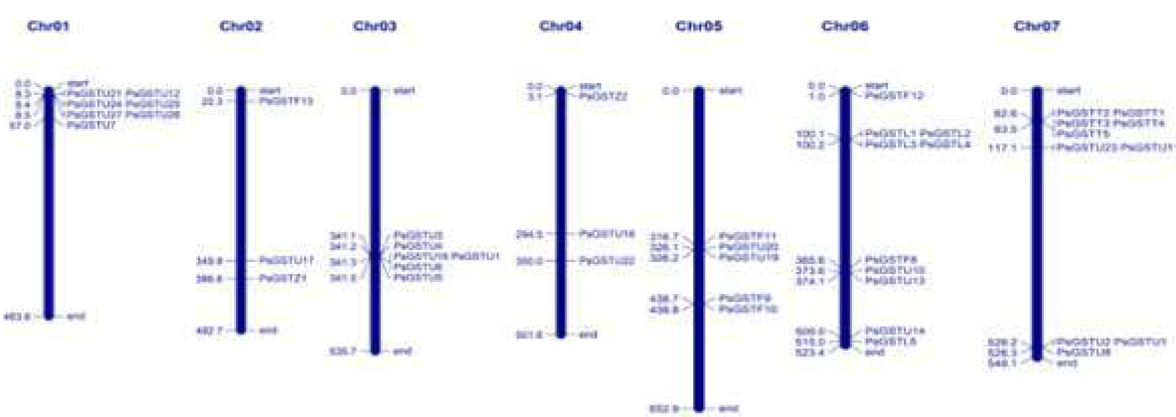


Fig 8.10 Chromosomal distribution of *PsGSTs*

Development of multiple disease resistant hybrids in solanaceous crops

A. Tomato

EVALUATION OF TOMATO HYBRIDS FOR BACTERIAL WILT RESISTANCE AND YIELD RELATED CHARACTERS

Fifty-five crosses of tomato were made involving eleven parents (Swarna Naveen, DT-7, HAT-296, RCDT-1608, Swarna Kanchan, RCDT-1116, RCDT-1128-1, HAT-311, HAT-310, HAT-159 and Swarna Lalima) in a diallel fashion (excluding reciprocals), and were evaluated for bacterial wilt resistance and yield related characters along with the parents in a RCBD with two replications (Table 8.3 and Table 8.4). A total of thirteen crosses were found promising with respect to yield, percent plant survival and fruit quality characters.

B. Brinjal

EVALUATION OF BACTERIAL WILT RESISTANT LINE OF BRINJAL IN AICRP TRIAL

An advance breeding line 'RCBR-935/HAB-935' with dark purple round fruits developed from a cross, HAB-917 × IC-261786 (3-5) was contributed for multilocation testing under AICRP(VC) IET 2024.

DEVELOPMENT OF BACTERIAL WILT RESISTANT HYBRIDS IN BRINJAL

Thirty six crosses of brinjal were developed involving nine parents (HAB-933, HAB-934, HAB-935, HAB-936, HAB-937, HAB-938, HAB-931, HAB-932 and HAB-381) in half diallel fashion during 2023-24.

C. Chilli

EVALUATION OF PROMISING HYBRIDS AND BACTERIAL WILT RESISTANT GERMPLASM OF CHILLI

Five hybrids of chilli (HC-75 × Swarna Arohi, HC-78 × Swarna Praphulya, HC-79 × Swarna Arohi, Swarna Apurva × Swarna Arohi and Swarna Apurva × HC-81) along with their parents, and twelve germplasm (IC-214965, IC-214966, IC-410423, EC-378632, EC-390029, EC-566920, EC-599969, IC-447065, IC-561622, IC-561626, HC-82 and HC-83) were evaluated for fruit yield, fruit quality and bacterial wilt resistance in the replicated trial. Among them, three hybrids (Swarna Apurva × HC-81, HC-75 × Swarna Arohi and Swarna Apurva × Swarna Arohi) and six genotypes (IC-214965, EC-378632, EC-390029, EC-566920, IC-561622 and IC-561626) were found promising for fruit yield, fruit quality and bacterial wilt resistance (Table 8.5).

Table 8.3 Genetic parameters assessed among 55 tomato crosses along with eleven parents

Sl. No.	Characters	Range	SE(m)	Combining ability	Genetic variance
1.	Percent plant survival against wilt	20-95	7.42	GCA significant SCA significant	Additive Dominance
2.	Yield (t/ha)	27.4-163.3	95.07	GCA significant SCA significant	Additive Dominance
3.	No. of fruits per plant	14.19-43.53	2.37	SCA significant	Dominance
4.	Mean fruit weight (g)	16.58-112.05	0.57	GCA significant	Additive
5.	Mean fruit length (cm)	2.62-7.32	0.04	GCA significant	Additive
6.	Mean fruit diameter (cm)	2.24-5.66	0.04	GCA significant	Additive

Table 8.4 Best crosses identified in tomato

Crosses	Plant survival against wilt (%)	Yield (t/ha)	No. of fruits/ plant	Mean fruit wt (g)	Mean fruit length (cm)	Mean fruit diameter (cm)
HADT-7 × HADT-296	90	60.48	27.6	64.4	3.96	4.06
HADT-7 × Swarna Lalima	80	62.40	30.3	74.0	4.54	5.10
HADT-296 × Swarna Lalima	85	110.80	27.2	71.2	4.3	5.2
RCDT-1608 × Swarna Lalima	90	108.30	32.6	59.7	3.84	5.08

Table 8.5 Evaluation of promising hybrids and germplasm in chilli

S.No.	Characters	Range	SE(m)	CV (%)
1.	Plant survival against wilt (%)	25-100	6.19	9.77
2.	Yield (t/ha)	0-15	15.14	17.58
3.	No. of fruits/plant	0-429.5	39.7	26.7
4.	Mean fruit weight (g)	2.08-6.88	0.22	8.47
5.	Mean fruit length (cm)	4.06-8.6	0.19	4.28
6.	Mean fruit diameter (cm)	0.60-1.21	0.05	9.11

AICRP trials conducted at FSRCHPR, Ranchi

A. Solanaceous vegetables (tomato, brinjal, chilli and capsicum)

A total of 10 trials were conducted in solanaceous vegetables under AICRP(VC). In tomato, four trials were conducted during 2023-24. All entries died due to bacterial wilt in Varietal (Det) AVT-II, Hybrid (Det) AVT-II and Cherry Tomato Varietal AVT-II. Under Cherry Tomato Varietal (IET), '2023/TOCVAR-10' was the highest yielder (201.7 q/ha) among the ten entries. Under interspecific grafting trial, seven treatments were evaluated for bacterial wilt resistance. Maximum fruit yield was obtained in 'RCDTH-21' grafted on 'HAB-930' rootstock (T6: 573.94 q/ha) followed by on 'HAB-921' (T4: 566.72 q/ha) and 'HAB-901' (T3: 550.61 q/ha) rootstocks, respectively. Plant survival was highest for T3 and T4 [HAB-901 (88.89%) and HAB-921 (83.34%), respectively] followed by T6 (HAB-930, 81.00%) root stocks. The entry '2022/CHIVAR-5' (77 q/ha) among ten entries under Chilli Varietal AVT-I, entry '2021/CHIVAR-14' (81.5 q/ha) among fourteen entries under Chilli Varietal AVT-II, entry '2023/CHIVAR-10' (65 q/ha) among eleven entries under Chilli Hot pepper Varietal IET and entry '2023/CHIHYB-8' among eight entries under Chilli Hot pepper Hybrid IET, were found promising during 2023-24. '2022/CAPVAR-5' (90.8 q/ha) among nine entries under Capsicum Varietal AVT-I and '2021/CAPVAR-7' (120.7 q/ha) among seven entries under Capsicum Varietal AVT-II, were found promising during 2023-24.

B. Cruciferous and root vegetables (cabbage, cauliflower and carrot)

Two trials in cabbage, six in cauliflower, and three in carrot were conducted during 2023-24. Entries '2022/CABHYB-4' (275 q/ha) under Cabbage Hyb AVT-I and '2021/CABHYB-3' (427.5 q/ha) under Cabbage Hyb AVT-II, '2023/CAUMLHYB-2' (44.5 q/ha) under Cauliflower Hyb (Mid Late) IET, '2022/CAUEHYB-1' (189 q/ha) under Cauliflower Hybrid (Early) AVT-I, '2022/CAUMHYB-6' (34 q/ha) under Cauliflower Hybrid (Mid) AVT-I, '2021/CAUMHYB-7' (44.8 q/ha) under Cauliflower Hybrid (Mid) AVT-II, '2023/CAULHYB-3' (42.4 q/ha) under Cauliflower Hybrid (Late) IET, '2023/CAULVAR-3' (43 q/ha) under Cauliflower Varietal (Late) IET, were found high yielding. Entries '2022/CARTRVAR-5' (716.8 q/ha) under Carrot Tropical AVT-I, '2022/CARTRVAR-6' (481 q/ha) under Carrot Temperate AVT-I and '2021/CARTHYB-2' (280.2 q/ha) under Carrot Hybrid Tropical AVT-II, were found promising during 2023-24.

C. Cucurbitaceous vegetables

A total of eighteen trials were conducted in cucurbitaceous vegetables during 2023-24. The entry '2021/CUCUVAR-5' (417 q/ha) in Cucumber Varietal AVT-II, '2022/CUCUVHYB-1' (344.5 q/ha) in Cucumber Hyb AVT-I, '2021/CUCUVHYB-1' (342.3 q/ha) in Cucumber AVT-II, '2023/CUCUHYB-4' (333.5 q/ha) in Cucumber Hybrid IET and '2023/CUCUVAR-1' (338.5 q/ha) in Cucumber

Varietal IET was found promising. In ridge gourd, '2021/RIGVAR-1' (104.9 q/ha) out of the six entries was found promising in Ridge gourd Var AVT-II. In sponge gourd, '2022/SPGVAR-7' (171 q/ha) in Sponge gourd Varietal AVT-I, '2021/SPGVAR-1' (137 q/ha) in Sponge gourd Varietal AVT-II and 2023/SPGVAR-5 (114.6 q/ha) in Sponge gourd Varietal IET were found high yielding.

Entries '2022/SSQVAR-1' (221.6 q/ha) in Summer Squash Varietal AVT-I, '2022/PUMVAR-1' (124.9 q/ha in Pumpkin Varietal AVT-I and '2021/PUMVAR-5' (114.1 q/ha) in Pumpkin Varietal AVT-II were found promising. Similarly, entries '2023/BOGHYB-6' (121 q/ha) in Bottle gourd Hybrid IET, '2023/BIGVAR-5' (144.7 q/ha) in Bitter gourd Varietal IET and '2023/BIGHYB-7' (168.3 q/ha) in Bitter gourd Hybrid IET were found promising. Entries '2022/MMVAR-1' (261.25 q/ha) in Muskmelon Varietal IET, '2022/MMVAR-3' (244.58 q/ha) in Muskmelon Varietal AVT-I and '2022/MMHYB-3' (342.9 q/ha) in Muskmelon Hybrid AVT-I excelled all other entries in the respective trials.

Morphological and molecular characterization of bottle gourd wilt complex

A survey was conducted in ten different districts of Jharkhand during summer 2024 to assess disease incidence severity in bottle gourd. The analysis showed 16.0 to 26.5% incidence of the wilt complex on bottle gourd crop cultivated in these districts. Minimum wilt incidence of 16.0% was recorded in Chatra district (Table 8.6). Pathogenicity test confirmed that all the isolates were pathogenic to bottle gourd. Wilt symptoms were observed after 16-27 days of infection. On the basis of microscopic structure, the disease-causing fungus was identified as Fusarium oxysporum. Plant inoculated with pathogen had typical symptoms of yellowing of leaves, drooping and wilting of plants. Microscopic observations revealed the presence of micro-conidia, macro-conidia and chlamydospore like structures in all the isolated fungi.

The DNA was isolated from the culture of each sample, and its quality was evaluated on 1.0% agarose gel. Fragment of 18S rRNA gene was amplified, and was used to carry out BLAST with the 'nr' database of NCBI GenBank database. Based on maximum identity score, sequences were selected and aligned. Distance matrix was generated using RDP database, and the phylogenetic tree was constructed using MEGA7. These molecular tools showed high similarity with top based nucleotide homology and phylogenetic analysis. The isolates *J2* and *J4* (Garhwa) were identified as *Fusarium oxysporum*, while the isolate *J5* (Daltenganj) and *J7* (Ranchi) were identified as *Fusarium solani* and *Fusarium chlamydospore*, respectively (Table 8.7, Fig 8.11).

Table 8.6 District wise wilt incidence on bottle gourd during summer 2024

District	Wilt incidence (%)
West Singhbhum	26.0
East Singhbhum	22.3
Bokaro	19.0
Ramgarh	24.5
Palamau	18.3
Garhwa	23.0
Chatra	16.0
Hazaribagh	22.3
Latehar	17.5
Ranchi	26.5
CD (P=0.05)	4.7

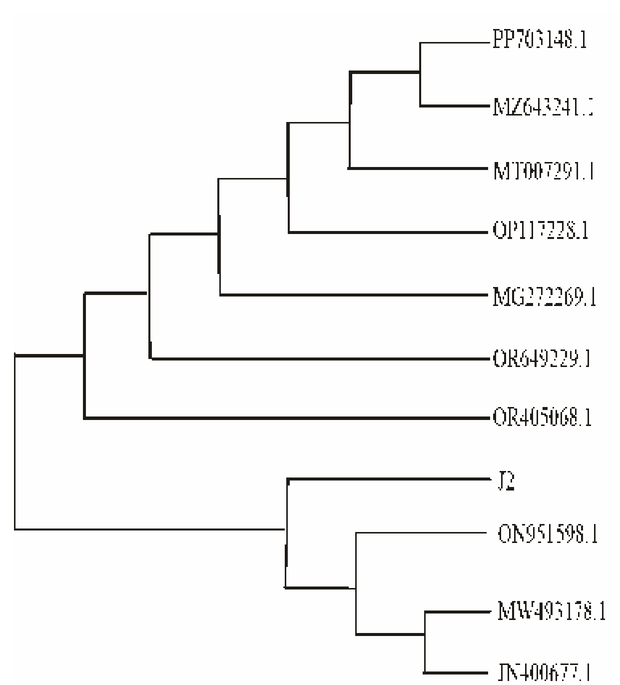


Fig 8.11 Molecular phylogenetic analysis by maximum likelihood method

Table 8.7 Sequences producing significant alignments

Description	Max Score	Total Score	Query Cover	E value	Identity	Accession
Fusarium oxysporum lentis isolate Fol12	883	883	100 %	0.0	99.59 %	ON951598.1
Fusarium solani isolate EF 51	878	878	100 %	0.0	99.38 %	OR405068.1
Fusarium solani isolate EF51	878	878	100 %	0.0	99.38 %	OR649229.1
Fusarium solani strain M5	878	878	100 %	0.0	99.38 %	MG272269.1
Fusarium solani isolate EF 51	878	878	100 %	0.0	99.38 %	OP117228.1
Fusarium solani isolate BF2	878	878	100 %	0.0	99.38 %	MT007291.1
Rhizoctonia solani isolate RR1	878	878	100 %	0.0	99.38 %	PP703148.1
Fusarium solani isolate Fsp-35	878	878	100 %	0.0	99.38%	MZ643241.1
Fusarium sp. strain CZGN-15	876	876	100 %	0.0	99.38%	MW493178.1
Fusarium oxysporum isolate Foc144	876	876	100 %	0.0	99.38%	JN400677.1

Mushroom

Collection and identification of wild mushroom germplasm

Surveys were conducted in the forest areas and local markets of Ranchi district of Jharkhand during 2024. Nine wild germplasm were collected, identified and preserved (Table 8.8, Fig 8.12).

Schizophyllum commune

Amanita caesarea

Amanita chepangiana or *loosi*

Collybia nuda

Pluteus chrysophlebius

Termitomyces medius or radicatus

Pleurotus Pulmonarius

Termitomyces hemii

Rugra (*Pisolithus arrhizus)*

Fig 8.12 Strains of mushroom collected, characterised and preserved

Table 8.8 Morphological characteristics of mushroom species

Strain	Order	Family	Description	Habitat
1. *Schizophyllum commune*	Agaricales	Schizophyllaceae	• The mushroom resembles undulating waves of tightly packed corals. Gillis or split gills vary from creamy yellow to pale white in colour • The cap is small, 1–4 cm wide with a dense yet spongey body texture	It is found in the wild on decaying trees after rainy seasons followed by dry spells where the mushrooms are naturally collected.
2. *Amanita caesarea*	Agaricales	Amanitaceae	• This mushroom has an orange-red cap, initially hemispherical before convex and finally flat • The surface is smooth, and margins striated, and it can reach 15 cm in diameter • The free gills are pale to golden yellow, as is the cylinder-shaped stipe, which is 8–12 cm tall • The spores are white	• *Amanita caesarea*, commonly known as Caesar's mushroom, is a highly regarded edible mushroom in the genus *Amanita* • Habitat: It grows individually or in groups from early summer to mid- autumn in forest area
3. *Amanita chepangiana* or *loosi*	Agaricales	Amanitaceae	• The cap of *Amanita chepangiana* is 150 mm wide, often pure white, sometimes with a slight grayish/brownish over the centre • The gills are free, close to sub crowded, white to very pale pinkish in mass • The stem is 150 - 160 mm long and about 20 mm wide (more or less); white.	The mushroom is edible and very much appreciated by the local population
4. *Collybia nuda*	Agaricales	Hymenogastraceae	• commonly known as the blewit or wood blewit ; previously described as *Lepista nuda* and *Clitocybe nuda* , is an edible mushroom • This mushroom can range from lilac to purple-pink	*Collybia nuda* is saprotrophic species, growing on decaying leaf litter
5. *Pluteus chrysophlebius*	Agaricales	Pluteaceae	• Caps: 1-3 cm wide; stipes 2-5 cm long and 1.5-3 mm thick • Cap**:** Moist when young; bright yellow, fading to yellow-brown in age; smooth to wrinkled in the centre • Gills: Free, whitish at first, then pale yellow, and finally pinkish at maturity	It is found in the wild on decaying trees after rainy seasons
6. *Termitomyces medius or radicatus*	Agricales	*Lyophyllaceae*	• Pileus: 5-11 mm diameter, • Stipe: 4 cm long • *Termitomyces* includes the largest edible mushroom in the world.	When a new termite colony is established, in most cases, the fungus is introduced through the activities of the termites collecting spores from the environment
7. *Pleurotus pulmonarius*	Agricales	*Pleurotaceae*	• Cap: 25-30 cm wide • Pileus: convex to flat • Stipe: short and offset • Spore print: white to yellowish	Temperate and subtropical forests of India
8. *Termitomyces hemii*	Agricales	*Lyophyllaceae*	• Pileus: 5-11 cm diameter, smooth, silky white surface • Stipe: 40 cm long	It has a symbiotic relationship with termites. The fruit bodies (mushrooms) produced by the fungus are edible
9. Rugra (*Pisolithus arrhizus)*	Boletales	sclerodermataceae.	• Potato shape 3.0-6.0 cm in diameter • Outer layer 1-3 mm thick, whitish in cross section • Inner tissue white or in colour • Habitat: growing on soil near various trees including saal, oak tree *etc*	Growing on soil near various trees including saal, oak tree *etc*

Evaluation of oyster mushroom on wheat and paddy straw

Advance varietal trial-2 comprising six high-yielding strains of oyster mushroom (*Pleurotus pulmonarius*) grown on wheat straw was conducted from December, 2023 to February, 2024. The yield and yield attributing characters along with biological efficiency of these strains was observed under Ranchi condition. Among the evaluated strains, the highest biological efficiency on wheat straw was recorded in *PP-23-06* (72.9%) followed by *PP-23-02* (70.6%). Highest weight of fruiting body was recorded in *PP-23-06* (10.0 g) followed by *PP-23-01* (9.3 g). On paddy straw, highest biological efficiency was recorded in *PP-23-06* (70.0%) followed by *PP-23-02* (67.2%). Highest weight of the fruiting body was recorded in *PP-23-06* (8.9 g) followed by *PP-23-01* (7.8 g). Time taken for the first harvest was also minimum in strain *PP-23-06* followed by *PP-23-02* (Fig 8.13) grown on both the substrates (wheat and paddy straw) (Table 8.9).

Evaluation of milky mushroom on wheat and paddy straw

Advance varietal trial-1 involving eight high yielding strains of milky mushroom (*Calocybe indica*) grown on Wheat straw was conducted during February-May, 2024. The yield and yield attributing traits along with biological efficiency of these strains were observed under Ranchi condition. Among the evaluated strains, the highest biological efficiency on wheat straw was recorded in *CL-23-101* (70.0%) followed by *CL-23-104* (68.0%), which was statistically at par with each other. Highest weight of fruiting body was recorded in *CL-23-101* (31.2 g). On paddy straw, highest biological efficiency was also recorded in *CL-23-101* (67.1%) followed by *CL-23-104* (66.1%), though it was statistically at par with each other. Highest weight of fruiting body was recorded in *CL-23-101* (30.4 g). Time taken for the first harvest was also minimum in strain *CL-23-101* (30.2 days) followed by *CL-23-104* (31.0 days) on wheat straw; on paddy straw, time taken for first harvest was minimum in *CL-23-101* (31.2 days) followed by *CL-23-104* (32.4 days)

Table 8.9 Performance of strains of *Pleurotus pulmonarius* on wheat and paddy straw in AVT-2

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
PP-23-01	68.86	65.85	25.9	26.5	9.3	7.8
PP-23-02	70.63	67.23	23.5	24.9	8.2	6.3
PP-23-03	62.48	58.96	27.8	30.0	7.2	6.1
PP-23-04	65.92	65.35	25.1	26.9	8.8	7.3
PP-23-05	67.93	61.02	28.6	30.3	6.0	5.7
PL-23-06	72.91	70.01	23.3	24.8	10.0	8.9
CD (P=0.05)	1.40	1.28	1.3	1.5	0.96	1.08

9 Medicinal and Aromatic Plants

Multipurpose trees and medicinal plants-based agroforestry models

The study focused on identifying the most suitable medicinal plant species for degraded land under rainfed conditions by screening 23 distinct species (Fig 9.1). Among them, four optimal species - hadjor (*Cissus quadrangularis*), shatavari (*Asparagus racemosus*), giloe (*Tinospora cordifolia*) and sarpgandha (*Rauvolfia serpentina*) - were selected for integration into the 'teak + karanj' and 'mahogany + karanj' agroforestry models. The inclusion of medicinal plants improved the soil nutrient status and properties in both agroforestry models compared to systems without medicinal plants. Among the four intercropped species, shatavari proved to be the most productive, with the highest fresh tuber yield recorded in the 'teak + karanj' model (13,350 kg/ha) (Table 9.1).

Fig 9.1 Medicinal plants-based agroforestry models at FSRCHPR, Ranchi

Table 9.1 Performance of different medicinal plants under field condition

Crop	Teak+ karanj system		Teak+ mahogany system	
	Yield (kg/ha fresh weight)	Mortality (%)	Yield (kg/ha fresh weight)	Mortality (%)
Shatavari	13350	2	11400	5
Giloe	10950	12	6600	18
Hadjod	9267	10	2340	14
Sarpagandha	1170	24	914.1	35

10 Conservation Agriculture and Natural Farming

Effects of long-term conservation agriculture (CA) on productivity of rice-based production system in irrigated agro-ecosystem

A long-term field experimentation was undertaken in CSISA (Cereal Systems Initiative for South Asia), Project Phase-I since 2009 (*Rabi*) on CA-based rice-wheat systems at ICAR Research Complex for Eastern Region, Patna. After 7th year of the experiment, ZTDSR-ZT mustard-ZT maize system in CA-based system faced a severe problem of rice mealy bug, and hence, this field was divided into 4-equal plot (ZTDSR, CTDSR, PTR, UPTR). After 2nd year of CT, these plots were again converted into ZTDSR. After 16th year, the maximum rice yield was recorded with TPR (6.24 t/ha), at being par with CTMTR (6.08 t/ha) (Table 10.1). Similar trends were followed in case of total biomass production also. The lowest rice yield was recorded in ZTDSR production system (4.64 t/ha).

Weed seed bank dynamics, resource-use efficiency and greenhouse gas footprint under diverse tillage production systems in Eastern Indo-Gangetic Plains

Adoption of climate-resilient technology, such as conservation agriculture (CA), is critical to minimizing greenhouse gas (GHG) emissions while enhancing crop productivity as well as soil health and environmental sustainability. However, weed interference remains a significant challenge to CA adoption. 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 in a rice-wheat-greengram system in Eastern Indo-Gangetic Plains (EIGP). The experiment followed a split-plot design with three main plots, four subplots, and three replications. The main plot treatments consisted of different tillage and crop establishment practices, while the subplot treatments included various weed management practices. Results indicated that the CA-based system [zero till direct seeded rice (ZTDSR) - zero till wheat (ZTW) - zero till greengram (ZTG)] combined with effective herbicide application improved weed control efficiency and cropping system productivity. The CA-based practice recorded a 5.90% higher rice grain equivalent yield than that in the conventional system [line-puddled transplanted rice (LPTPR)-conventional till (CT) wheat-CT greengram]. Weed emergence varied across CT and CA-based plots. Among the weed management strategies, pre-emergence application of pyrazosulfuron-ethyl (25 g/ha) followed by (*fb*) post-emergence application of cyhalofop-butyl + penoxsulam (100 + 25 g/ha, tank-mix) at 20 days after sowing (DAS) significantly reduced weed density and biomass in rice, achieving 89.40% weed control efficiency. In wheat, post-emergence application of clodinafop-propargyl + metsulfuron-methyl (60 + 5 g/ha, tank-mix) at 25 DAS recorded 93.20% weed control index. For greengram, pre-emergence application of pendimethalin (1000 g/ha) *fb* post-emergence application of imazethapyr (100 g/ha) at 20 DAS resulted in 78.10% weed control efficiency. The CA-based system (ZTDSR-ZTW-ZTG) significantly enhanced soil organic carbon content by 35.90%, 15.70%, and 26.70% at 0–7.5 cm, 7.5–15 cm, and 15–30 cm soil depths, respectively, as compared to the CT system. This practice also resulted in significantly higher active and passive C pool (Fig 10.1). Additionally, the CA practice reduced the global warming potential by 33.50% relative to the CT system. Thus, the integrated effects of crop residue retention and herbicides proved to be an integrated weed management strategy for sustainable intensification of rice-wheat-greengram system under CA contributing to climate change mitigation in EIGP.

Table 10.1 Rice yield as influenced by different tillage-cum-crop-establishment methods under long-term CA-system in irrigated agro-ecosystem (mean data of *Kharif* 2022)

Crop scenario	Crop establishment	Grain yield (t/ha)	Straw yield (t/ha)	Residue load (t/ha)	Root biomass (t/ha)	Total biomass (t/ha)
S1: TPR-CTW-Fallow	Random transp.	6.24^{a}	8.95^{a}	-	0.88^{d}	16.07^{ab}
S2: CTMTR-ZTW-ZTM	Machine transp.	6.08^{ab}	7.80^{b}	1.54^{abc}	1.14^{bc}	16.56^{a}
S3: ZTDSR-ZTW-ZTM	Zero-till	4.86^{c}	6.11^{cd}	1.60^{a}	1.25^{a}	13.82^{c}
S4: ZTDSR-ZTMu-ZTMa	Zero-till	4.64^{cd}	6.33^{c}	1.55^{ab}	1.16^{b}	13.68^{cd}

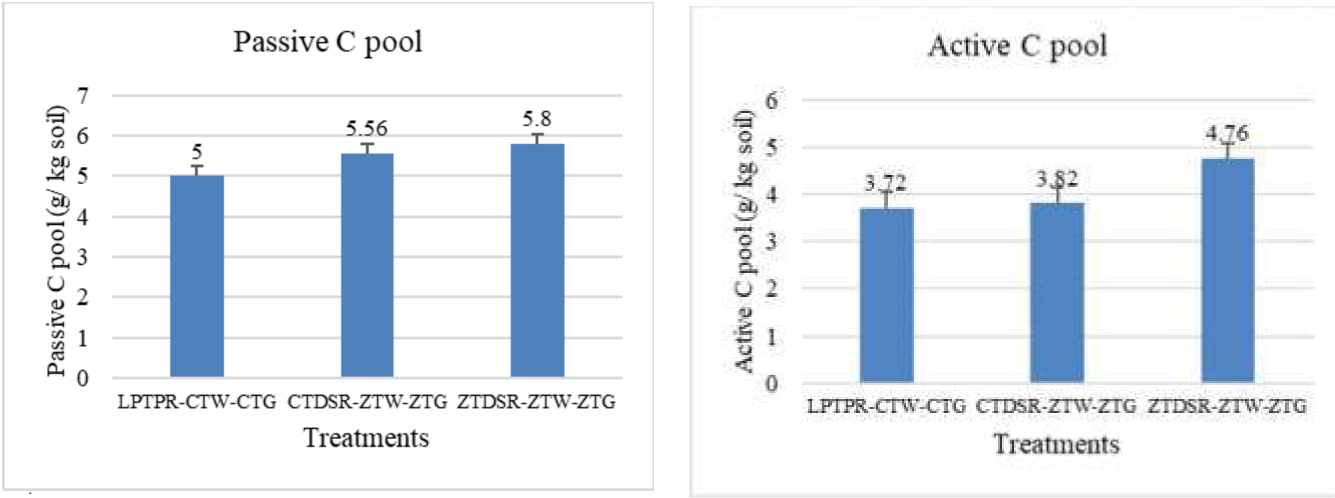


Fig 10.1 Active and passive carbon pool in rice-wheat-greengram system across treatments

Studies on the efficacy of natural farming vis-à-vis existing farming systems

The performance of rice-wheat-greengram cropping system was studied under different cultivation practices involving natural farming, organic farming, integrated nutrient management (INM) and conventional practices at Patna. The experiment was initiated in July 2022 to study the efficacy of natural farming over other farming practices. A standard package of practices for each farming practice was followed. In the case of natural farming, a standard methodology was adopted in which seeds of rice, wheat and greengram were treated with *beejamrita* before sowing. *Ghanjeevamrita* was applied at the time of land preparation, whereas *Jeevamrita* was applied at 15 days intervals; bio-mulch (paddy straw and wheat straw) was used in wheat and greengram to suppress weeds. *Azolla* was grown in rice plots following natural and organic farming practices. Application of *Neemastra* was done for pest and insect control. In the case of other farming practices, recommended doses of N, P, K (120:60:40 kg/ha) were applied to rice and wheat crops in organic and inorganic form as per the treatment. In Organic farming, FYM and vermicompost were applied to fulfill the requirement of nitrogen, phosphorus and potassium; whereas requirements of aforementioned nutrients in conventional practices were met respectively through addition of urea, DAP and MoP to the soil. In INM practices, application of N, P and K was done through a combination of both organic (50%) and inorganic fertilizer (50%). The initial status of the soil was recorded for further comparison. The experimental soil is sandy loam in texture with a pH of 7.72, bulk density of 1.57 Mg/m^3 and organic carbon of 0.51%; the soil was low in available nitrogen (165 kg/ha), medium in available P (16 kg/ha) and available K (112 kg/ha). In the case of water management, three treatments based upon IW: CPE, *viz*., 0.6, 0.8, and 1.0 (*i.e.*, W1, W2 and W3, respectively) were applied. Rice variety 'Swarna Shreya', wheat variety 'HD 2967' and greengram variety 'Virat' were grown during the *Kharif*, *Rabi* and summer seasons, respectively.

The yield of rice was significantly higher under INM practices (5.01 t/ha) than under all farming practices, followed by 4.33 t/ha under conventional systems. The yield of rice under the organic farming system (4.16 t/ha) was at par with that of the conventional system. Natural farming practices produced 3.65 t/ha. In the case of wheat, yield obtained under organic (2.47 t/ha) and natural farming (2.41 t/ha) was at par with each other although lesser than INM (4.25 t/ha) and conventional practices (3.90 t/ha). Greengram performed better under natural farming condition, and produced 17.50 percent higher yield than that under conventional farming (0.80 t/ha). The yield of wheat and greengram was converted to rice equivalent yield (REY) (Fig 10.2). Based on REY, the system productivity of rice-wheat-greengram under natural farming, organic farming, conventional and INM practices was respectively recorded as 9.68 t/ha, 9.85 t/ha, 11.27 t/ha and 12.60 t/ha.

After the completion of second crop cycle, it was observed that available N content was lower than the initial value under all farming practices, whereas in the case of available phosphorous and potassium significant differences were observed. Higher organic carbon was present in the soil of organic farming plots (0.62%) followed by INM (0.60%) and natural farming (0.60%). Natural farming recorded the lowest temperature for all three crops, while the conventional farming had the highest. Natural and organic farming systems helped to maintain lower soil temperatures compared to conventional farming, especially during the peak heat periods.

Evaluation of a natural farming module at FSRCHPR, Ranchi

The experiment was undertaken to evaluate a natural farming module involving different cropping systems for assessing crop productivity, soil fertility, plant protection, nutritional quality, system productivity and economic viability. The cropping patterns-paddy-lentil, black gram-niger, finger millet-mustard and cowpea-chickpea-were assessed under both natural and conventional farming practices (Fig 10.3). Conventional farming included seed treatment with Bavistin, application of FYM @ 1 t/ha, and recommended doses of fertilizer for different crops: black gram, chickpea and lentil (NPK::25:50:25), finger millet (NPK::40:30:20), niger (NPK::20:20:20), mustard (NPK::50:25:20), cowpea (NPK::20:40:20) and paddy (NPK::80:40:40). Natural farming included seed treatment with *Bijamrita*, basal application of *Ghanjivamrita* @ 1 t/ha, followed by fortnightly top drenching of *Jivamrita* @ 500 l/ha throughout the cropping season, along with application of paddy straw mulch @ 5 t/ha. As needed, *Neemastra* spray @ 10 mL/liter of water was applied to standing crops.

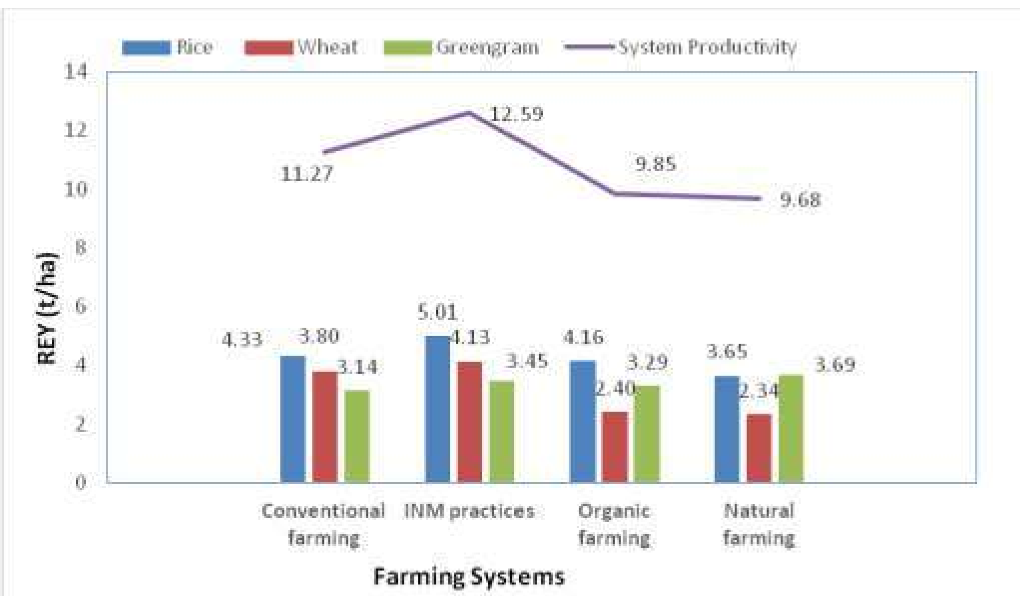


Fig 10.2 Rice equivalent yield and system productivity under different farming systems

Fig 10.3 Comparative plot view of *Kharif* crops under conventional and natural farming

The microbial count, soil chemical and biological properties of natural and conventional farming plots were analyzed across four cropping systems. Table 10.4 shows that soil pH improved under natural farming, averaging 6.13 compared to 5.84 in conventional farming, with the black gram-niger system recording 6.06. Soil EC and organic carbon (%) were also higher in natural farming. Table 10.5 presents biological properties, where DHA and SMBC levels were consistently higher under natural farming. The cowpea–chickpea system recorded the highest values: 129.40 µg TPF/g/d and 354 µg/g, respectively.

The growth and yield attributes of different cropping systems were recorded and analyzed for rice equivalent yield (REY), land use efficiency (LUE) and system productivity (SP) under conventional and natural farming. In *Kharif*, conventional farming had higher REY in black gram-niger (13.72 q/ha), paddy-lentil (18.85 q/ha) and cowpea-chickpea (52.69 q/ha), while finger millet (35.59 q/ha) performed relatively good under natural farming. However, in *Rabi*, natural farming outperformed in all systems: black gram-niger (4.56 q/ha), paddy-lentil (15.63 q/ha), cowpea-chickpea (13.87 q/ha) and finger millet (10.23 q/ha). Natural farming showed higher LUE across all systems: black gram-niger (52.10 %), paddy-lentil (58.93 %), cowpea-chickpea (63.00 %) and finger millet (63.00 %). Similarly, system productivity was higher in natural farming for black gram-niger (9.71 kg/ha/day), paddy-lentil (15.62 kg/ha/day) and cowpea-chickpea (35.35 kg/ha/day), except for finger millet (20.86 kg/ha/day), which performed better under conventional farming.

Table 10.4 Soil chemical properties of different cropping systems under natural and conventional farming (2023-24)

Treatments	Soil pH			Soil EC (dS/m)			SOC (%)		
	NF	CF	Mean	NF	CF	Mean	NF	CF	Mean
Black gram-niger	6.17	5.95	6.06	0.83	0.66	0.74	0.76	0.76	0.76
Paddy-lentil	6.27	5.70	5.98	0.83	0.71	0.77	0.78	0.70	0.74
Cow pea-chickpea	6.07	5.95	6.01	0.81	0.79	0.80	0.72	0.67	0.70
Finger millet-mustard	6.01	5.77	5.89	0.82	0.65	0.74	0.78	0.60	0.69
CD (P = 0.05)	0.116	NS	NS	0.057	NS	NS	0.060	NS	NS

EC: electrical conductivity, SOC: soil organic carbon, NF: natural farming, CF: conventional farming

Table 10.5 Soil biological properties of different cropping systems under natural and conventional farming (2023-24)

Treatments	DHA (µg TPF/g/d)			SMBC (µg/g)		
	NF	CF	Mean	NF	CF	Mean
Black gram-niger	114.5	110.5	112.5	219.5	266.5	243.0
Paddy-lentil	106.9	105.5	106.2	306.3	254.0	280.1
Cowpea-chickpea	129.4	112.1	120.7	354.1	303.5	328.8
Finger millet-mustard	108.7	100.9	104.8	246.1	215.5	230.8
CD (P = 0.05)	6.3	8.9	NS	21.2	30	42.4

SMBC: soil microbial biomass carbon, DHA: dehydrogenase activity, NF: natural farming, CF: conventional farming

11 Farming System Research

Evaluation of Integrated farming system developed at ICAR RCER, Patna

In the state of Bihar, the average land holding size is even less than one acre (>90 %), and rice-wheat is the dominant cropping system. Farmers hardly earn Rs 25,000-30,000 per year, which is very little to support a family having 5-6 members. To enhance the farmers' income and livelihood of the farmers along with other benefits, *viz.*, nutritional security, man-days generation, efficient use of available natural resources, soil fertility enhancement and curtailed cost of production, integrated farming system (IFS) models have been developed to suit varying ecologies of Bihar (Fig 11.1). One acre IFS model (suitable for the irrigated midland situation) and two-acre IFS model (suitable for lowland ecology) provided an annual net income of Rs 1,06,350/- (B-C ratio of 2.01) and Rs 2,16,628/- (B-C ratio of 2.05), respectively, which is about three to four times higher than that of rice-wheat cropping system. In addition, one-acre IFS model integration (field crops + horticultural crops + goatry + poultry + mushroom) produced 3.12 t of vermicompost, 2.61 t of goat manure and 1.58 t of poultry manure, which were equivalent to 111.0 kg of urea, 237.0 kg of SSP and 62.0 kg of MOP. Additional employment of 86 man-days was also generated through this integration. In another IFS model, named two-acre IFS model (field crops + horticultural crops + fish/duck + dairy), the integration produced 15.6 t of cow dung, 9.6 t of vegetable wastes, 1.05 t of duck droppings and 3.02 t of green manure biomass (recycled within the system), adding 71.6 kg of N, 60.4 kg of P and 44.7 kg of K in the soil, which were equivalent to 155.4 kg of urea, 377.5 kg of SSP and 74.5 kg of MOP. Additional employment of 104 man-days was also generated through the system.

Energy budget-based productivity assessment

The crop or livestock productivity assessment based on energy budgeting is essential to make the best use of the existing natural resources to withstand changing climate scenarios. In the current investigation, total energy input required for goat rearing was 24.84 GJ/20 goats/year followed by 9.98 GJ/0.2 ha/year, 3.72 GJ/0.05 ha/year, 2.73 GJ/0.05 ha/year, 2.12 GJ/0.05 ha/year, 1.58 GJ/50 birds/cycle of 60 days and 0.21 GJ/60 days of a cycle for field crops, vegetable, green fodders, fruits, poultry and mushroom cultivation, respectively. Among all the studied agricultural production systems, required labour energy input was maximum in field crops followed by vegetables, green fodder crops, goatry, poultry (broiler), fruit and mushroom cultivation, respectively. Moreover, diesel and electrical energy inputs were recorded maximum in the field crops, followed by green fodder and vegetable

Fig 11.1 Performance of rice under long-term CA-based rice-wheat system at ICAR RCER, Patna

crop production systems. The direct and indirect energy sources were calculated and found to be 2.98 GJ and 24.53 GJ, respectively in field crops and goat rearing. Similarly, renewable and non-renewable energy sources were utilized in goat rearing and field crops as 24.39 GJ and 6.99 GJ, respectively. The energy use efficiency ratio was estimated, and found to be highest in fodder crops (8.66) followed by field crops (6.06), vegetables (2.51), fruits (1.97), mushrooms (1.62), poultry (0.26) and goatry (0.17). Here, it is important to mention that goatry and poultry farming are the least energy efficient agricultural production systems, which produced negative energy mileage (Table 11.1). The energy use efficiency ratio for the main output (EERm) has shown that green fodders and field crops yielded better energy productivity. The net energy gain was recorded maximum from field crops, followed by from green fodder crops, vegetables, fruit crops and mushroom productions (Fig 11.2). The energy profitability of different agricultural production units under one acre IFS was also analysed and found that green fodders cultivation was most profitable in terms of energy, and produced EP ratio of 7.66 followed by field crops (5.06) and vegetables (1.51), respectively. Overall, the total energy input and output in the experimental one-acre IFS model was calculated to be 45.08 GJ and 102.54 GJ, respectively, resulting in an *energy efficiency ratio* of 2.27 (Table 11.2).

Optimization of IFS model design

Resource survey was conducted, and data were collected from two villages, *viz.*, Yashwantpur and Mirzapur, besides from an already developed IFS model at ICAR-RCER Patna. The main components of the IFS model at Yashwantpur are crop, horticulture, livestock and fish. Optimization for getting maximum profit was done for Yashwantpur village (2-Acre IFS model) using Python software (Pulp algorithm) in Anaconda Spyder environment. This optimization model would work for any combination of components of IFS according to the needs of farmers. The gross income of farmers before optimization was Rs. 3,21,612, and after optimization

Table 11.1 Details of the one-acre IFS model

S. No.	Sub-system	Area (m^2)	Component	Season	Days
1	Field crops	2000	Rice	June-Nov	135-140
			Wheat	Nov-Mar	140-145
			Maize	Nov-Apr	160
			Lentil	Nov-Mar	130
			Moong	Nov-Mar	60-70
2	Fodder crop	500	Sorghum	June-Sep	90-100
			Cowpea	June-Sep	80-100
			Berseem	Oct-Mar	60-150
			Oat	Oct-Mar	60-135
3	Vegetables	500	Okra	May-Aug	95-100
			Tomato	Oct-Mar	130-140
			Onion	Oct-Mar	
			Cauliflower	Oct-Feb	
			Cabbage	Oct-Feb	100-110
4	Fruit crops	500	Lemon	-	-
			Guava	-	-
			Banana	-	-
5	Mushroom	Oyster		Oct- March	176
6	Poultry	50 numbers		60 days/cycle	
7	Goatry	20 numbers		365	

of land area, the gross income rose to Rs. 4,10,155; it increased the gross income by Rs. 88,543 (27.5%) after optimization (Table 11.3).

Location-specific IFS models for rainfed ecosystem of eastern plateau and hill region

Under one-acre IFS model, field crops, fruit and vegetable cultivation and dairy were chosen as the primary enterprises, while composting was included as a secondary one to support the system sustainability. Land allocation among these components was carefully optimized based on the nutritional requirements of a farm family. The specific distribution of land across these enterprises, along with the duration of their respective operations, is presented in Table 11.4.

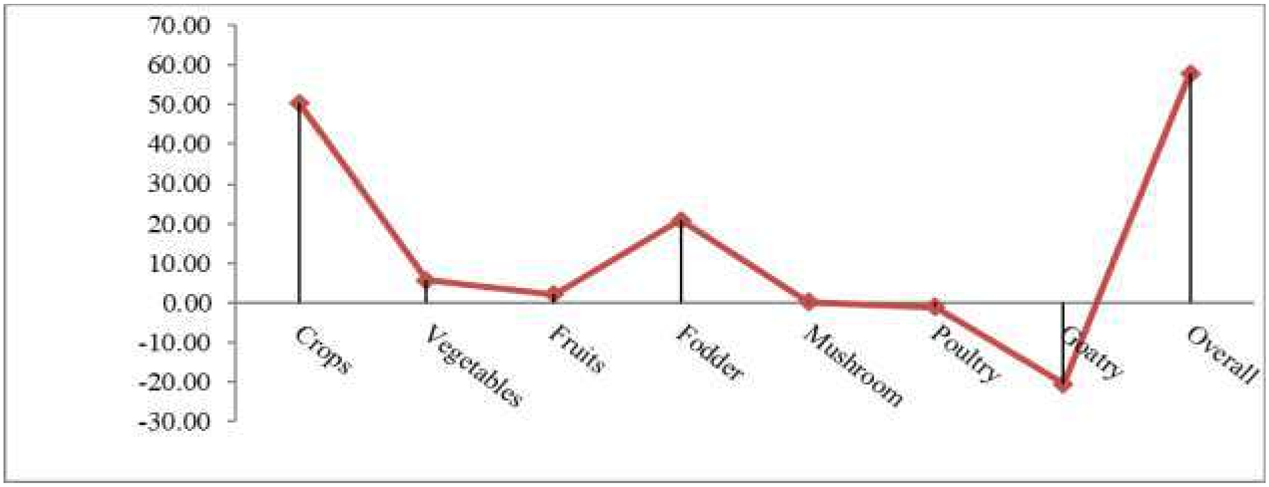


Fig 11.2 Net energy gain under IFS system

Table 11.2 Energy indices under IFS

	Crops	Vegetables	Fruits	Fodder	Mushroom	Poultry	Goatry
TE input (GJ)	9.98	3.72	2.12	2.73	0.21	1.48	24.84
TE output (GJ)	60.44	9.35	4.18	23.63	0.34	0.38	4.22
TE output main (GJ)	28.08	2.12	1.38	23.63	0.31	0.31	3.65
EER	6.06	2.51	1.97	8.66	1.62	0.26	0.17
EERm (main output)	2.81	0.57	0.65	8.66	1.48	0.21	0.15
NEG	50.46	5.63	2.06	20.90	0.13	-1.10	-20.62
EP	5.06	1.51	0.97	7.66	0.62	-0.74	-0.83
DE	2.98	1.18	0.37	1.28	0.19	0.46	0.31
ID	6.99	2.54	1.75	1.45	0.02	1.02	24.53
RE	1.75	1.04	0.56	0.33	0.19	1.22	24.39
NR	8.23	2.68	1.56	2.40	0.02	0.26	0.45
HEP	56.69	17.15	16.66	49.47	1.79	1.50	13.63

TE: total energy, EER: energy efficiency ratio, NEG; net energy gain, EP: energy profitability, DE: direct energy, IE: indirect energy, RE: renewable energy, NRE: nonrenewable energy, HEP: human energy profitability

Table 11.3 Two-acre IFS model at Yashwantpur village of Nalanda district

Components	Area (Acre)	Total/gross income (Rs)	Optimized area (Acre)	Optimized gross income (Rs)
Crop	1.4	58810	1.0	51260
Horticulture	0.2	64282	0.3	84640
Livestock	0.08	119540	0.08	119540
Fish	0.32	78980	0.62	154715
Total	2.0	321612	2.0	410155

Energy Budgeting of one-acre rainfed IFS model

The Energy indices for a one-acre rainfed IFS model provides a comprehensive evaluation as to how energy is utilized and recovered across various farming components (Table 11.5). Each component differs in its energy input and output, indicating its efficiency and contribution to the overall sustainability of the system.

In field crops, the TE input was 14.030 GJ, while the TE output was significantly high at 38.361 GJ, resulting in a NEG of 24.33 GJ. The EER was 2.73, which means for every unit of energy invested, about 2.7 units were gained. When only the TE output main was considered, the EERm was still satisfactory at 1.33. This indicates that field crops are highly energy-productive, and contribute significantly to the system's energy sustainability. The vegetable component showed a TE input of 2.29 GJ and a low TE output of 1.96 GJ, resulting in a negative NEG of -0.33 GJ and an EER of 0.855. This suggested energy inefficiency, where the input outweighed the output. The EERm further droped to 0.418 when only the main product was considered. This negative energy balance could be attributed to high input costs relative to the yield, and indicated the need for optimization in vegetable production.

The fruit component demonstrated good energy performance with a TE input of 1.28 GJ and an output of 2.39 GJ, producing a positive NEG of 1.11 GJ and an EER of 1.86. The main output EERm was also above one (1.07). This showed that fruit production is energy-efficient with relatively low input requirements and good output returns. However, the energy input was dominated by indirect energy (1.12 GJ), indicating room for increasing renewable energy usage. Fodder production stood out as the most energy-efficient component in the IFS model. With a minimal TE input of 1.26 GJ and a high TE output of 19.53 GJ, it recorded a NEG of 18.26 GJ and

Table 11.4 Details of one-acre rainfed IFS Model

Sub-System	Area (m^2)	Component	Season	Days
Field crops	3035.13	Paddy	June- Nov	110-125
		Pigeonpea	June- March	240-250
		Maize	June- Nov	90-110
		Groundnut	June- Nov	130-135
		Chickpea	Nov-March	90-110
		Linseed	Nov-March	90-110
Vegetables	303.51	Elephant foot Yam	June- Jan	210-240
		Dioscorea	June- Jan	210-240
Fruits	323.74	Guava	Perennial	-
Dairy	50.5	No. of cattle: 2	-	-
Compost	50.5	Vermicompost	-	-
		FYM	-	-
Fodder	283.27	Napier	-	-

Fig 11.3 IFS model developed at FSRCHPR, Ranchi

EER of 15.42. Interestingly, the energy output from the main product was even higher than the total (23.63 GJ), resulting in an EERm of 18.65. This anomaly suggested a high caloric or energy value assigned to the main fodder biomass. Fodder also had the lowest non-renewable energy use (0.92 GJ) and moderate HEP of 0.10, indicating its strong role in energy sustainability.

The dairy component appeared to be highly energy-intensive, with the highest TE input at 28.93 GJ and a relatively low TE output of 7.46 GJ, producing a negative NEG of -21.46 GJ. The EER was extremely low at 0.25, and the EERm droped further to 0.01 when only the main product (milk) was considered. This clearly indicates inefficiency in energy terms. Though dairy contributes significantly to livelihoods and nutrient cycling, its heavy reliance on indirect energy (27.83 GJ) and minimal main product energy output raised sustainability concerns. Composting, though a small-scale component, demonstrated a positive energy balance with low input (0.58 GJ) and modest output (0.80 GJ), resulting in a positive NEG of 0.22 GJ and an EER of 1.37. The EERm for compost was 0.53, indicating that even the main output alone covered most of the energy input. Importantly, almost all the input energy was renewable (0.57 GJ out of 0.58 GJ), making composting a sustainable and eco-friendly practice within the IFS model. Thus, the energy indices from this one-acre IFS model revealed that field crops, fodder, fruits and compost are energy-efficient, and contribute positively to the system sustainability.

Table 11.5 Energy indices for one-acre rainfed IFS model

Energy indices	Field crops	Vegetables	Fruits	Fodder	Dairy	Compost
Total energy input (GJ)	14.03	2.28	1.28	1.26	28.93	0.58
Total energy output (GJ)	38.36	1.95	2.39	19.53	7.46	0.80
Total energy output main (GJ)	18.69	0.95	1.38	23.63	0.31	0.31
Energy efficiency ratio (EER)	2.73	0.85	1.86	15.42	0.25	1.37
Main output energy efficiency ratio (EERm)	1.33	0.41	1.07	18.65	0.01	0.53
Net energy gain (GJ)	24.33	-0.33	1.11	18.26	-21.46	0.22
Energy profitability	1.73	-0.14	0.86	14.42	-0.74	0.37
Direct energy (GJ)	3.20	0.53	0.16	0.47	1.07	0.23
Indirect energy (GJ)	10.37	1.26	1.12	0.79	27.83	0.34
Renewable energy (GJ)	2.65	0.63	0.36	0.18	28.90	0.57
Non-renewable energy (GJ)	7.50	1.48	0.77	0.92	0.00	0.00
Human Energy profitability	0.02	0.00	0.01	0.10	0.00	0.00

12 Crop Diversification

Diversification of traditional rice growing areas with suitable alternate crops

A pilot project on crop diversification, initiated in the West Champaran and East Champaran districts of Bihar, aimed at enhancing agricultural productivity, promoting sustainable agriculture and improving livelihood security in the region (Fig 12.1). West Champaran was selected for the first phase (2023-24) of the programme, covering a total of 100 hectares during the *Kharif* season of 2024. The project showcased a transformative impact compared to benchmark data, particularly in terms of productivity, resource efficiency and income enhancement. Traditional cropping systems, such as rice and maize, were replaced or supplemented with diversified crops like maize (Shaktiman-5), soybean (P-1241), pigeonpea (IPA 203) and finger millet (Rajendra Madua-1).

Additionally, innovative intercropping systems, such as maize-pigeonpea and pigeonpea-soybean, were introduced, resulting in improved yields and resource-use efficiency. Maize, soybean, pigeonpea and finger millet yielded 68.4 q/ha, 24.8 q/ha, 27.8 q/ha and 21.7 q/ha, respectively. These crops demonstrated greater profitability, and emerged as a high-return alternative to water-intensive rice cultivation, promoting both sustainability and economic viability. The project also demonstrated notable resource savings. These diversified crops consumed 44.3% less water compared to rice, and increased water use efficiency by 155%, offering an effective solution to water issues. Intercropping systems reduced labor costs by 19.8% through optimized field operations, while efficient soil fertility management decreased fertilizer demand by 38-46%. These interventions collectively enhanced resource-use efficiency and sustainability. Farmers experienced around 116% increase in average income, driven by the higher yields and market rates of diversified crops. Intercropping combinations further amplified profitability by maximizing land use. Overall, the project highlighted the economic and ecological benefits of crop diversification, establishing it as a viable strategy for enhancing productivity, conserving resources and ensuring agricultural sustainability.

Fig12.1 Glimpses of crop diversification project in the West and East Champaran districts

Standardization of agro-techniques in nutri-cereals for enhancing productivity in eastern India

A long-term field experiment was initiated during *Kharif* 2020 at ICAR Research Complex for Eastern Region, Patna with an objective of designing the most productive, profitable and sustainable climate resilient cropping system for eastern India. During the 1st and 2nd years, 7-nutri-cereals including jowar (CSV 15) and bajra (Proagro 9001) and five minor nutri-cereals, namely ragi (RAU 8), barnyard millet (VL 207), foxtail millet (Rajendra Kauni), proso-millet (TNAU 202) and kodo-millet (JK 41) were evaluated under three different planting window, *i.e.*, starting with onset of monsoon, and later at 10-days intervals (5, 10 and 25 July) (Fig 12.2). The soil of the experimental site was loamy in texture (50.4, 35 and 14.6 percents sand, silt and clay, respectively) with pH of 7.5, EC of 0.12 dS/m, SOC content 6.0 g/kg, $KMnO_4$ oxidizable N 64.6 mg/kg, Olsen P 23.9 mg/kg, NH_4OAc exch. K 78.3 mg/kg and DTPA-extractable Zn 0.66 mg/kg (0-15 cm). From findings of 1st/2nd years, 2nd planting window after the onset of monsoon (up to 15th of July) performed better in terms of crop productivity. Among nutri-cereals, jowar (3.43 t/ha) and bajra (2.89 t/ha) as the major, and barnyard millets (2.06 t/ha), ragi (1.93 t/ha) and kodo-millet (2.05 t/ha) as the minor nutri-cereals, were identified as the most productive when planted on/before 15th of July.

Based on local preferences of nutri-cereals, bajra (among major millet), and ragi and barnyard millets (among minor nutri-cereals) were identified for varietal testing. Among the varieties, 'Progro-9001' in bajra, 'RAU 8' in ragi, and Barnyard cv. 'DHBM-93-2' in barnyard millet were identified as the most promising. Similarly, among weed management treatments, 2-hand weeding (25 and 45 DAS) had resulted in significantly higher yields of bajra (3.08 t/ha, ragi (2.29 t/ha) and sawa (1.61 t/ha), but being at par with atrazine@0.5 kg/ha (PE) *fb* 1 HW (30 DAS). Amongst the nutrient management, application of 100% RDN led to significantly higher yields of bajra (2.83 t/ha), ragi (2.25 t/ha) and sawa (1.54 t/ha), although at par with 75% RDN (IN) and 25% RDN (FYM). In the 5th year (2023-24), the experiment was carried out in RCBD to design the most resilient nutri-cereals cropping system for mid Indo-Gangetic plains (Table 12.1). Crop yield range in the case of ragi was 1.71-1.98 t/ha, whereas it was 2.49 to 2.79 t/ha in bajra. Data recording has been continuing in *Rabi* crops (lentil, chickpea, safflower and mustard).

Fig 12.2 Performance of bajra and ragi under cropping systems mode at ICAR RCER Patna

Table 12.1 Performance of millet-based cropping systems under rainfed conditions (mean data of 2024-25)

Cropping systems	Grain yield (t/ha)	Stover yield (t/ha)	Biol. yield (t/ha)	Green fodder yield (t/ha)	Dry-fodder yield (t/ha)	Days to 50% flowering	Days to crop maturity
Ragi-based cropping system							
Ragi-lentil	1.89	0.91	2.80	26.8	10.1	55	91
Ragi-chickpea	1.98	0.85	2.83	25.4	9.12	57	92
Ragi-safflower	1.78	0.94	2.72	23.2	8.98	59	94
Ragi-mustard	1.71	1.02	2.73	21.2	8.35	61	95
Bajra-based cropping system							
Bajra-lentil	2.66	1.57	4.23	56.4	23.1	80	112
Bajra-chickpea	2.79	1.56	4.35	54.7	21.6	81	114
Bajra-safflower	2.58	1.15	3.73	52.7	21.2	83	113
Bajra-mustard	2.49	1.04	3.53	51.9	21.0	85	115

Evaluation of crop establishment methods for improving the productivity of rice-fallow system in eastern India

A long-term field study was initiated during rainy season of 2016 to find out the most suitable rice-winter cropping rotations, and appropriate crop establishment methods and residue management practices in rice - fallow system of eastern India (Fig 12.3). Treatments comprised six levels of crop establishment methods-cum-residue management (CERM) practices: zero-till-direct seeded rice (ZTDSR), conventional-till-DSR (CTDSR), transplanted puddle rice (TPR), ZTDSR with rice residue retention (ZTDSRR+), CTDSR with rice residue retention (CTDSRR+), TPR with rice residue retention (TPRR+) and six post–rainy crops, *viz*., chickpea (Pusa 3043), lentil (HUL 57), safflower (PBNS 12), mustard (Pro-agro 5111), linseed (T 397) and *toria* (TS 36) fitted in a split-plot design. After 9th year, rice yields were higher in general under TPR. Rice productivity was 57.9 and 37.6 percents higher with TPR (5.27 t/ha) than with ZTDSR (3.34 t/ha) and CTDSR (3.83 t/ha) systems (Table 12.2). Irrespective of tillage and cropping systems, the effect of residue management on crop yield was more pronounced in all the treatments. During 9th year of winter cropping, the incidence of dry-root rot in chickpea was severe in ZTDSR followed by CTDSR in residue retained plots. It is interesting to note that the yield of all post-rainy crops was higher in ZTDSR/CTDSR production system than that in TPR. However, TPR production system adversely impacted the performance of all post-rainy pulses/oilseed crops over time.

Table 12.2 Rice yield as influenced by different crop-establishment-cum-residue management (CERM) practices and succeeding winter crops under long-term CA-based rice-fallow system of eastern India (mean data of *Kharif* 2024 after 9th year of experimentation)

CERM		Rice yield (t/ha)						Mean
		Chickpea	Lentil	Safflower	Linseed	Mustard	Toria	
[ZTDSR-ZT] R-	CA	3.35	3.21	3.15	3.29	3.33	2.96	3.22
[ZTDSR-ZT] R+		3.42	3.48	3.37	3.58	3.59	3.34	3.46
[CTDSR-ZT] R-	pCA	3.80	3.52	3.51	3.71	3.82	3.80	3.69
[CTDSR-ZT] R+		4.12	3.83	3.70	3.90	4.15	4.11	3.97
[TPR-ZT] R-	FP	5.28	5.39	4.99	5.13	4.99	5.09	5.14
[TPR-ZT] R+		5.49	5.56	5.28	5.24	5.36	5.48	5.40
CD (P = 0.05)		-	-	-	-	-	-	

CA: conservation agriculture, pCA: partial conservation agriculture, FP: farmers practices, R+ : 30% residue retention, R- : without residue retention

Fig 12.3 Performance of rice under different CERM and preceding winter crops at ICAR RCER

13 Carbon Sequestration and Nutrient Dynamics

Soil organic carbon fractions in different agricultural production system

The different fractions of TSOC, *viz.*, very labile carbon (C_{VL}), labile carbon (C_L), less labile carbon (C_{LL}) and non-labile carbon (C_{NL}), showed significant variation across the agricultural production systems. The C_{VL} stock of MMAR (mango + mahogany + aonla + rice) in all the soil depths was significantly high over the control, napier grass and rice production system. The highest C_{VL} stock in the entire 0-0.60 m soil depth was 22.18 Mg/ha in MMAR, which was significantly superior to plum orchard, control, napier grass and rice production system (Table 13.1). The highest C_L stock in 0-0.60 m soil depth was 15.47 Mg/ha in MMAR, and was significantly highest over plum orchard, control, napier grass and rice production system. The C_{LL} stock in the entire depth of 0-0.60 m was highest of 11.94 Mg/ha in MMAR, which was significantly better than other production systems except MMPR (mango + mahogany + peach + rice). The highest C_{NL} stock in the entire 0-0.60 m soil depth was 13.8 Mg/ha in MMAR, and was significantly better than control, napier grass and rice production system.

Table 13.1 Distribution of soil organic carbon fractions at different soil depths in 7-year-old agricultural production system

Treatments	Soil organic carbon fraction (Mg C/ha soil)				
	0-0.15 m	0.15-0.30 m	0.30-0.45 m	0.45-0.60 m	Total (0-0.60 m)
Very labile pool (C_{VL})					
T1: Control	5.38^{c}	3.38^{c}	3.05^{c}	2.69^{c}	14.49^{c}
T2: Napier	6.02^{c}	4.01^{c}	3.38^{c}	3.37^{abc}	16.79^{bc}
T3: Rice	5.9^{c}	3.81^{bc}	3.29^{c}	2.49^{c}	15.5^{bc}
T4: MMR	6.24^{bc}	5.29^{a}	4.5^{ab}	4.13^{a}	20.15^{a}
T5: Plum orchard	6.23^{bc}	4.76^{ab}	3.66^{bc}	3.04^{bc}	17.69^{b}
T6: MMAR	7.17^{a}	5.86^{a}	4.98^{a}	4.17^{a}	22.18^{a}
T7: MMPR	6.94^{ab}	5.75^{a}	4.64^{ab}	3.82^{ab}	21.16^{a}
Labile pool (C_L)					
T1: Control	4.36^{d}	2.32^{b}	2.2^{b}	1.82^{b}	10.7^{d}
T2: Napier	4.73^{bcd}	2.79^{b}	2.83^{a}	2.04^{b}	12.39^{c}
T3: Rice	4.57^{cd}	2.4^{b}	2.31^{b}	1.91^{b}	11.18^{d}
T4: MMR	5.43^{ab}	3.51^{a}	3.21^{a}	2.88^{a}	15.03^{a}
T5: Plum orchard	4.73^{bcd}	3.51^{a}	3.02^{a}	2.28^{b}	13.54^{b}
T6: MMAR	5.58^{a}	3.76^{a}	3.29^{a}	2.84^{a}	15.47^{a}
T7: MMPR	5.36^{abc}	3.66^{a}	3.17^{a}	2.75^{a}	14.95^{a}
Less labile pool (C_{LL})					
T1: Control	2.6^{a}	1.73^{c}	1.22^{d}	1.3^{c}	6.85^{c}
T2: Napier	2.86^{a}	1.5^{c}	1.61^{c}	1.31^{c}	7.28^{c}
T3: Rice	2.71^{a}	1.94^{bc}	1.4^{cd}	1.23^{c}	7.28^{c}
T4: MMR	3.25^{a}	2.41^{ab}	2.29^{b}	2.34^{b}	10.28^{b}
T5: Plum orchard	3.22^{a}	2.4^{ab}	2.1^{b}	2.52^{ab}	10.25^{b}
T6: MMAR	3.4^{a}	2.86^{a}	2.92^{a}	2.76^{a}	11.94^{a}
T7: MMPR	3.35^{a}	2.89^{a}	2.37^{b}	2.37^{b}	10.99^{ab}

Non-labile pool (C_{NL})					
T1: Control	3.7[a]	2.97[a]	2.37[a]	2.35[a]	11.4[c]
T2: Napier	3.75[a]	3.49[a]	3.1[a]	1.88[a]	12.23[bc]
T3: Rice	3.61[a]	3.43[a]	2.63[a]	2.33[a]	12.01[bc]
T4: MMR	3.94[a]	3.77[a]	3.08[a]	2.2[a]	13[ab]
T5: Plum orchard	4.22[a]	3.3[a]	2.91[a]	2.45[a]	12.89[ab]
T6: MMAR	4.41[a]	3.79[a]	3.28[a]	2.32[a]	13.8[a]
T7: MMPR	4.03[a]	3.85[a]	3.09[a]	2.23[a]	13.2[ab]

MMR: mango + mahogany + rice, MMAR: mango + mahogany + aonla + rice, MMPR: mango + mahogany + peach + rice; within a column, values indicated by the same letters are not significantly different at P = 0.05 by Duncan's multiple range test (DMRT)

Organic amendments for phosphorus mobilization in acidic soils

A field experiment was conducted at FSRCHPR, Ranchi to study the effect of organic amendments on phosphorus mobilization in acidic soils. The experiment was laid out in a RCBD 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 (3t/ha), T7 = vermicompost (5t/ha), T8 = vermicompost (7 t/ha), and T9 = green manuring (*dhaincha*). While nitrogen and potassium were applied uniformly as per RDF, phosphorus was omitted in treatments from T3 to T9 to assess mobilization in soil.

The microbial count analysis revealed significant variations among treatments. The bacterial population (CFU × 10^6 per gram of soil) was the highest in T4 (40.1), followed closely by T5 (38.1) and T3 (38.6). The fungal population (CFU × 10^4 per gram of soil) was significantly enhanced in T7 (9.80) and T8 (8.50), suggesting that vermicompost applications improved fungal growth. Actinomycetes population (CFU × 10^6 per gram of soil) was the highest in T8 (6.69), indicating improved microbial diversity with organic amendments. The data on soil enzyme activities in the experiment demonstrated that organic amendments, particularly vermicompost and PSB application (notably in treatments T6, T7, and T8), significantly enhanced microbial activity and soil health. The higher fluorescein diacetate (FDA) activity (Fig 13.1) in T7 and T8 reflected increased microbial biomass and overall enzymatic potential, while increased acid phosphatase activity (Fig 13.2) in vermicompost applied treatments (T6, T7, T8) indicated improved phosphorus mineralization and cycling. Additionally, the highest dehydrogenase activity (DHA) observed in T8 suggested enhanced microbial respiration and energy metabolism. Thus, the higher organic inputs promoted microbial-mediated biochemical processes essential for phosphorus solubilization and nutrient availability, in phosphorus-deficient acidic soils through sustainable management practices.

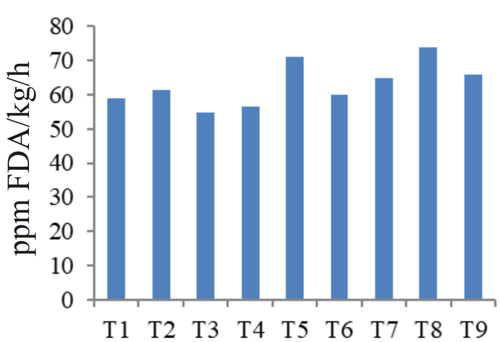


Fig 13.1 Effect of organic amendments on fluorescein diacetate activity (FDA) in soil

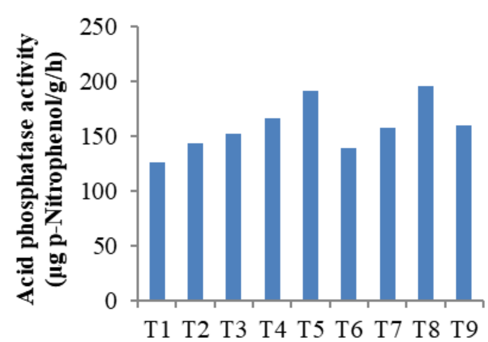


Fig 13.2 Effect of organic amendments on soil enzyme activity of acid phosphatase

Impact of tillage and crop establishment methods on soils health, yield gains and water productivity

The experiment comprised of nine different treatments (seven rice-based cropping system: 1-7, and two millet-based cropping system: 8-9) was initiated during October 2023. The treatments were: SC-1 (conventional tillage practices with full dose of fertilizer and irrigation requirement of crops), SC-2 (partial conservation agriculture with full dose of fertilizer and 80% irrigation requirement of crops), SC-3 (partial conservation agriculture with full dose of fertilizer and 60% irrigation requirement of crops), SC-4 (full conservation agriculture with full dose of fertilizer and 80% irrigation requirement of crops), SC-5 (full conservation agriculture with full dose of fertilizer and 60% irrigation requirement of crops), SC-6 (full conservation agriculture with 75% dose of fertilizer and 80% irrigation requirement of crops), SC-7 (full conservation agriculture with 75% dose of fertilizer and 60% irrigation requirement of crops), SC-8 (full conservation agriculture with full dose of fertilizer and 80% irrigation requirement in millet based cropping system), and SC-9 (full conservation agriculture with 75% dose of fertilizer and 80% irrigation requirement in millet based cropping system).

Effect on chemical and biological properties of soil

The soil parameters like pH and soil organic carbon did not vary among the treatments in both the soil depth of 0-15 and 15-30 cm (Table 13.2). The soil pH varied from 4.92 to 5.10 in the surface soil, while it varied from 5.0 to 5.24 among the treatments. The available N content was significantly high in the treatment SC-1 (202.4 kg/ha) compared to SC-3 in the surface soil. At 15-30 cm soil depth, the available N content was significantly high in SC-9 (200 kg/ha) as compared to SC-6. The available-K content in the post-harvest soil varied from 160.80 to 207.60 kg/ha in surface soil, while it was 152 to 183.80 kg/ha in 15-30 cm soil depth. The K availability was significantly high in SC-1 (207.6 kg/ha) compared to SC-3, SC-4, SC-5 and SC-7 in the surface soil, while SC-8 registered highest available-K in sub-surface soil. The available-P content in both the soil depth was non-significant among the treatments.

Effect on soil biological activity

The soil biological activity, *viz.*, dehydrogenase activity and soil microbial biomass carbon were higher in the surface soil than sub-surface soil. The dehydrogenase activity and soil microbial biomass carbon were influenced by various tillage and crop establishment methods in rice and millet-based cropping system. The SC-4 recorded significantly high dehydrogenase activity in both the soil depth of 0-15 and 15-30 cm (124.80 and 102.30 µg TPF/g/d, respectively). The soil microbial biomass carbon varied from 123.30 to 179 µg/g in the surface soil, while it was 95.50 to 214.20 µg/g at 15-30 cm soil depth. The soil microbial biomass carbon was significantly high, i.e., 179 and 214.20 µg/g, respectively in 0-15 and 15-30 cm soil depth (Table 13.3).

Table 13.2 Effect of tillage and crop establishment methods on chemical properties of soil

Treatment	Soil pH		Soil organic carbon (g/kg)		Available N (kg/ha)		Available P (kg/ha)		Available K (kg/ha)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
SC-1	4.93	5.24	5.25	3.54	202.4^{a}	185.5^{ab}	42.85^{a}	34.18^{ab}	207.6^{a}	170.9^{abc}
SC-2	5.10	5.02	5.41	3.70	175.5^{ab}	182.6^{ab}	38.94^{a}	30.75^{b}	180.3^{abc}	153.8^{bc}
SC-3	4.90	5.10	5.24	3.43	167.6^{b}	190.4^{ab}	37.24^{a}	32.40^{ab}	175.1^{bc}	162.0^{bc}
SC-4	4.92	5.09	5.40	3.73	183.4^{ab}	188.2^{ab}	40.34^{a}	31.13^{b}	178.8^{bc}	155.7^{bc}
SC-5	4.98	5.13	5.20	3.22	181.8^{ab}	181.8^{ab}	39.38^{a}	30.40^{b}	172.7^{bc}	152.0^{c}
SC-6	4.99	5.21	5.32	3.67	187.4^{ab}	170.0^{b}	41.24^{a}	33.68^{ab}	193.2^{ab}	168.4^{abc}
SC-7	4.96	5.16	5.32	3.67	182.6^{ab}	178.8^{ab}	40.16^{a}	32.08^{b}	160.8^{c}	160.4^{bc}
SC-8	4.92	5.06	5.38	3.65	178.7^{ab}	182.9^{ab}	39.14^{a}	36.76^{a}	187.0^{abc}	183.8^{a}
SC-9	4.97	5.04	5.19	3.71	181.2^{ab}	200.1^{a}	39.86^{a}	34.89^{ab}	199.7^{ab}	174.4^{ab}

Table 13.3 Effect of tillage and crop establishment methods on soil biological activity

Treatments	Dehydrogenase activity (µg TPF/g/d)		Soil microbial biomass carbon (µg/g)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm
SC-1	83.2[cd]	70.7[c]	134.4[bc]	214.2[a]
SC-2	118.1[ab]	95.0[ab]	151.0[abc]	134.3[b]
SC-3	99.2[bcd]	83.3[abc]	134.7[bc]	95.5[c]
SC-4	124.8[a]	102.3[a]	179.0[a]	140.9[b]
SC-5	78.3[d]	69.9[c]	123.3[c]	101.4[c]
SC-6	102.1[bc]	86.8[abc]	157.4[ab]	128.4[b]
SC-7	92.1[cd]	78.9[bc]	136.2[bc]	144.2[b]
SC-8	113.5[ab]	96.5[ab]	176.8[a]	146.4[b]
SC-9	97.0[bcd]	82.8[abc]	128.1[c]	100.9[c]

Effect on crop yields and water productivity

The mustard grain yield exhibited significant variation across different treatments, with the highest yield of 1.4 t/ha recorded in SC-2 which incorporated partial conservation agriculture, full-dose fertilizer application and 80% irrigation (80ET). On average, treatments with 80ET achieved a grain yield of 1.12 t/ha, reflecting a 15.5% increase over those receiving 100% irrigation (100ET). The yield in SC-2 was significantly high compared to SC-1, SC-3, SC-5, SC-6, SC-7 and SC-8, highlighting the effectiveness of optimized irrigation and nutrient management. Root volume, a critical factor influencing water and nutrient uptake, drought tolerance and overall plant health showed minimal variation across treatments. However, the highest root volume of 6.73 cm^3/plant was recorded in SC-2, suggesting a better-developed root system under optimized conservation practices. Water productivity varied from 0.18 to 0.30 kg/m^3 across treatments, with SC-2 achieving the highest (0.30 kg/m^3). Additionally, the mean effect of 60% irrigation (60ET) resulted in the highest overall water productivity of 0.26 kg/m^3, representing a 40% improvement over 100ET (Table 13.4). These findings suggested that adopting conservation agriculture with optimized irrigation strategies could significantly enhance mustard yield and improve water use efficiency, making it a viable approach for sustainable agriculture in water-limited regions.

Table 13.4 Effect of tillage and crop establishment methods on mustard grain yield, water productivity and root volume

Treatment	Mustard grain yield (t/ha)	Water productivity (kg/m^3)	Root volume (cm^3/plant)
SC-1	0.97[bc]	0.18[c]	6.00[a]
SC-2	1.40[a]	0.30[a]	6.73[a]
SC-3	0.99[bc]	0.25[abc]	6.17[a]
SC-4	1.22[ab]	0.26[ab]	6.50[a]
SC-5	1.07[bc]	0.27[ab]	6.60[a]
SC-6	0.84[c]	0.18[c]	5.67[a]
SC-7	1.03[bc]	0.26[ab]	6.43[a]
SC-8	0.99[bc]	0.21[bc]	6.33[a]
SC-9	1.17[ab]	0.25[ab]	6.70[a]

Bio-nano sulphur formulation of methanotrophs for decarbonization, disease resistance and sustaining productivity in rice-oilseed cropping system

A novel research initiative (funded by the NASF) was initiated in July 2024 under the leadership of ICAR-NRRI, Cuttack, with ICAR-RCER serving as the consortium partner. The project aims to develop and evaluate bio-nano sulphur formulations of methanotrophs to mitigate greenhouse gas emissions, enhance disease resistance and sustain productivity in rice-oilseed cropping systems. During the first year of experiment, field trials were conducted to assess the impact of different treatment combinations on rice productivity and GHG emissions during the *Kharif* season (Fig 13.3). The experimental design included four treatments, *viz.*, T1: RDF (N:P:K::120:50:50 kg/ha), T2: RDF + methanotrophs, T3: RDF + elemental sulphur, and T4: RDF + methanotrophs + elemental sulphur.

Yield analysis revealed that the integrated application of RDF, methanotrophs and elemental sulphur (T4) resulted in a 57% increase in grain yield compared to the control treatment (T1). Furthermore, T2 and T3 demonstrated 17% and 29% higher yields, respectively, than T1. In terms of methane (CH_4) emissions, the RDF-alone treatment (T1) recorded a methane flux of 28.90 kg/ha, whereas the lowest emissions were observed in T4, with a significant reduction to 11.60 kg/ha. The application of methanotrophs (T2) and elemental sulphur (T3) independently also contributed to methane mitigation, but were less effective than their combined application in T4.

Fig 13.3 Experimental site of the project

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14 Soil and Water Conservation

Multiple use of water

Enhancement of agricultural productivity through multiple use of water

A water-efficient 'multiple use of water' (MUW) model was developed at the Sabajpura farm, Patna to address the issue of increasing water stress due to high agricultural water demand and inefficient irrigation practices. This innovative model integrates water harvesting and its conservation, ground water recharge, smart water application techniques like drip and sprinkler irrigation, fertigation for nutrient management, and resource conservation technologies for enhancing input use efficiency, improving soil health and reducing global warming potential (GWP).

Components of MUW model

The layout of the MUW model is shown in Fig 14.1. The total area of the newly developed model is 0.65 ha. This model involves studies in eight different areas covering various aspects of water, soil and other components.

Farm pond excavated for composite fish farming

A farm pond measuring 48 m × 30 m × 2.5 m (storage capacity: 2000 m^3) was excavated in a low-lying area of the project site. The side slopes of the pond were maintained at a 1:1 ratio and stabilized with locally available dub grass to prevent the formation of rills. The farm pond harvests and stores runoff water from the project site. It is refilled with groundwater as needed, and water from the pond is diverted to various plots through gravity or a pressurized irrigation system based on crop water requirements. This ensures the water quality in the pond for fish farming. A staff gauge is installed for taking depth of water in the pond on a daily basis (mean water depth is maintained at 1.6 m). Near the farm pond, a pan evaporimeter and rain gauge is also installed to study water balance in farm pond.

An experiment was conducted to assess the growth, survival percentage and production performance of different fishes in the composite culture system. Stunted fingerlings of *Catla catla*, *Labeo rohita*, *Cirrhinus mrigala*, *Ctenopharyngodon idella*, and *Pangasianodon hypophthalmus* at the combination of 35:30:20:10:5 were stocked at the rate of 10,000/ha. A commercially available floating pelleted supplementary diet was provided @ 4% of the body weight, having 28% crude protein. A broadcasting feeding method was followed to feed the fish. Samplings for estimation of water quality parameters were carried out during morning hours at monthly intervals. A portable digital instrument was used to measure pond water temperature, pH, and dissolved oxygen content. Parameters such as alkalinity and hardness were estimated using the titrimetric method, and nitrite, nitrate, and ammonia

Fig 14.1 Layout of the new MUW model and the field view after its establishment

were estimated using Kit. Every month, 30 fish of each species were sampled from the pond with the help of a dragnet to determine their weight gain percentage, specific growth rate, and feed conversion ratio (Fig 14.2). Additionally, fruits (guava, acid lime, banana and moringa) and vegetables (tomato and brinjal) were planted along the margins of the pond dyke to optimize land use.

Evaluating duck rearing in MUW system versus indoor housing

This study aimed to evaluate the economic benefits of raising ducks in MUW system vs. indoor rearing while examining the impact on pond water quality. A bamboo-based duck shed, measuring 10×8×7 $feet^3$, was set up on the dyke of a fish pond (Fig 14.3). Twenty-four ducks of similar age (3-4 months) were divided into two groups (11 female and one male in each group). Birds of Group 1 (average weight 1.04 ± 0.018 kg) were kept indoor at ICAR main campus, while the birds of Group 2 (average weight 1.04 ± 0.023 kg) were reared in the pond-based IFS at the Sabajpura farm. The birds were given commercialized poultry feed mixed with paddy in equal amount @130 g/day/bird in both the groups. The total egg production for initial first month was significantly high in G2 (78 eggs) as compared to G1 (38 eggs). The average monthly body weight of the birds of G2 was 1.24 ± 0.029 kg and 1.22 ± 0.033 kg while the same of G1 was 1.22 ± 0.018 kg and 1.26 ± 0.014 kg, respectively. Pond flora and insects, which were additional sources of feed for the ducks reared in IFS, could contribute to high egg production as compared to those kept indoor.

Modified raised-sunken conservation bed for enhancing land and water productivity

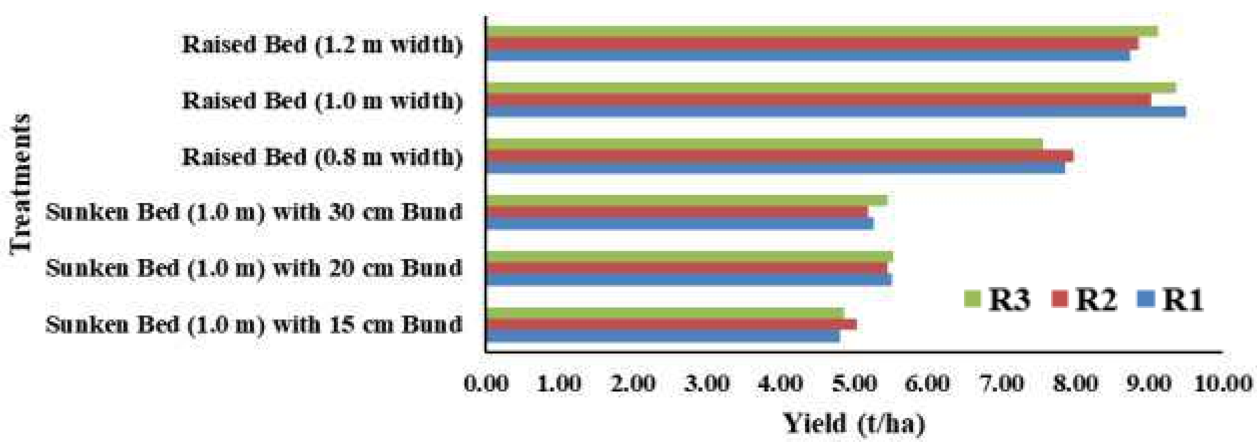
The modified raised sunken conservation bed (MRSCB) technology offers an innovative and sustainable approach to tackling the challenges of low agricultural productivity and inefficient water management prevalent in the lowland ecosystems of

Fig 14.2 Fish sample for recording its length, and pond dike intensification with fruits trees and vegetables

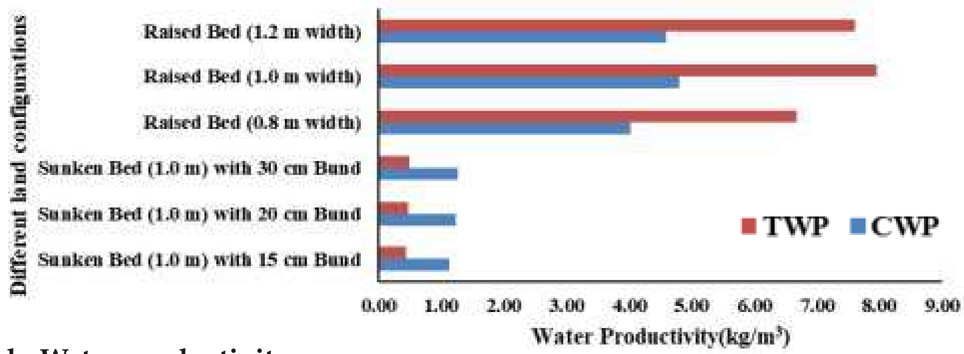
Fig 14.3 Ducks rearing in MUW system

eastern India. The permanent MRSCB system involves creating alternate raised beds and trenches (sunken beds) using a simple cutting and filling method. In the first year, the experiment included three raised bed width (0.8 m, 1.0 m and 1.2 m) combined with bund height of 15 cm, 20 cm and 30 cm and a 1.0 m-wide sunken bed. Paddy was cultivated on the sunken bed, while okra was grown on the raised beds. Irrigation was provided only to paddy, while okra depended on residual soil moisture. The results indicated that a 20 cm bund height resulted in the highest paddy yield (5.5 t/ha) due to optimal water retention, whereas a 15 cm bund led to water stress (4.9 t/ha), and a 30 cm bund retained excess moisture, reducing the yield (5.3 t/ha) only slightly. Okra performed best on 1.0 m raised beds (9.3 t/ha) due to adequate moisture retention, while 0.8 m beds had lower moisture availability, and 1.2 m beds experienced excessive drying, leading to reduced yields (7.8 t/ha). Additionally, in the paddy (sunken bed system), increasing bund height from 15 cm to 30 cm enhanced both crop water productivity (CWP) and total water productivity (TWP), with CWP rising from 1.13 to 1.27 kg/m^3 and TWP from 0.43 to 0.49 kg/m^3, indicating better water retention and efficiency. In the Okra (raised bed system), the 1.0 m wide raised bed achieved the highest CWP (4.79 kg/m^3) and TWP (7.95 kg/m^3), outperforming the 0.8 m and 1.2 m wide beds, suggesting that 1.0 m wide beds optimized water use efficiency and productivity in okra cultivation. Overall, the study demonstrated that the sunken bed system effectively conserved water for paddy, while lateral moisture movement supported okra growth, minimizing irrigation needs. A 20 cm bund height and a 1.0 m raised bed width were identified as the most effective combination for sustainable crop production and efficient water management (Fig 14.4 and 14.5).

Fig 14.4 Rice in sunken beds and okra on raised beds in MRSCB technology



a. Yield variations



b. Water productivity

Fig 14.5 (a) Yield, and (b) water productivity variations in raised and sunken bed experiment

Water management in rice-based system

Rice-wheat cropping system is the dominant cropping system of Indo Gangetic plains. This practice has resulted in several problems along with resource depletion, deterioration of the soil fertility, increasing problem of weeds, insect-pest and diseases, stagnation in system productivity and profitability of the cropping system and lowering of the groundwater table. Keeping all these points in view under crop component of MUW model, four cropping systems, *viz.*, (i) rice-wheat-green gram, (ii) rice-lentil- green gram, (iii) rice-maize-green gram, and (iv) rice-cauliflower-spinach-green gram, were undertaken. During *Kharif* season, four methods of irrigation, namely (i) alternate wetting and drying (AWD), (ii) critical stages (iii) sensor-based irrigation, and (iv) flood irrigation, were proposed to apply in rice crop through pond water. In the first year of the project (as the project has been in the establishment phase), flood irrigation was provided to all the rice plots. It was observed that the plant height and panicle length of rice variety 'Swarna Poorvi-3' ranged from 114.8 to 129.6 cm and 28.52 – 29.64 cm, respectively. The grain yield ranged from 5.73 t/ha to 6.04 t/ha. Total water productivity varied from 0.66 – 0.69kg/m^3 (Fig 14.6).

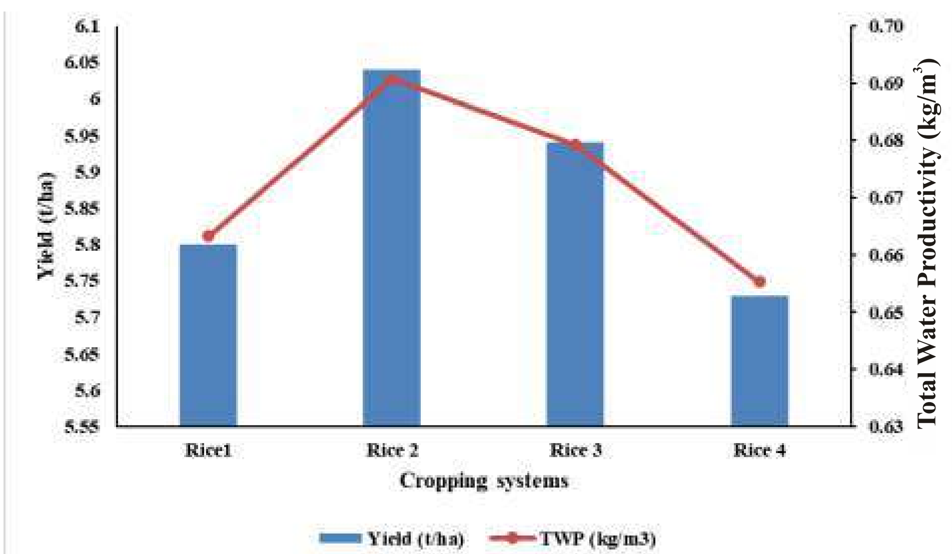


Fig 14.6 Grain yield and total water productivity of rice

Water management in mango and banana

A mango block (0.17 ha) and a banana block (0.03 ha) have been established to provide income stability and enhance water productivity (Fig 14.7). Mango and banana were grown under various mulching and fertigation practices for efficient water utilization. Grafted sapling of mango variety 'Amrapali' was planted at the end of the rainy season at a spacing of 5 m × 5 m. in other block, tissue culture sapling of banana variety 'G 9' was also planted at the end of the rainy season of 2023 at a spacing of 2 m × 2 m. Three mulching treatments, i.e., weedmat, woven coir geo-textile mulching and no mulch (control), were proposed to be common for both mango and banana. In mango, two irrigation treatments, i.e., inorganic fertigation through drip and ring basin irrigation with farmers' practice of fertilization (control) were adopted, whereas for banana also the aforesaid two irrigation treatments were followed. Suitable intercrops like lentil, vegetable peas, and the like are being integrated to enhance income and sustain soil health.

Integrated modelling approach for developing drought management strategies in the Sakri river basin

This study was conducted in the Sakri River Basin of India. The results showed that 46.82%, 32.46% and 20.73% and 56.56%, 23.66% and 19.7% of the basin areas, based respectively on the results of morphometric and PCA approaches, came under high (H), medium (M) and low (L) priority, respectively. The priority map was developed for evaluating the surface runoff and soil erosion in the Sakri river basin. As per morphometric results, relief, linear and areal parameters played an important role in the control of soil erosion and surface runoff by recommending suitable soil and water conservation measures on sub-watershed basis (Table 14.1). In this study, suitable water harvesting measures were identified and suggested based on the elevation, drainage pattern, soil, land use land cover and priority ranking of sub-watershed. Low priority sub-watershed, mostly having less than 1% slope could be managed by the farm pond, tanks, reservoir, check dam, grassed waterways and gully plugging soil and water harvesting structures. In high priority watershed having slope of 5%, drought situation could be managed by harvesting water through constructing structures like CB, BBF, CBT, GB and CTCD. These water harvesting measures are generally feasible in these basins because approximately 80% of landholding comes under small and marginal category. They can adopt recommended technology at lower cost and also can minimize the negative impact of climate change. Medium priority sub-watershed could be managed by recommended structures in low as well as high priority sub-watersheds.

(a)

(b)

Fig 14.7 Mango (a) and banana (b) plants under drip-based fertigation system

Table 14.1 Recommended water harvesting structure in sub-watersheds

Sub-watershed	Slope (%)	Priority	Recommended water harvesting structure
SW1	0-0.5	Low	Farm pond, tanks, check dam, reservoir, grassed waterways and gully plugging
SW2	0-0.5	Low	Farm pond, tanks, check dam, reservoir, grassed waterways and gully plugging
SW3	0.5-1	High	Farm pond, tanks, check dam, reservoir and grassed waterways
SW4	1-5	Medium	Contour bunding (CB), broad bed and furrow (BBF), conservation bench terrace (CBT), graded bunding (GB) and contour trenches conservation ditches (CTCD)
SW5	1-5	High	CB, BBF, CBT, GB, CTCD
SW6	1-5	High	CB, BBF, CBT, GB, CTCD
SW7	1-5	Medium	CB, CBT, BBF, CTCD, GB
SW8	1-5	High	CB, BBF, CBT, GB, CTCD
SW9	1-5	High	CB, BBF, CBT, GB, CTCD
SW10	1-5	Medium	CB, CBT, BBF, CTCD, GB
SW11	1-5	Low	CB, BBF, CBT, GB, CTCD

Simulating soil water and nutrient dynamics in rice-wheat-moong cropping system

An experiment on rice-wheat-moong cropping system was conducted during the year 2023-24. Soil samples at three different depths (N_1: 0-15 cm, N_2: 15-30 cm, and N_3: 30-45 cm) in the root zone were collected and analysed in the lab to determine soil moisture. In the rice crop, four irrigations were applied, the first on 14th of August (226 day), second on 2nd September (245 day), third on 19th of September (262 day), and fourth on 12th of October (285 day). Moisture variation in the soil profile as predicted by HYDRUS 1D model is presented in Fig 14.8, and a comparison of predicted and observed moisture content at three depths and two days, i.e., 15th of September and 27th of September is presented in Fig 14.9. This clearly indicated variation in soil moisture due to the occurrence of rainfall, irrigation application, evapotranspiration and deep percolation processes. Fig 14.9 shows that predicted moisture content was comparable, and slightly higher than observed one with R^2=0.68.

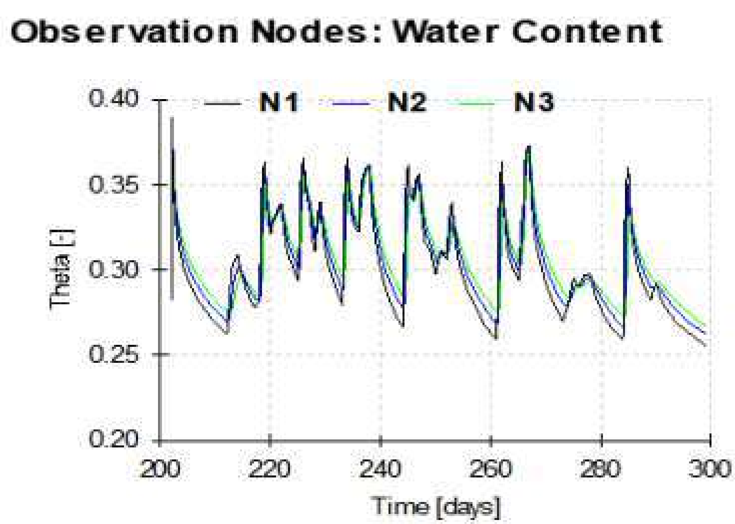


Fig 14.8 Soil moisture variation with time in rice crop

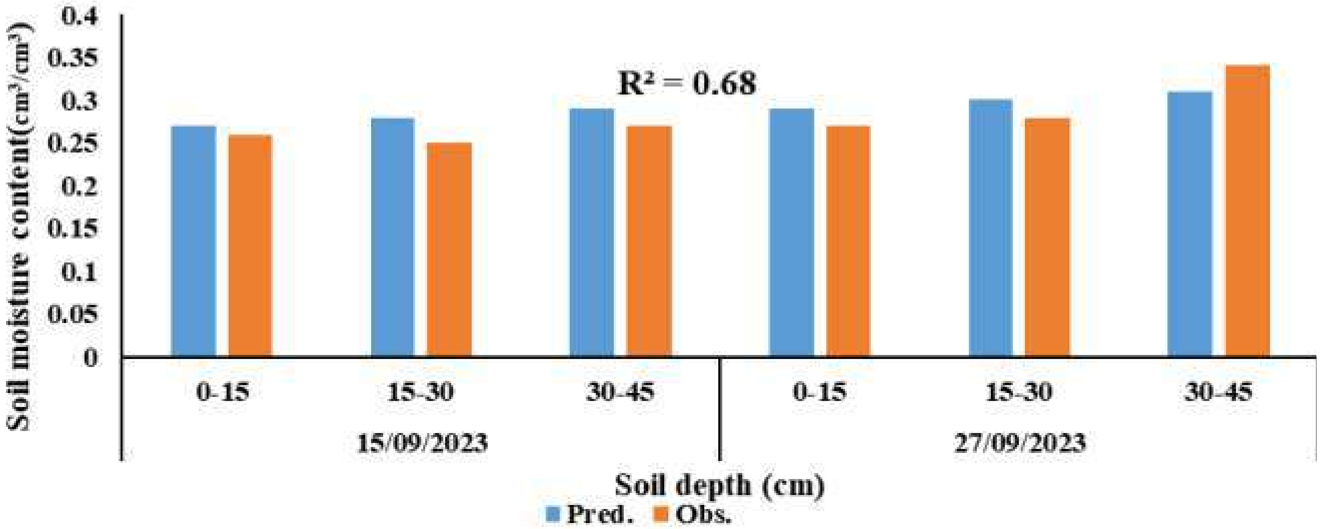


Fig 14.9 Comparison of predicted and observed soil moisture in rice crop

Wheat crop was sown on 20th of November (day 1), and harvested on 25th of March (day 127). Four irrigations were applied, the first on 11th of December (day 22), the second on 2nd of January (day 44), third on 25th of January (day 67), and the fourth on 6th of February (day 79). Moisture variation in the soil profile under wheat crop predicted by HYDRUS 1D model is presented in Fig 14.10, and comparison of predicted and observed moisture content at three depths and four days, i.e., 29th of December, 19th of January, 9th of February and 5th of March is presented in Fig 14.11. Fig 14.10 indicates variation in soil moisture due to the irrigation application and evapotranspiration processes. Fig 14.11 shows that predicted moisture content was comparable, and slightly lower than observed with R^2=0.73.

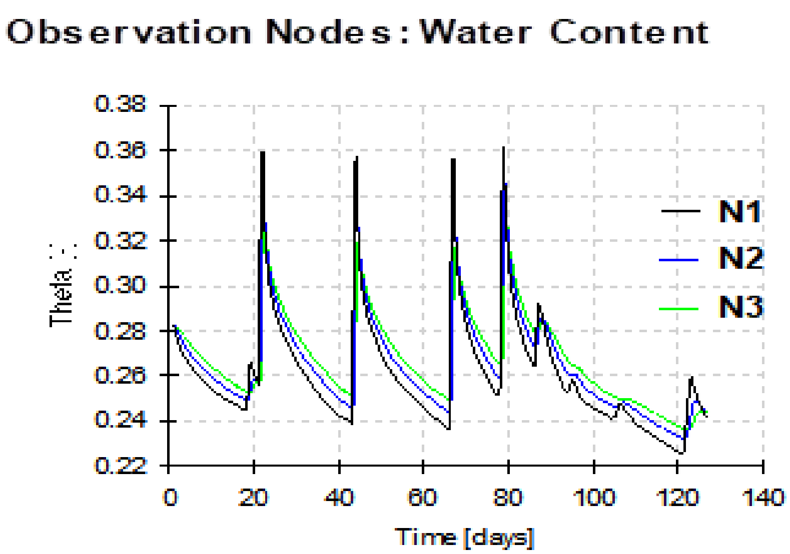


Fig 14.10 Soil moisture variation with time in wheat crop

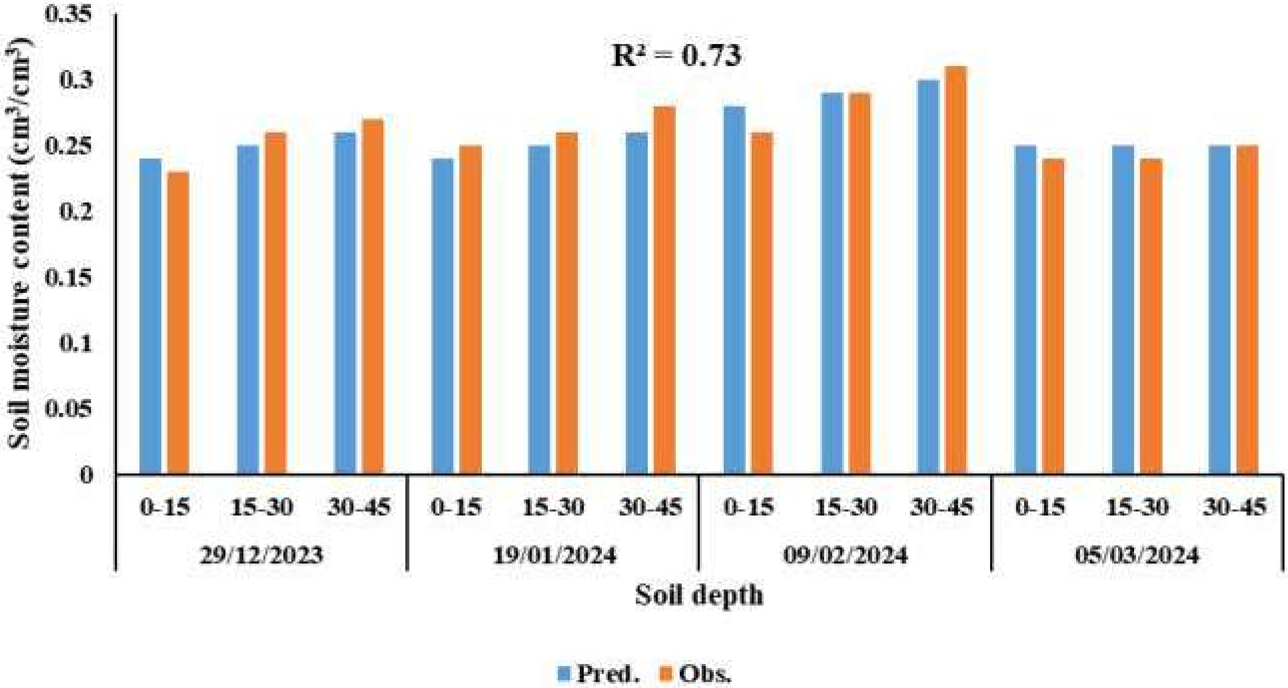


Fig 14.11 Comparison of predicted and observed soil moisture in wheat crop

Moong crop was sown on 17th of April (day 108) and harvested on 1st July (day 183). Three irrigations were applied, i.e., the first on on 18th of April (day 109), second on 2nd May (day 123) and the third on 3rd June (day 155). Moisture variation in the soil profile under moong crop predicted by HYDRUS 1D model is presented in Fig 14.12, and a comparison of predicted and observed moisture content at three soil depths is presented in Fig 14.13. Fig 14.12 indicates variation in soil moisture due to the irrigation application and evapotranspiration processes. Fig 14.13 shows that predicted moisture content was comparable and slightly higher than observed at 0-15 and 15-30 cm depth, but equal on 30-45 cm depth. It may be concluded that HYDRUS 1 D model is capable of predicting spatial and temporal variation of soil moisture under different crops.

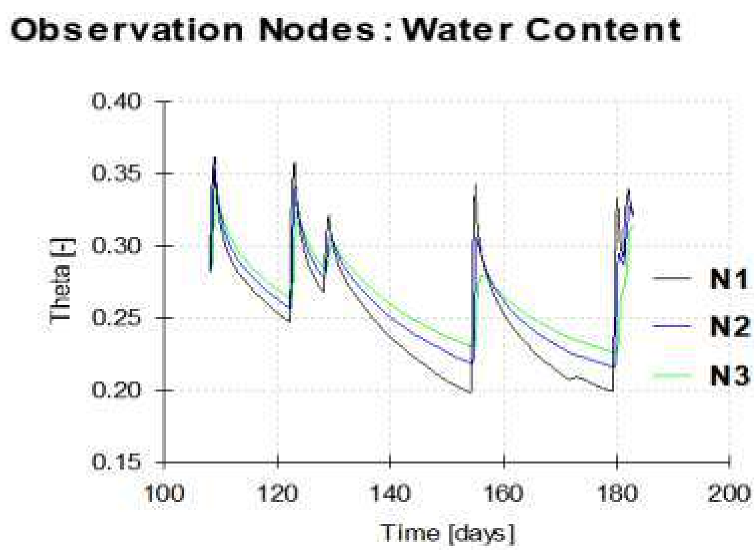


Fig 14.12 Soil moisture variation with time in moong crop

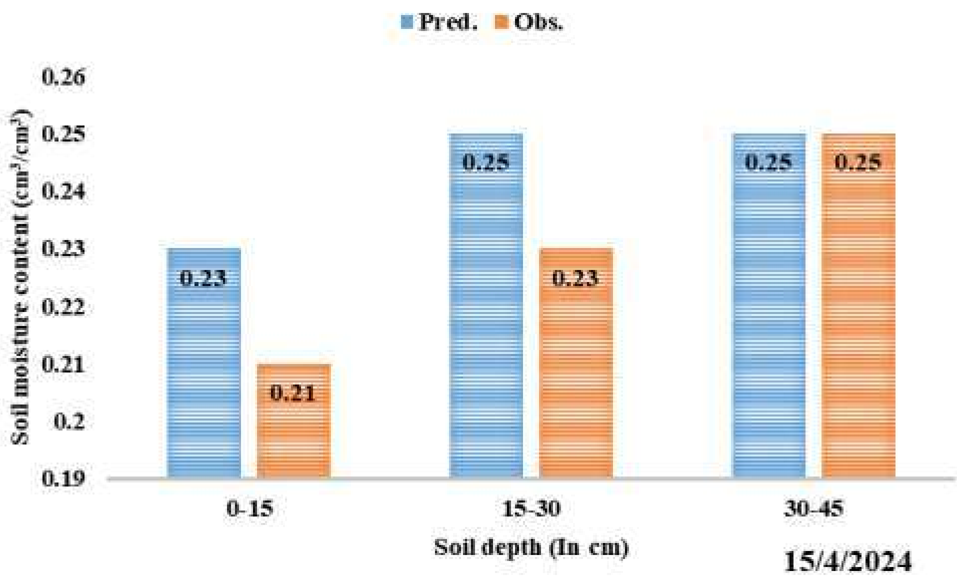


Fig 14.13 Predicted vs. observed soil moisture in moong crop

Performance evaluation of micro irrigation system powered with 2 hp solar centrifugal pump

An experiment was conducted to evaluate the operational characteristics of an online and inline drip irrigation system and mister sprinkler system installed over an area of 144 m² (16 m × 9 m) powered by a 2 hp surface solar pump during the monsoon season (July–September) of 2024. The spacing of the lateral was kept 0.35 m apart, and spacing of drippers in both inline and online drip irrigation system was 0.40 m. In contrary, the lateral-to-lateral distance and mister to mister distance was kept 1.3 m apart in mister sprinkler irrigation system. 30 sample catch cans were buried in soil for recording the discharge of drippers in both online and inline systems whereas discharge from three misters were recorded using catch cans placed at 5 radial distances from each mister, i.e., catch can be placed at 25 cm, 50 cm, 75 cm, 100 cm and 125 cm from the misters. The experiment was carried out once every 10 days in each month, with each session lasting 2 h and 30 min from 11.0 am to 2.30 pm. The performance of the online and inline drip irrigation system was measured with dripper coefficient of manufacturing variation *(Cv)* and uniformity coefficient *(EU)* while the performance of mister irrigation system was measured with Christiansen uniformity coefficient *(Cu).*

During the experimental period, the average solar radiation recorded at 11.0 am and 2.30 pm was 815 W/m² and 462 W/m², respectively. The system's average discharge was observed to be 1.46 l/s at an average pressure of 0.67 kg/cm². The average discharge from the inline drippers (1.51 l/h) was significantly lower than the rated discharge (2 l/h), indicating insufficient system pressure to achieve the desired discharge rate. The average coefficient of variation *(Cv)* for the inline drippers' discharge was observed very high (0.38) with poor average *EU* of 12%. While in the case of online drippers, the average discharge was recorded as 3.2 l/h, which was lower than the rated discharge of 4 l/h. The average coefficient of variation *(Cv)* for the online drippers' discharge was observed 0.23 with a poor average *EU* of 43%. As the numerical values of *Cv* was more than 0.15 and *EU* was less than 75% in both the drip irrigation system, the performance of the inline and online drip irrigation system could be unacceptable. However, the performance of online drip irrigation system was higher than inline drip irrigation system. For mister irrigation system, the value of the *Cu* was recorded as 52%. As the value of *Cu* was less than 0.85, the performance of mister irrigation powered solar surface pump could be considered poor.

Determining optimum decision variables in furrow irrigated system

Water front advance study was conducted for a furrow having 0.4% slope. The advance curve showed that water flew slowly (11.1 to 9 m/min) in the initial stage up to a distance of 15 m, because soil moisture in the upstream of furrow was less (26.6 to 28.8%). After 15 m of distance from the initial point of measurement, water flow was found rapid (6.3 to 5.7 m/min) because of higher moisture content (29.5 to 38.2%) in the downstream of furrow. The discharge rate of water flow from pipe was kept constant at 0.4 l/s by an experimental set up having 1000 l of water tank with an arrangement of ball valve and siphoning of extra water through another outlet above the ball valve so that a constant head discharge could be maintained.

Assessment of evapo-transpiration and crop coefficients for mango and litchi

This study aimed to assess the evapotranspiration (ET) and crop coefficients (Kc) of mango and litchi orchards in the eastern plateau and hill region using remotely sensed data and the surface energy balance approach. Landsat images (Path-Row: 140-42 for Bihar, and 140-44 for Jharkhand) were used, capturing thermal radiation (Band 10, 100 m resolution) and visible-infrared bands (Bands 1–7, 30 m resolution). Additionally, hourly weather data from NASA Power, Sentinel-based land use land cover (LULC) data (10m resolution), and SRTM digital elevation model (DEM) from USGS were integrated for precise analysis. The NDVI trends for mango and litchi orchards in Muzaffarpur and Ranchi showed seasonal variations (Fig 14.14). In Muzaffarpur, mango NDVI gradually

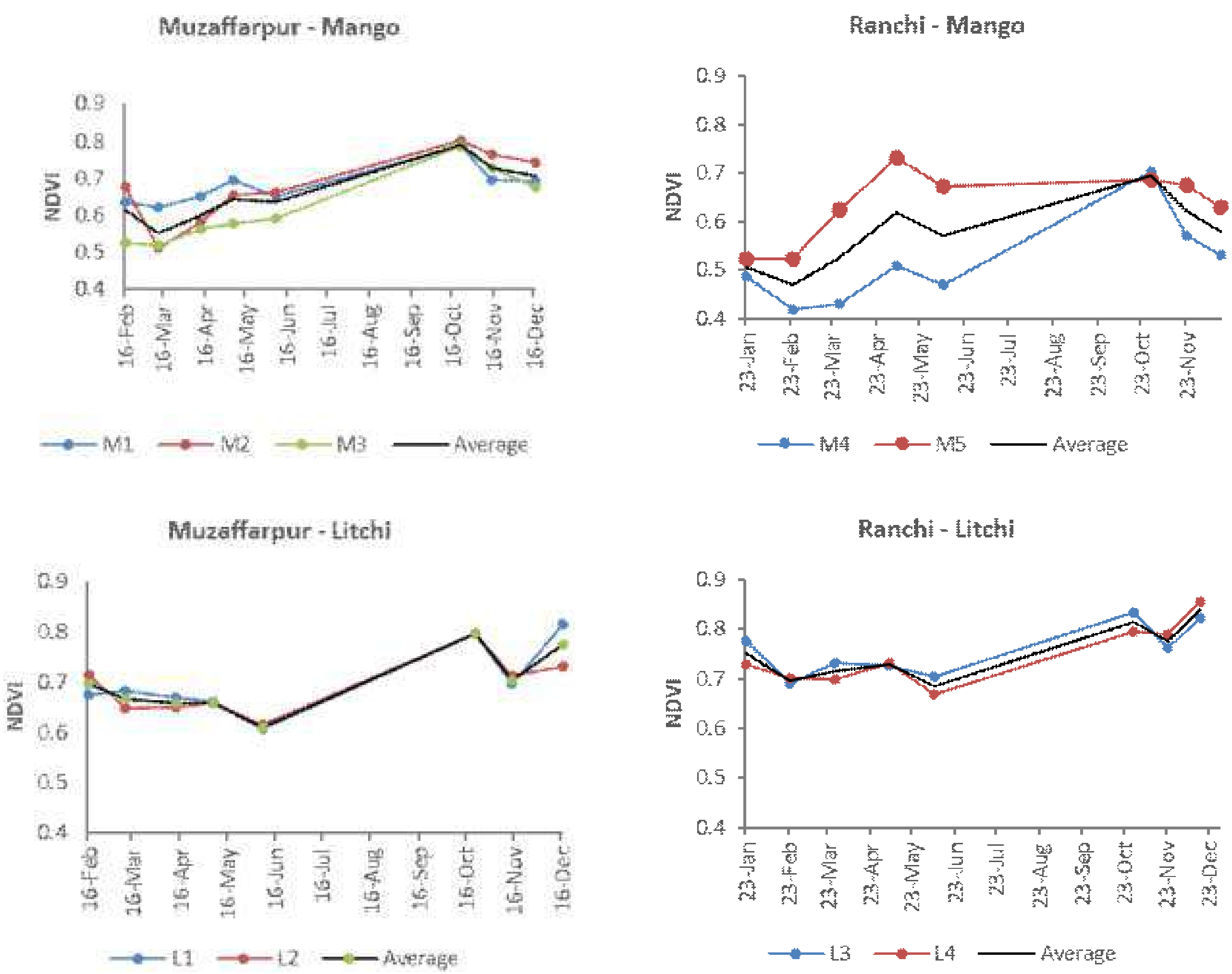


Fig 14.14 NDVI patterns of the mango and litchi orchards at Muzaffarpur and Ranchi

increased from February to October, peaking around 0.8, while litchi remained stable with minor fluctuations. In Ranchi, mango NDVI was initially low in January but peaked around May, showing significant vegetative growth. Litchi NDVI in Ranchi remained consistently high, fluctuating between 0.6 and 0.9. A slight mid-year dip was observed in both locations, followed by recovery. These patterns reflected seasonal canopy changes influenced by crop growth stages and environmental factors. The surface energy balance algorithm estimated ET by computing the energy balance at the land surface using satellite imagery, where the energy available for ET was converted into an equivalent amount of water (mm) evaporated from the plant canopy. This approach was successfully applied to mango and litchi orchards in Muzaffarpur and Ranchi, yielding Kc values that ranged from 0.4 to 0.63 for litchi and 0.42 to 0.69 for mango over one cropping cycle (Fig 14.15). Seasonal variations in ET were observed, particularly during the summer months, highlighting the need for location-specific irrigation planning. The estimated Kc values provided valuable insights for optimizing irrigation schedules for these fruit crops, ensuring efficient water resource management and improved productivity in the region.

UAV-based crop water stress mapping for precision irrigation

Effective irrigation management requires an accurate assessment of spatial and temporal variations in crop water stress. This study utilized unmanned aerial vehicles (UAVs) equipped with multispectral sensors (MSS) and thermal band (TB) sensors to evaluate the crop water stress index (CWSI) in wheat under varying irrigation conditions (Fig 14.16). A controlled water deficit experiment was conducted during the late vegetative, reproductive, and maturation growth stages. CWSI was derived from canopy temperature, ambient air temperature and vapor pressure deficit (VPD). To improve stress prediction, six machine learning (ML) models - linear model (LM), random forest (RF), decision tree (DT), support vector machine (SVM), extreme gradient boosting (XGB) and artificial neural network (ANN) - were trained using pre-heading, post-heading and seasonal datasets. The top five vegetation indices (VIs), selected through recursive feature elimination (RFE) along with thermal data, were used as model inputs.

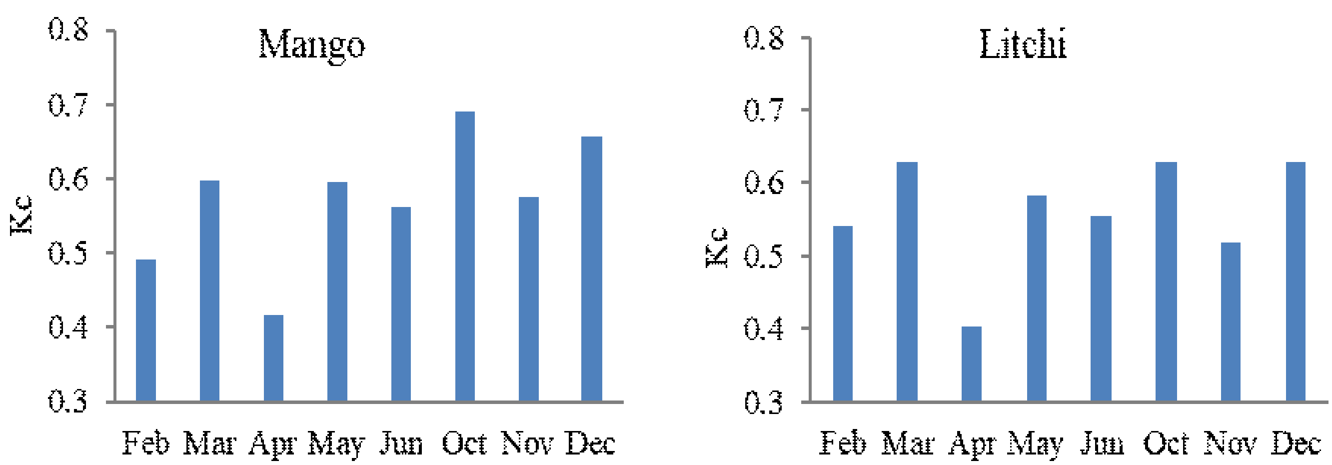


Fig 14.15 Estimated values of crop coefficients for mango and litchi

Fig 14.16 UAV-based MSS and thermal mapping of winter wheat

The analysis showed that ML models trained on seasonal datasets outperformed those using only pre-heading or post-heading data. The RF model achieved the highest accuracy, with R^2 values of 0.87, 0.82, and 0.93 and RMSE values of 0.09, 0.05, and 0.06 for seasonal, pre-heading, and post-heading datasets, respectively (Fig14.17). SHapley Additive exPlanations (SHAP) analysis identified red normalized value (RNV), TB, and green red vegetation index (GRVI) as the most critical predictors of CWSI. The CWSI maps effectively highlighted spatial variations in water stress, aligning with irrigation patterns (Fig 14.18). The RF model effectively mapped CWSI variations across six flight dates, capturing spatial and temporal water stress in wheat. On the first flight, mean CWSI for T1-T3 ranged from 0.19 to 0.20, while T4 neared the irrigation threshold (0.34), indicating early stress due to a longer irrigation gap. By the milking and dough formation stages, all plots showed increasing stress, with T3 and T4 reaching severe levels (CWSI = 0.74-0.83). Variability in CWSI was lower at extreme stress levels, while mid-range stress showed more fluctuations. These findings demonstrated that integrating UAV-based remote sensing with ML techniques could enhance precision irrigation strategies, leading to improved water use efficiency and crop productivity.

Development of sustainable agroforestry models for seasonally water-stressed agro-ecosystem of Bihar

To restore and enhance efficient utilization of natural resources in waterlogged areas through agroforestry interventions, 72 saplings each of four tree species (totalling 288 saplings), *viz.*, arjun (*Terminalia arjuna*), mahogany (*Swietenia macrophylla*), kadamb (*Neolamarckia cadamba*) and jamun (*Syzygium cumini*), were planted over one-hectare area at the Sabajpura farm of the institute during July, 2024. The experiment was laid out in RCBD with nine treatments, replicated three times, including sole tree plantations, sole cropping and intercropping systems. The saplings were planted at a spacing of 8m × 4m, with each experimental plot measuring 32m × 12m, accommodating 12 trees per plot (Fig 14.19).

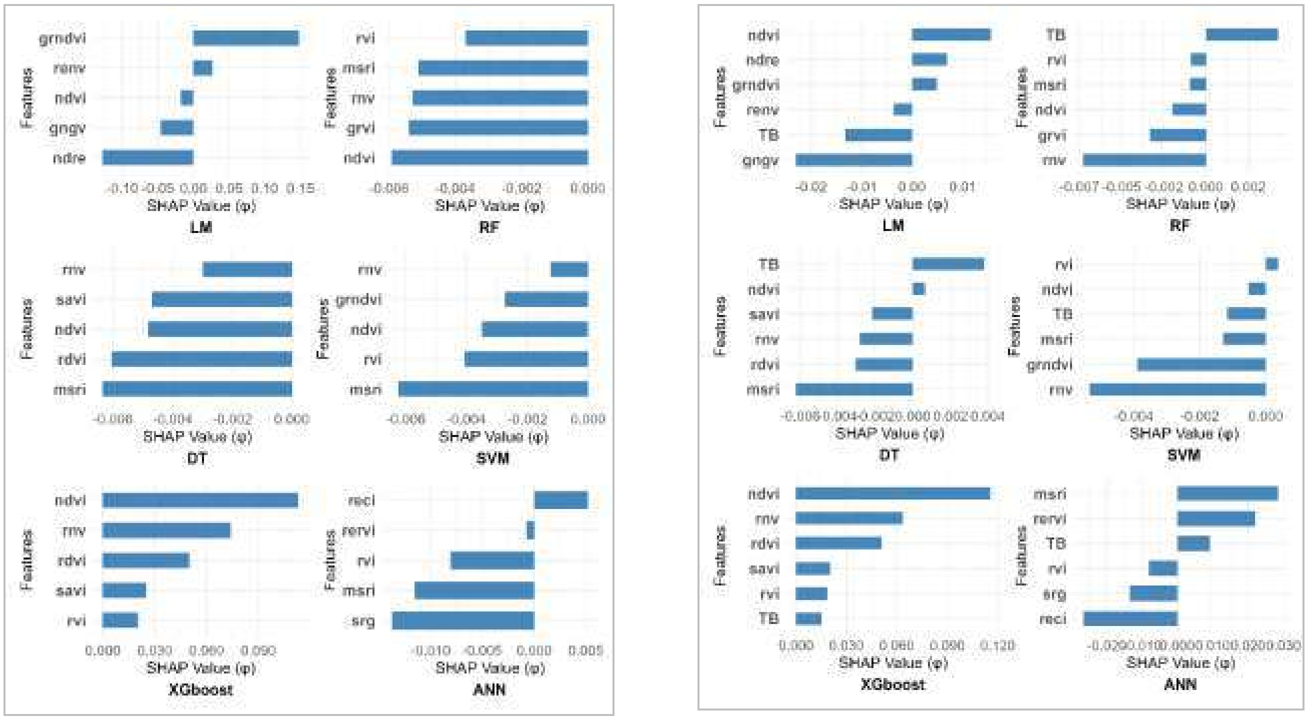


Fig 14.17 Importance of predictor in different ML algorithms, mapped using SHAP function (a) without inclusion of thermal band, and (b) with inclusion of thermal band; LM: linear model, RF: random forest, DT: decision tree, SVM: support vector machine, XGB: extreme gradient boosting

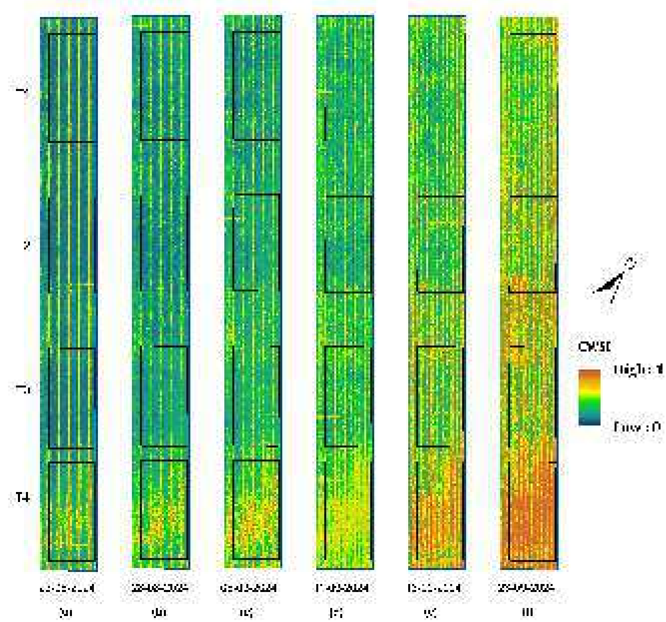


Fig 14.18 Variation in the CWSI at different growth stages of winter wheat mapped using RF model

Fig 14.19 Agroforestry plantation establishment for restoring seasonally waterlogged areas

Initial soil analysis was done with soil samples taken from seven depths from 0-15 cm to 90-100 cm for pH, EC, SOC and available N, P and K. The results indicated alkaline pH of soil ranging from 7.91 to 8.11, with low to medium SOC levels from 0.47% (in the topsoil) to 0.11% (at one meter soil) depth. Nutrient availability showed a decreasing pattern with depth, with available N ranged from 157.1 kg/ha to 84.3 kg/ha, P from 14.7 kg/ha to 5.6 kg/ha and K from 239.7 kg/ha to 197.1 kg/ha (Table 14.2). These parameters highlighted the need for undertaking appropriate strategies to improve soil fertility and productivity. Early observations indicated satisfactory plant establishment with successful intercropping of lentil during the *Rabi* season.

Table 14.2 Initial soil database at the agroforestry experimental site

Particulars	**0-15 cm**	**15-30 cm**	**30-45 cm**	**45-60 cm**	**60-75 cm**	**75-90 cm**	**90-100 cm**
Soil pH	8.11	8.06	8.12	8.07	7.93	7.96	7.91
Soil EC (dS/m)	0.11	0.12	0.10	0.09	0.07	0.07	0.05
Organic Carbon (%)	0.47	0.41	0.35	0.27	0.18	0.10	0.11
Available N (kg /ha)	157.10	143.30	128.8	109.60	98.80	86.70	84.30
Available P (kg/ha)	14.70	13.30	11.20	10.30	8.30	7.60	5.60
Available K (kg/ha)	239.70	232.30	227.10	220.70	211.70	203.20	197.10

15 Livestock Health and Production

Characterization of *Chotanagpuri* buffaloes

With the mandate of achieving zero non-descript population, the *Network Project on Animal Genetic Resources* was undertaken with financial support from ICAR-National Bureau of Animal Genetic Resources, Karnal. During the year 2024-25, characterization work was undertaken in the state of Jharkhand, and a unique population called 'Chotanagpuri buffalo' was characterized. Chotanagpuri buffaloes were found distributed in the Chotanagpur plateau region, which comprises the districts from Khunti and Ranchi in the west to Dumka and Pakur in the east. These buffaloes were maintained in small sized herds by the farmers with an average herd size of 3.7 comprising 1.9 adult females, 1.2 female calves and 0.6 male calf. These buffaloes were medium sized with black coat colour. The horns were loosely curved with sickle shaped curvature.

The height at withers, body length and chest girth of Chotanagpuri female buffaloes were found to be 97.21 ± 0.37 cm, 92.55 ± 0.35 cm and 112.67 ± 0.35 cm, respectively in one year, 120.37 ± 0.73 cm, 116.88 ± 0.68 cm and 148.12 ± 0.59 cm, respectively in 3 years, and 133.60 ± 0.58 cm, 135.07 ± 0.52 cm and 184.14 ± 0.53 cm, respectively in 7 years of age. Males were heavier than females in all age groups (Fig 15.1). The body weights of female buffaloes were estimated to be 95.89 ± 1.34 kg in 1 year, and 458.22 ± 0.78 kg in adults. Chotanagpuri buffaloes were poor milkers with an average milk yield of 1.70 kg per day with the peak yield of 3.6 kg per day. The milk samples collected from these buffaloes were analyzed for their composition, and the fat, protein, lactose and SNF percentages were found to be 7.45, 4.08, 4.65 and 9.15, respectively. In addition, male buffaloes were also used for various agricultural operations for about 4 to 6 h in a day.

Network project on buffalo improvement

A network project on buffalo improvement has been implemented in ICAR-RCER, Patna with the lead centre being ICAR-Central Institute for Research on Buffaloes, Hisar. The centre maintained *Murrah* breed with the herd strength of 103 buffaloes during the year 2024-25. Among them, the number of adults, heifers, male calves and female calves was respectively 58, 20, 14 and 11. The herd mortality was restricted to 1.7%, whereas the mortality for less than 3 months aged calves was 3.8%. Respiratory and digestive tract infections were the primary reasons for mortality among calves. The standard lactation milk yield, total lactation milk yield and average

(a)

(b)

Fig 15.1 Chotanagpuri buffalo bull (a), and Chotanagpuri female (b) peak yield for the previous year were found to be 2068.37 ± 78.23 kg, 2448.17 ± 51.58 kg and 10.61 ± 0.72 kg, respectively. In addition, the service period, dry period and inter-calving interval were recorded as 142.36 ± 7.67 days, 115.20 ± 10.41 days and 447.88 ± 8.53 days, respectively during the said period. By using the 'AI Management System' software, the individual buffalo was tracked for each reproduction event for undertaking suitable intervention practices.

Assessing genetic variability in duck of eastern states

A study was undertaken to generate mitochondrial genome maps of duck germplasm from the eastern region of India using whole genome sequencing. The research covered seven duck germplasm, including four established breeds (White Pekin, Khaki Campbell, Indian Runner and Maithili) as well as three indigenous types from Bihar, Chhattisgarh and West Bengal. The annotated mitogenome sequences of these germplasm were submitted to GeneBank, which were assigned the accession numbers OQ561754 through OQ561760, respectively. All germplasm exhibited circular mitochondrial genomes with comparable lengths: 16,604 base pairs for West Bengal, Chhattisgarh, Indian Runner and Khaki Campbell, and 16,605 bp for Bihar, 16,606 bp for White Pekin and 16,607 bp for Maithili. Consistent with other members of the Anatidae family, each mitogenome contained 37 genes - 22 tRNAs, 2 rRNAs, 13 protein-coding genes (PCGs) and a non-coding D-loop region. In all the seven mitogenomes, PCGs, excluding ND6 and COX1, were located on the heavy strand, as were both rRNAs. All the tRNAs were also located on the heavy strand except for tRNA-Ile, tRNA-Trp, tRNA-Ala, tRNA-Asn, tRNA-Cys, tRNA-Thr, and tRNA-Pro. The gene arrangement and AT content remained consistent across all the seven mitogenomes. Phylogenetic analysis indicated that despite phenotypic variations, all germplasm shared a common ancestry, and were closely related. A comparative analysis of the seven mitochondrial genomes revealed approximately 400 unique genetic variations, which warrant further investigation across a larger sample size to identify potential breed-specific markers.

Transcriptome and metagenome approach to characterize genetic basis of prolificacy in goats

Ethical approval for the study was obtained from IAEC and CCSEA prior to its commencement. The experimental animals 'Black Bengal' and 'Jamunapari' does were carefully screened, selected and procured. To examine the effects of parity and breed on ovulation rate in estrus does, transvaginal Doppler ultrasonography was standardized using a 7 MHz probe. This non-invasive technique was utilized during the breeding season to monitor reproductive structures over the 19 to 21 day estrous cycle. Ultrasonographic evaluations were carried out daily from the beginning of estrus (day 0) through day 8, followed by alternate-day scans until the subsequent estrus. This protocol facilitated clear visualization of ovarian structures: follicles appeared as anechoic, round areas without color flow, while the corpus luteum (CL) was identified as a hypoechoic, circular structure with visible color flow, signifying vascularization (Fig 15.2, 15.3). The Doppler mode was essential for assessing blood flow, providing critical insights into CL activity and reproductive status. To assess differences in the

Fig 15.2 Ultrasonography revealing follicles and corpus luteum in ovary

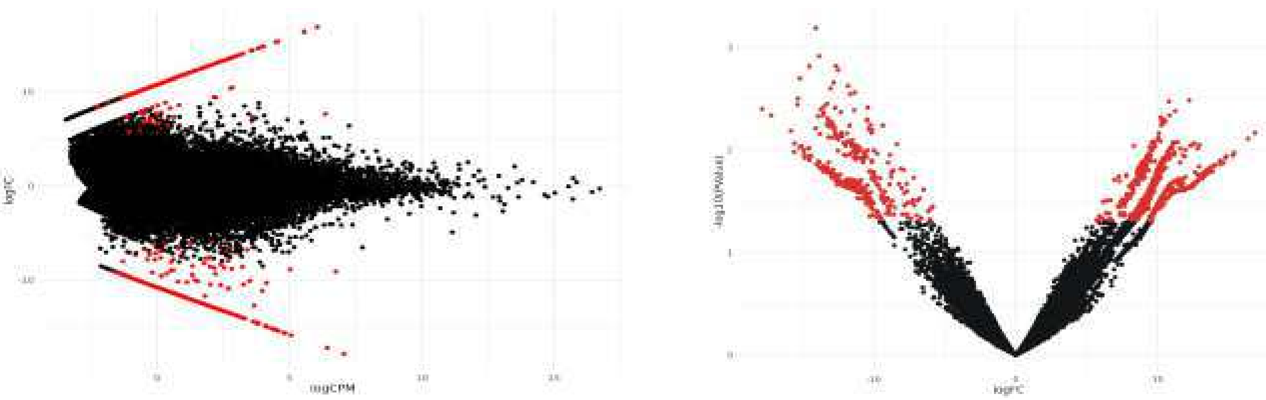
Fig 15.3 Surgical validation showing ovarian structures

Fig 15.4 Vaginal swabs for culturing and DNA extraction

vaginal microbiota composition between single and multiple ovulating does, vaginal swabs were collected during estrus, and subjected to 16S rRNA gene sequencing (Fig 15.4). Concurrently, to isolate aerobic culturable bacteria, the swabs were inoculated on various media, and incubated at 37°C for 24-48 h. Bacterial identification was performed based on colony morphology on general and selective media, along with Gram staining. To date, eleven bacterial isolates have been identified from six non-estrus does and confirmed via Sanger sequencing. These isolates have been assigned NCBI accession numbers: PQ031225, PQ037632, PQ044599, PQ037636, PQ044597, PQ008724, PQ008725, PQ044601, PQ008594, PQ008625, and PQ044602.

Exploring genetic basis of mastitis resistance in livestock

Milk of 248 animals (130 cow and 118 buffalo) from the institute's livestock farm and farmers' fields were screened for sub clinical mastitis by California mastitis test (CMT). Out of these 248 animals, 98 animals (47 cows and 51 buffalo) were positive for subclinical mastitis. For transcriptome analysis, milk samples were collected from four crossbred cattle suffering from subclinical mastitis and four healthy crossbred cattle. RNA was isolated from milk somatic cells using standard protocol. KAPA mRNA HyperPrep Kit was used to prepare libraries for Illumina sequencing. The average number of total reads and mapped reads for six libraries of cattle samples were 2629225 and 21345091, respectively. The mean mapping percentage against cattle reference assembly was 85.12%. The annotation of the transcriptome count table was created using the feature counts option of Rsubread package using the gene transfer format (GTF) as a reference. The assembled transcriptome expression was estimated using the DESeq2 package of R. Subsequent analysis was limited to only those differentially expressed genes that had log2 fold change ≥ 2.0, p-value ≤ 0.05 and false discovery rate (FDR) ≤ 0.05 to limit the number of DEGs and identify only those genes that has strong expression changes. Differential gene expression analysis revealed that 2677 genes showed differential gene expression in animals suffering from subclinical mastitis. Out of the total differentially expressed genes, 2336 showed significant upregulation, whereas 341 genes showed significant downregulation in animals suffering from subclinical mastitis in comparison to healthy animals. MA plot and volcano plot (Fig 15.5) for differentially expressed transcripts were drawn. BOLA DRA, BOLA DRB3, CD164, CD74, SAMHD1, and GPR183 are some of the important immunity-related genes that showed significant downregulation in animals suffering from subclinical mastitis, whereas ASB11, UPP1 and ESR1 are some of the common genes that showed the highest upregulation in animals suffering from subclinical mastitis.



(a) (b)

Fig 15.5 MA plot (a) showing differentially expressed transcripts, and Volcano plot (b) showing the distribution of expressed transcripts

AICRP on goat improvement

All India Coordinated Research Project on Goat Improvement was started at ICAR Research Complex for Eastern Region, Patna in the year 2018-19. The centre continued its activities in the four clusters of Bihar, which were selected based on the Bengal goat population density. During the year, the population growth in the selected villages expanded to the tune of 152.29% with addition of breedable does and new births. The mortality was controlled within 4.54% due to comprehensive efforts of vaccination, deworming, timely therapeutic interventions and awareness programme. The average body weights at 3, 6, 9 and 12 months of age were recorded as 4.05 ± 0.02 kg, 6.67 ± 0.02 kg, 9.16 ± 0.03 and 11.68 ± 0.04 kg, respectively. Body weight was increased in comparison to previous year, and by 18-27% as compared to the base year (2018-19) in different age groups. Age at first mating increased to 279 days in comparison to 276 days in previous year where it was 196 days in base year. A total of 4510 does were available for breeding. Average litter size was 1.79 ± 0.19. Institute added six multiplier flock in the reporting period. Significant improvements in the socio-economic conditions of goat farmers registered under the project was also observed. Income per adult goat in project area increased to Rs. 8234 in 2024-25 in comparison to Rs 7627 in 2023-24 and Rs 3482 in 2019-20. A training of three days duration and two workshops of one day duration were organized for skill development of goat farmers. A total of ten health camps were organized to provide health care facilities to goat rearers (Fig 15.6).

Fig 15.6 Animal health camps organized to provide therapeutic interventions to the goats

Evaluation of diara land farming for sustainable food production

A study was undertaken to evaluate the sustainable food production system in diara land (river bed) of Bihar. Every year, these areas experience occasional flooding; this brings sediments, contributing to the enrichment of the soil with nutrients. In the present study, two sites of Ganga river (Buxar and Begusarai) and 2 sites of Gandak river (East Champaran and Vaishali) were selected. Elevation analysis revealed that a mean elevation of river bed diara and upland diara were about 49 m and 51 m, respectively in Gandak river at Hajipur, Vaishali. In this study, Google Earth data and Geographic Information System (GIS) techniques were employed to quantify the extent of diara land along the Gandak River. The total diara land including both riverbed and upland diara in Bihar's Gandak river basin was determined to be 56,304 hectares.

In upland diara agricultural activities commence in early November, taking advantage of the river's early water recession. On the other hand, farming in the riverbed diara began after second fortnight of November. In the upland diara, wheat was the predominant crop cultivated by farmers, supplemented by other crops such as mustard, potato, and winter vegetables. Conversely, watermelon took precedence in riverbed diara, accompanied by crops like sponge gourd, bottle gourd and cucumber. The diara cropping season concluded in May or early June. To protect the crops from chilling winter in riverbed diara, farmers used to provide thatch in east-west direction. The material used for thatching was the dry *khus* grass (*Chrysopogon zizanioides*) that naturally grew in the river bank (Fig 15.7). It has been observed that in riverbed diara, where the sand content is relatively high, farmers preferred cultivating watermelons exclusively. In the upland diara, the initial irrigation for crops was done using the water left in the abandoned river channels. Farmers, who had irrigation facilities, provided a second irrigation, while other farmers relied on residual soil moisture. In upland diara, farmers supplemented the nutrient requirement of plants by adding FYM and inorganic fertilizers. Depth-wise soil nutrients and water quality parameters were analyzed. The result showed that organic carbon content of soil varied from 0.20 to 0.77% at different depth; however, N, P and K content of soil varied from 53-176, 7-54 and 175-800 kg/ha, respectively. The pH of the soil varied from 7.5 to 8.2. In the case of riverbed diara, farmers employed a unique technique to address water and nutrient requirements for crops. Initially, when the plants were small, water needs were met through river water. Alongside of each plant row, farmers dug a 10-15 cm depth channel, adding fertilizers (poultry manure and other inorganic fertilizers) to it after mixing it with the soil. The purpose was to encourage crop roots to extract nutrients and water from the channel. Since groundwater in riverbed diara was shallow, especially during the summer months when the groundwater depth decreased, farmers deepened the channels and continuously added fertilizers, mixing them with the soil. However, this water and nutrient management process was labor intensive.

Fig.15.7 Protection vegetable crop by thatching with *Khus* grass

Assessment of ecosystem services rendered by indigenous livestock and poultry species and breeds

Indigenous buffalo provides a wide range of ecosystem services that contribute to agricultural sustainability, rural livelihoods and environmental regulation. This study employed economic valuation methods including market price, replacement cost and hedonic pricing to assess the lifetime value of provisioning, regulating, supporting and socio-cultural services, while accounting for associated disservices. The total estimated value of ecosystem services provided by a female 'Murrah' graded buffalo during its lifetime was Rs 12,34,675 with provisioning services accounting for Rs 8,43,214 (68.3%), supporting and habitat services Rs 5,906 (0.5%), regulating services Rs 23,355 (1.9%) and socio-cultural services Rs 3,62,200 (29.3%). However, disservices including methane emissions, water quality deterioration and soil erosion were estimated at Rs 95,399 highlighting potential trade-offs in buffalo rearing (Fig 15.8). These findings accentuated the economic and ecological significance of indigenous buffalo while emphasizing the need for sustainable management strategies to optimize benefits and mitigate adverse effects.

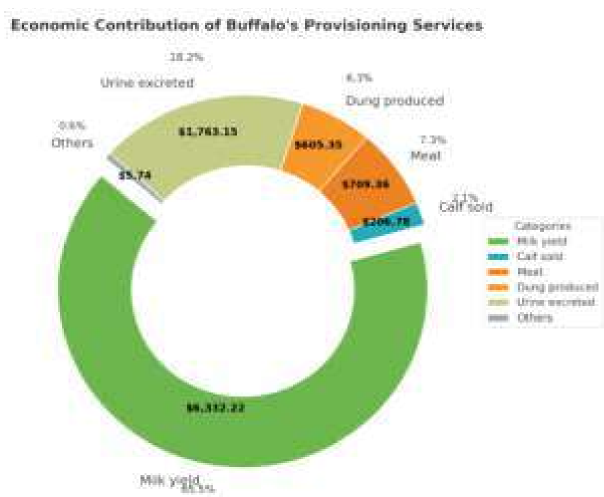


Fig 15.8 Economic contribution of provisioning services rendered by buffalo

Genetic polymorphisms of candidate genes associated with production traits in goats

Genetic effects of STAT3 gene polymorphism on body size traits in Assam hill goats

Blood samples were collected from the Assam hill goats, and genomic DNA was extracted utilizing the Qiagen DNeasy Blood and Tissue Kit. PCR primers were designed using Primer3 Plus software, explicitly targeting regions of the STAT3 gene. PCR-RFLP was employed to identify polymorphic loci (SNP1: g.42111147A>C-*Msp1* and SNP2: g.42111756 G>A-*Taq1*), and investigate their relationship with growth parameters, marking the first report in Assam hill goats. Association studies indicated that the *AA* and *GG* genotypes showed marginally elevated values for specific biometric traits compared to the other genotypes; however, only body length and chest circumference revealed a significant correlation ($P<0.05$). The current study demonstrated that the *AA* and *GG* genotypes showed superior growth traits in comparison to other genotypes, indicating that STAT3 might be a promising candidate gene for goat breeding (Fig 15.9). Nevertheless, further investigations are required to validate the impact of genotypes on the growth performance of goats before implementing marker-assisted selection in a wide variety of goat breeds and large populations.

Genetic diversity of the β-Lactoglobulin (β-LG) gene polymorphism in Black Bengal and Assam Hill goats

β-Lactoglobulin (β-LG) represents the leading non-casein whey protein found in the milk of bovine animals and the majority of ruminants. Preliminary analyses of the β-LG gene in goats indicate that polymorphic variations in this gene may have an impact on traits associated with production. Hence, the current research was conducted to investigate the genetic variations within the targeted regions (exon 7' to 3' flanking area) of β-LG gene in 'Black Bengal' and 'Assam Hill' goats. Blood samples were collected from each breed and genomic DNA was extracted using QIAamp DNA mini kit. According to the PCR-RFLP analysis, the *SNP1-SacII* locus of the β-LG gene was characterized by the presence of two alleles, *A* and *G*, and three distinct genotypes: *AA*, *AG* and *GG* in the analyzed breed. The frequencies of alleles *A* and *G* in the 'Black Bengal' goat breed were determined to be between 0.47 and 0.53, while the 'Assam Hill' goat breed displayed frequencies ranging from 0.38 to 0.62. This research indicated moderate polymorphism information content (PIC) values of 0.374 for the 'Black Bengal' goat and 0.360 for the 'Assam Hill' goat. The 'Black Bengal' goat exhibited an effective number of alleles (Ne) of 1.992, along with an observed homozygosity (Ho) of 0.5018 and an expected heterozygosity (He) of 0.4982 for the variant *SNP1-SacII*. In comparison, the 'Assam Hill' goat demonstrated a higher observed Ho of 0.528. The other genetic parameters for the 'Assam Hill' goat, including the Ne and He respectively at 1.891 and 0.471, showed a notable similarity to those of the 'Black Bengal' goat. The polymorphic loci were demonstrated to be in a state of Hardy-Weinberg disequilibrium in the examined goat breed (P<0.05). Nevertheless, further research with large sample sizes and diverse breeds are required to verify and utilize these findings.

Effect of POU1F1 gene polymorphism on growth traits in Assam Hill goats

The pituitary specific transcription factor 1 (POU1F1) is a potential gene that influences the growth and body mass of the animal. Hence, the current research was conducted to investigate the genetic variations within the POU1F1 gene and their association with biometric characteristics in 'Assam Hill' goats. PCR-RFLP was employed to identify polymorphic loci (SNP1-*Hinf1* & SNP2-*Hinf1*) linked to growth parameters such as body weight (kg), body length (cm), height at the withers (cm) and chest circumference (cm). The analysis revealed that the POU1F1 gene's SNP1-Hinf1 locus is characterized by three distinct genotypes: *TT*, *TC* and *CC*. In contrast, the SNP2-Hinf1 locus is represented by *AA* and *AC* genotypes. In the analyzed goat breed, the frequencies of the *T* and *C* alleles were observed to be 0.62 and 0.38, respectively, whereas the frequencies of alleles *A* and *C* were determined as 0.54 and 0.46, respectively. The polymorphic loci were demonstrated to be in a state of Hardy-

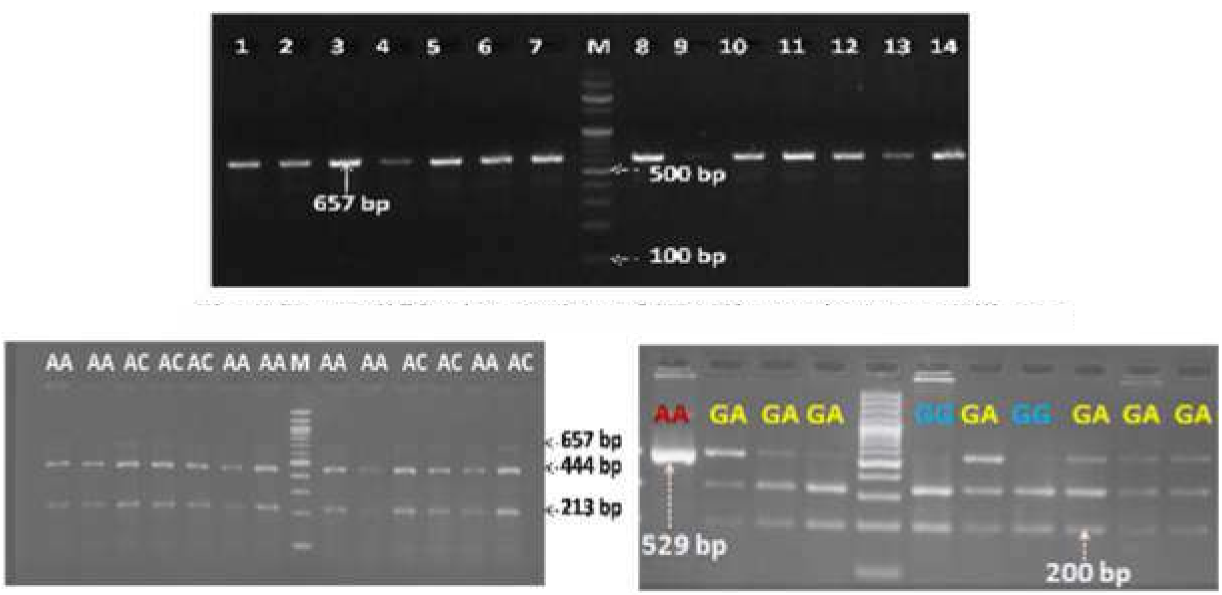


Fig 15.9 PCR-RFLP products of STAT3 gene of Assam Hill goat

Weinberg disequilibrium in the examined goat breed (P<0.05). The growth traits of the breed were found to be linked to variations in the POU1F1 gene. In the examined breed, the *TT* and *AA* genotypes exhibited slightly higher values for certain biometric traits than other genotypes; nonetheless, only body weight and chest circumference demonstrated a significant correlation (P<0.05). Therefore, the *TT* and *AA* genotypes could be used as potential markers for improved growth parameters in the studied breed. However, further research with large sample sizes and diverse breeds is required to verify and utilize these findings.

Status of fluorosis in livestock of Bihar and evaluating the ameliorative effect of nutraceuticals on the affected cattle population

In the reported year, a project activity was performed in Tilauthu and Sheosagar subdivision of the Rohtas district. Besides, a part of the work was conducted explicitly in Seikhpura as part of a student's MVSc research work. More than 350 samples (including groundwater and animal blood and urine samples) were collected. GPS data and other information from farmers as well as clinical examination and history of animal production, reproductive parameters and water source were recorded (Fig 15.10). The fluoride content was estimated using routine procedures using an ion-selective electrode, and hemato-biochemical evaluation was partially outsourced to BVC, Patna. The current study showed that animals suffered from dental and osteal fluorosis due to fluoride-contaminated water. The application of banana leaf biochar in contaminated water had a positive ameliorative effect. The fluoride levels in groundwater ranged from 0.6 to 9.74 ppm, with the highest found in Bhagalpur district. Affected cattle had visible symptoms of chronic fluorosis with serum levels ranging from 0.01 to 0.39 and in urine 1.86- 39.75 ppm.

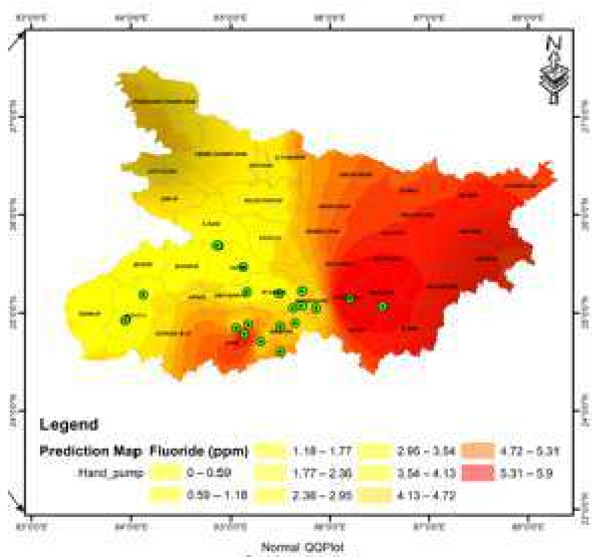


Fig 15.10 Dental fluorosis in buffalo reared in a fluoride-affected area and prediction map of fluoride in groundwater in Bihar

Reproductive abnormalities in ruminants and associated common pathogens in special reference to Leptospirosis

Under this project, animal health camps were organized to study reproductive abnormalities in ruminants and associated pathogens at different places of Bihar (Fig 15.11). In 2024-25, 228 animals from Jehanabad, Nalanda, Sheikhpura, Bhagalpur and Rohtas districts were included in the study. Based on history and clinical observations, 35.10% of adult female bovines were found to have some reproductive problems. The remaining females had diverse health issues, with parasitic infestation (34.50%) as the most common problem. Infectious Bovine Rhinotracheitis (IBR) and Leptospira sero-surveillance were screened using bovine-specific commercial ELISA plates. Screening for *Brucella* infection continued using conventional RBPT (IVRI) and bovine-specific ELISA. However, none tested positive for *Leptospira* sp. Biochemical alterations with higher SAP, AST activity, and a rise in creatinine and BUN levels in animals found with reproductive disorders. Serum hormone levels of follicle-stimulating hormone (FSH), progesterone (P4) and cortisol were estimated based on Bovine-specific ELISA, and the data are being processed.

Characterization of indigenous chicken breed of Jharkhand

This study aimed to characterize indigenous chicken breeds in Jharkhand based on their phenotypic traits. The indigenous chicken breed 'Charka' was characterized for phenotypic parameters, growth, reproduction and production traits across three districts of Jharkhand, namely Ranchi, Khunti and West Singhbhum (Fig 15.12). These regions are characterized by subtropical climate with hot summers and mild winters, which impact livestock development and adaptation.

A total of 590 mature 'Charka' chickens (comprising 248 males and 342 females) were assessed through visual appraisal and linear body measurements. The study revealed an average flock size of 10.51 birds, with hens reaching their first egg-laying age at 6.34 months and producing an average of 13.19 eggs per clutch. Fertility and hatchability rates of fertile eggs set (FES) were recorded at 75.49% and 69.66%, respectively under natural hatching conditions. Among male chickens, 50.40% had single combs, 72.58% had white feather plumage, 78.63% had yellow shanks, 62.50% had red earlobes and 74.60% had white skin. In hens, 85.00% had single combs, 41.52% had white earlobes (followed by 35.38% with pinkish-white earlobes), 72.51% had yellow shanks and 54.10% had white feathers (followed by 34.60 % with black feathers).

Fig 15.11 Reporductive health camp in Jehanabad, and primer-based detection of *Leptospira sp* from isolated DNA from suspected blood samples

Males were generally heavier, averaging 1.78 kg, than females (1.19 kg). The average morphometric measurements for male 'Charka' chickens included body length (26.54 cm), shank length (9.86 cm), shank circumference (2.60 cm), wingspan (35.65 cm), comb length (7.11 cm), tail length (26.77 cm) and beak length (2.66 cm). For hens, the corresponding measurements were 23.28 cm, 7.83 cm, 2.35 cm, 25.94 cm, 2.63 cm, 15.56 cm and 2.34 cm, respectively. The broad wingspan enables these birds to evade predators by flying, and their natural brooding ability enhanced reproductive efficiency. However, the scavenging nature of these chickens led to uncontrolled mixing and a lack of organized mating programme. This study emphasizes the importance of conserving indigenous chickens through proper characterization and breeding strategies.

Sustainable poultry feed formulations for desi chicken of Jharkhand with left-over fermented rice

This poultry feed trial comprised four distinct formulations (T1, T2, T3, T4) with varying levels of crushed maize, groundnut cake and left-over fermented rice (LFR) to optimize performance and reduce costs (Fig 15.13). Crushed maize content varied across the treatments, 64% (T1), 51% (T2), 36% (T3) and 0% (T4). Groundnut cake was added at 12% (T1), 5% (T2), and omitted in T3 and T4. LFR was introduced as a low-cost ingredient, increasing from 20% (T2) to 40% (T3) and 76% (T4). While all formulations included consistent levels of wheat bran, fish meal, mineral mixture and common salt, the nutrient composition differed, with crude protein (CP) ranging from 14.78% to 17.42% and metabolizable energy (ME) from 2056 to 3086 Kcal/kg. The highest body weight gain (414.54 g) and best feed conversion ratio (FCR: 1.56) were recorded in T3, while T4 (despite its low feed cost of Rs 14.92/kg) was the least efficient (FCR: 2.14). These findings underscore the potential of LFR as an economical and sustainable poultry feed ingredient.

(a)

(b)

Fig 15.12 Male (a) and female (b) of 'Charka' chicken

(a)

(b)

Fig 15.13 LFR (a) rice after making *handia*, and Poultry fed (b) with fermented rice formulated feed

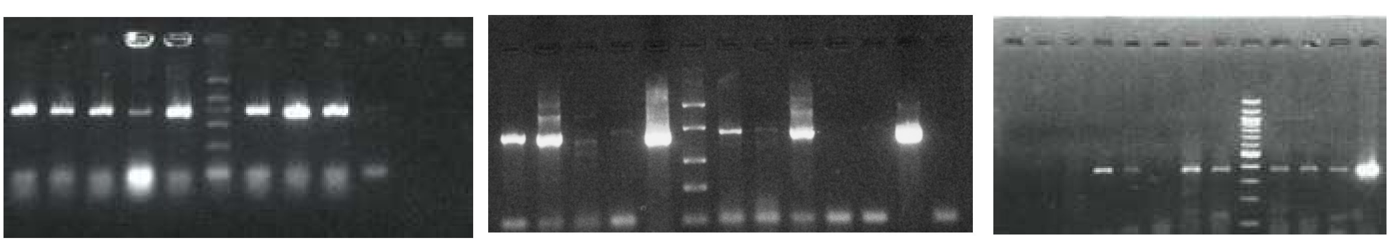
Effect of environmental exposure of arsenic in animals of Bihar

Samples were collected from Haldi Chapra (Maner, Patna) and different villages in Bhagalpur district of Bihar. Samples were evaluated for arsenic content in drinking water, fodder and biological samples (Fig 15.14). At Haldi Chapra, the levels of arsenic (µg/L) in samples of water, wheat straw, blood, faeces, milk, urine and hair were 85.82 ± 11.09, 685.63 ± 136.79, 1266.67 ± 200.69, 1257.38 ± 341.39, 525.5 ± 95.2, 27.8 ± 5.7 and 798.4 ± 81.8, respectively. The arsenic in milk, urine and hair was also higher, but the percentage of positive samples out of the total collected samples was 100, 85.71, 33.33, 85.71, 12.5, 20 and 10, respectively. The level of arsenic in all the samples of water, wheat straw, faecal, milk, urine, hair from Fatehpur, (Narpatganj, Araria) were found to be below the detection level (control). Digested samples from different villages of Bhagalpur district were sent for arsenic analysis.

Identification and characterization of common zoonotic pathogens in domestic animals

A total of 95 goat and cattle rectal swabs and 55 milk samples were collected from herds having history of diarrhoea or mastitis in recent past at different locations of Bihar. A total of 76 vaginal swabs were collected from Black Bengal goats. The samples were used for isolation and identification of *E. coli*. The isolated *E. coli* strains were processed for DNA extraction and PCR to study the prevalence of pathogenic *E. coli* collected from local poultry and cattle population. The study identified a total of 90 *E. coli* isolates. *E. coli* were screened for confirmation of species by primers USPA F and R, and the presence of virulence factors were determined by PCR with primers for VTcom, VT1, VT2 and *eae* genes. From the 72 isolates collected from goat faecal swabs, 52 isolates were found to have shiga toxin producing potential. Out of 11 isolates collected from cattle faecal samples, 4 were positive for shiga toxin gene. Two isolates from vaginal swabs were capable of producing shiga toxin. Out of 90 isolates, 29 were shiga toxin 1 (STX1) positive (Fig 15.15a), and 31 were STX 2 positive (Fig 15.15b); 12 isolates were both STX1 and STX2 positive. From the 90 isolates collected across the animals, 23 isolates were positive for *eae* gene (Fig 15.15c). The *shiga toxin producing* and *eae bearing* isolates have been summarized in Table 15.1. As the shiga toxin producing *E. coli* have the ability to cross species barrier, it is essential to have control measures to prevent zoonotic infections with shiga toxin producing *E. coli*.

Fig 15.14 Sample collection for arsenic content assessment in animals



(a) (b) (c)

Fig 15.15 Amplification of VT1 (a), VT2 (b) and *eae* (c) of *E. coli*

Table 15.1 Summary of Shiga toxin producing and *eae* bearing *E. coli*

Sample type	No. of samples	No. of isolated *E. coli*	No. of Shiga toxin producing *E. coli*	No. of *eae* bearing *E.coli*
Goat rectal swab	72	68	52	18
Cattle rectal swabs	12	11	4	4
Milk sample	55	4	0	0
Goat vaginal swabs	76	7	2	2

Assessment of antimicrobial drug resistance in bacteria of animal origin

A total of 145 *E. coli* were isolated from faecal samples collected from cattle, buffaloes and poultry. They were identified based on staining, cultural, biochemical characteristics and PCR. Somatic (O) antigen based serotyping results showed that the *E. coli* belonged to different serogroups. All the 145 tentatively identified *E. coli* were confirmed by uidA gene PCR wherein they produced an amplicon of expected size of 187 bp (Fig 15.16a) Bacterial culture from 55 milk samples from cattle and buffaloes resulted in isolation of 15 *Staphylococcus aureus*, 19 Staphylococci spp. and 11 Streptococcus spp. They were identified and confirmed based on colony characteristics, staining, biochemical characteristics and PCR. All the 15 tentatively identified *S. aureus* were confirmed by molecular test PCR as they produced amplicon of 279 and 700 bp for thermonuclease and coagulase gene, respectively. All the bacterial isolates of *E. coli* and *S. aureus* have been cryopreserved for future use.

Laboratory based antimicrobial sensitivity profile of *E. coli* isolates revealed that more than 45 % were multidrug resistant strains and mostly resistant to commonly used antibiotic drugs. 55 *E. coli* were phenotypically confirmed Extended Spectrum β-lactamases (ESBL) producer strains as tested by Double disc synergy test. All the *Staphylococcus aureus*, Staphylococci spp. and Streptococcus spp. were also subjected to antimicrobial sensitivity testing.

In genotypic study, *amr* genes relevant for ESBL production like *int1*, *int2*, *int3*, *sul1*, *TEM*, *SHV*, *OXA-1,4,30*, *CTX-M*, *KPC* and *NDM* were assessed in *E. coli* isolates by PCR (Fig 15.16 b-f)

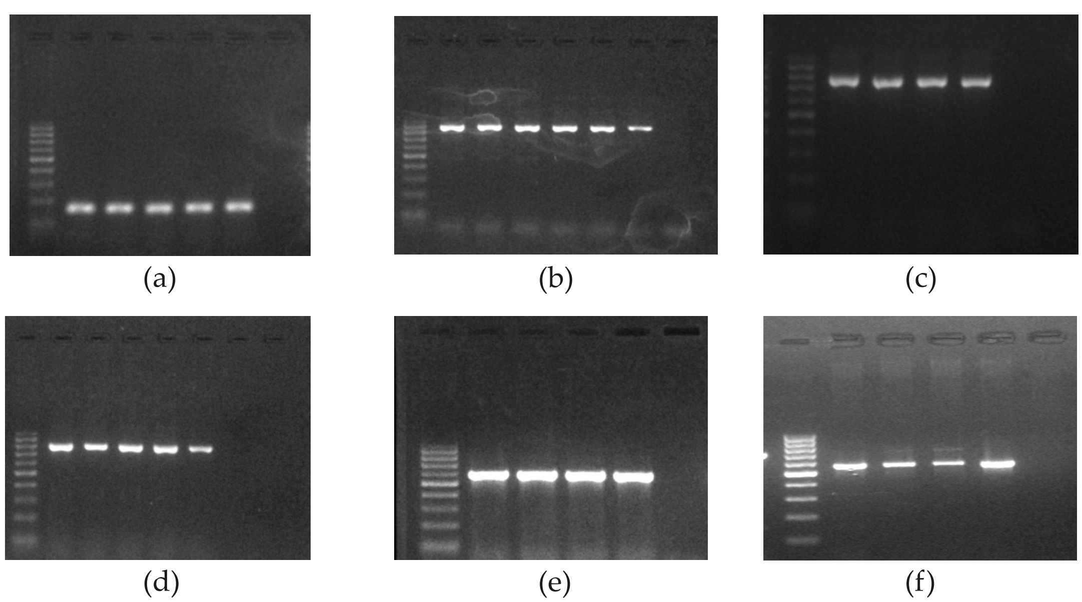


Fig 15.16 Amplicons of *uidA* (a), *int1* (b), *sul1* (c), *TEM* (d), *CTX* (e) and *OXA-1,4,30* (f) of *E. coli*.

16 Fisheries Resource Management and Aquaculture

Seed rearing of Pangasius in biofloc system of culture

Fish farming plays an important role in improving rural livelihood and alleviating poverty among rural communities. Pangasius (*Pangasianodon hypophthalmus*) is an important cultivable candidate fish species in India, and at present large-scale production of this species is going on in the eastern region. Quality seed is the bottleneck for the production of pangasius. To cater the need for quality seed, an attempt was made to raise a small fry of this species for the production of fingerling or advanced fingerling in biofloc units.

To evaluate the performance of fry of Pangasius in biofloc, an experiment was conducted with six treatments to compare the performance of fry raised in a normal outdoor system. The 5000 L capacity circular units were used for both biofloc system of seed raising as well as for normal outdoor units in the experiment (Fig 16.1). Varying stocking densities were used *viz.* T1BF (biofloc unit with 150 numbers/m^3 of fry), T2BF (biofloc unit with 200 numbers/m^3 of fry), T3BF (biofloc unit with 250 numbers / m^3 of fry), T4BF (biofloc unit with 300 numbers/m^3 of fry), T5N (normal outdoor unit with 150 numbers/m^3 of fry) and T6N (normal unit with 200 numbers/m^3 of fry) (Fig 16.1a). The study was conducted for a period of 112 days, and regular water quality parameters, weight gain as well as haematological parameters at the end of the experiment were collected and analysed. Maximum survival (59.07%) was achieved in biofloc system with a stocking density of 150 numbers/m^3 of fry (T1BF), and the minimum (32.10%) was recorded in normal outdoor conditions with 200 numbers/m^3 of fry (T6N). Maximum average body weight, SGR (%) and percentage weight gain were achieved in T2BF treatment. Maximum biomass production of 24.82 kg was achieved in T3BF, which was mainly due to better survival and higher stocking densities. In comparison with biofloc and natural systems of seed rearing, it was found that survival and production were much higher in biofloc system of culture than that of natural systems. The current study showed that biofloc unit could also be used for seed raising of Pangasius fish.

(a)

(b)

Fig 16.1 Seed transported to biofloc unit seed stocking at different stocking densities (a) in biofloc unit and seed stocking (b) at different stocking

Standardization of culture technique of Pabda

Polyculture of high value fish like Pabda (*Ompok bimaculatus*) was conducted in the institute fish farm. An earthen pond of 3000 m^2 was split into three halves of 1000 m^2 each using mesh net and bamboo poles. The experimental design for the trial was as follows: T_1 (Polyculture)-Pabda and IMC with commercial feed, T_2 (Polyculture)-Pabda and IMC with organic manure, and T3 (Monoculture)-Pabda alone with commercial feed. The pond was thoroughly sun-dried; thereafter, liming (10 kg/0.1ha), organic manure (10 kg/0.1ha of cow dung), and inorganic fertilizers such as urea (300g/0.1ha) and DAP (50g/0.1ha) were applied to each treatment. Carps and Pabda were stocked at 5000 and 20,000 nos/ha in polyculture, respectively, while Pabda alone was stocked at 60000 nos/ha in the monoculture system. Feeding was carried out in T_1 and T_3 at 5% of body weight for the first two months, and then dropped to 3% for both treatments. The best production performance and recovery percentage were recorded in T1 (polyculture with commercial feed), followed by T2 (polyculture with organic manure) and T3 (Pabda monoculture with commercial feed) (Fig 16.2, 16.3, 16.4 and 16.5).

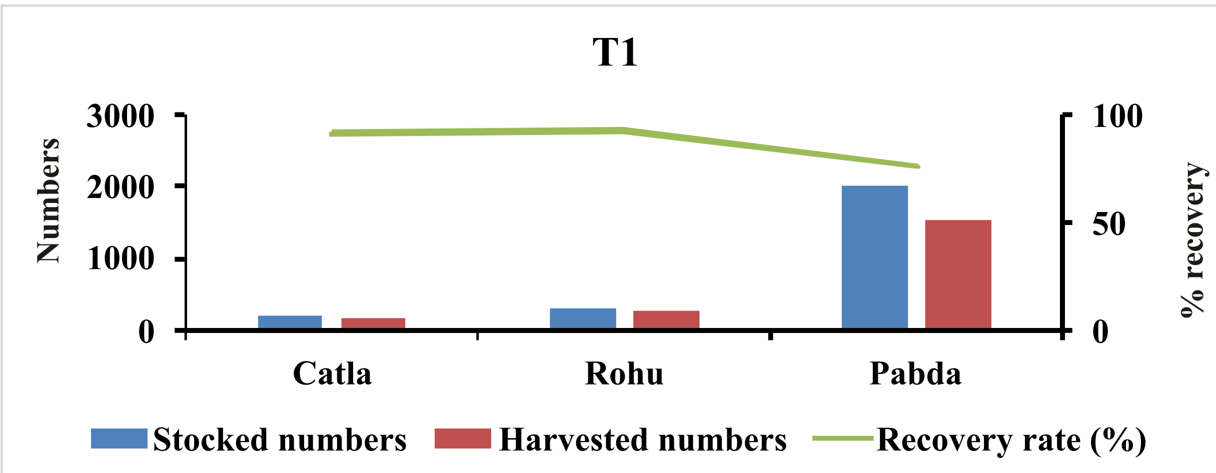
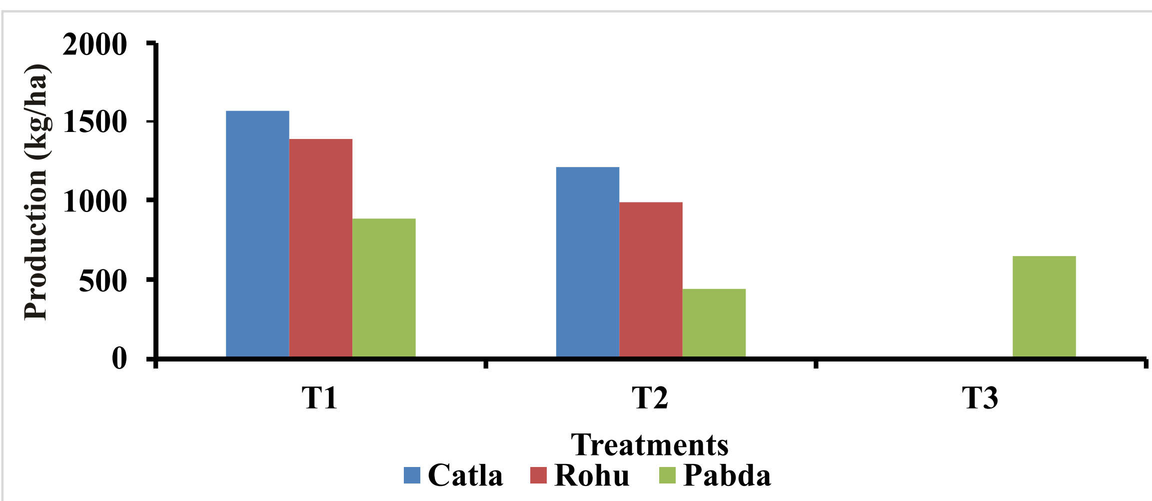


Fig16.2 Percentage recovery of catla, rohu and pabda in polyculture (commercial feed) system



16.3 Percentage recovery of catla, rohu and pabda in polyculture (organic manure) system

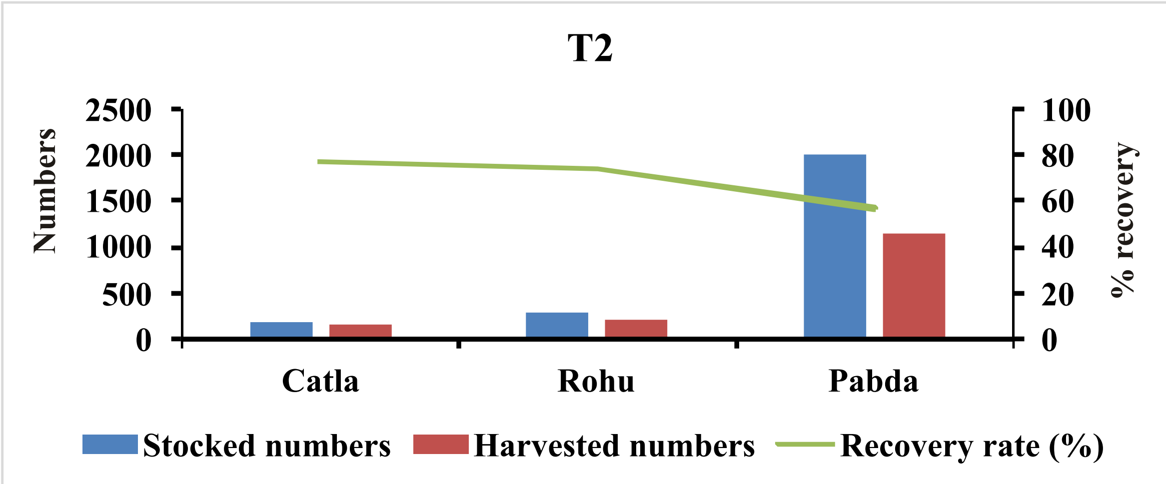


Fig 16.4 Percentage recovery of catla, rohu and pabda in polyculture (commercial feed) system

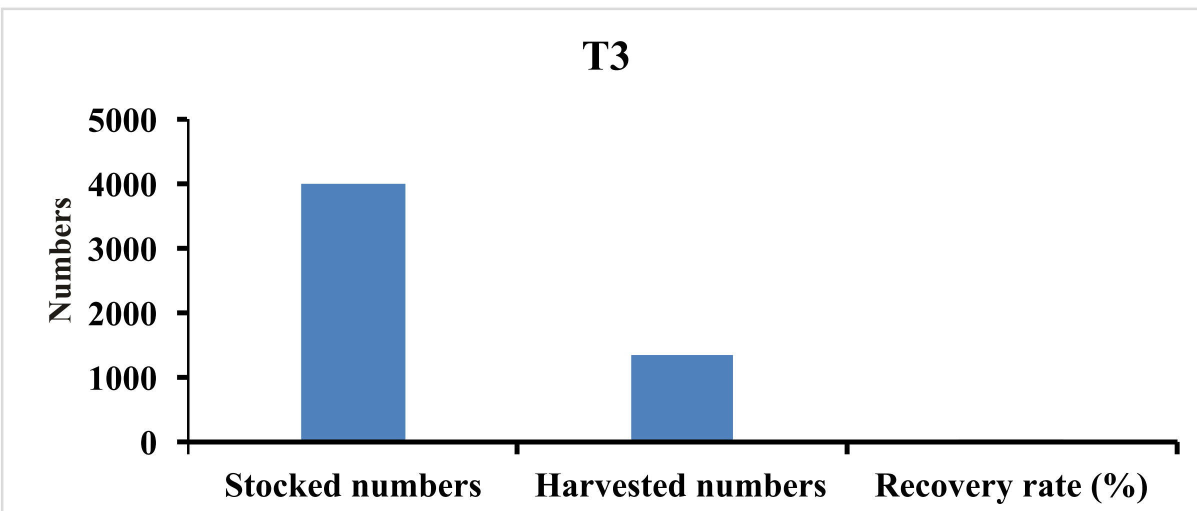


Fig16.5 Percentage recovery of pabda in monoculture (commercial feed) system

Delineation of wetlands in Bihar in view of fisheries management practices

The total documented wetland areas consists of 9,41,000 ha of *chaurs* and floodplain wetlands and 9,000 ha of oxbow lakes or *mauns* for use in fisheries. However, total fish productivity of wetland in Bihar is very poor (40-50 kg/ha/year) as compared to the Indian wetland (1000-2000 kg/ha/year). Three wetlands, namely Sonmar Chaur (Samstipur), Kanwar Lake (Begusarai) and Kasariya *Dhar* (Khagaria), were identified in Bihar to assess fisheries production, and to observe the effect of existing fisheries management practices on the ecosystem of the wetlands. Keeping these in view, the land use and land cover of selected wetlands were delineated using GIS technology (Fig 16.6). Rain water has been the primary water source for all these wetlands. During the monsoon season, heavy rainfall causes these wetlands to become completely flooded.

Sonmar Chaur covered an estimated area of 203 acres, with 107 acres utilized for aquaculture, mainly cultivating catla, rohu, mrigal and bighead carp, while the remaining area was used for agricultural crops. Before the introduction of aquaculture, fishermen used to capture a diverse variety of fish from the rainfed wetland. Although aquaculture increased the production to 4.7-6 tons/ha/year, it also resulted in reduced biodiversity. Currently, 40 farmers were found involved in fish farming through cooperative pond-based aquaculture. This collective farming model facilitated mass fish production, enabling farmers to procure aquaculture inputs at lower costs and sell their produce at higher market prices.

Kanwar lake, the largest freshwater Ramsar site in Asia, has a total water spread area of 63,000 ha during the monsoon season. However, during the post-monsoon period, the water area gets reduced to 2,426 ha. Fishing was permitted to all nearby fishermen, who were accustomed to using traditional methods (such as traps and hook & line) to catch various fishes (such as catla, rohu, Channa spp, Puntius spp, singhi, Chanda spp, *Tetraodon cutcutia*, *Mastacembalus* spp, *Esomus danricus*, prawns and *Pila globosa*). This wetland served as a vital breeding ground for various fish species. It also supported a variety of aquatic plants, including lotus (kamal), blue lotus (neelkamal), water lilies, cyprus, eichhornia and narkat (*Arundo donax*). Farmers harvested 1,000 lotus leaves within four hours, and sold them at Rs 2 per leaf. Additionally, *narkat* from this lake was used for livestock feed and thatched home construction. Once the floodwaters receded, the dried lands were repurposed for cultivating crops such as wheat, maize, mustard, sugarcane and paddy.

Kasariya Dhar is home to over 60 fish species. However, only the *Fishermen's Cooperative Society* of Chautham block was authorized to be engaged in fishing activities. Despite its high biodiversity, fish productivity in this wetland was low, averaging 50-100 kg/ha/year. Fishermen employed seine nets and hook & line methods for fishing. Over 75% of the wetland was densely covered with Eichhornia, posing a major challenge to fishing activities. Due to low fishing pressure, the wetland provided a suitable habitat for fish to thrive, fulfilling their feeding and breeding requirements. Kasariya Dhar was a notable source of *Notopterus* species, which are in high demand in Bihar. The variation of water quality parameters in three types of wetlands of Bihar is mentioned in the Table 16.1.

Overall, these wetlands play a crucial role in Bihar's fisheries, providing livelihoods to local fishermen and farmers while serving as important ecological habitats. However, challenges such as low productivity, invasive vegetation and biodiversity loss need to be addressed through better management and conservation strategies.

Table 16.1 Water quality parameters in three wetland assessed during December 2024

Parameters	Somnar chaur	Kanwar lake	Kasaraiya Dhar
Water temperature (°C)	18.10	21.97	21.17
Transparency (cm)	94.00	75.33	75.67
pH	7.58	6.75	6.70
Ammonium (ppm)	0.05	0.08	0.09
Nitrite (ppm)	0.13	0.13	0.11
Phosphate (ppm)	0.17	0.17	0.19
Alkalinity (ppm)	244.00	121.33	184.87
Hardness (ppm)	228.00	188.67	180.43
Dissolved oxygen (mg/L)	9.60	4.46	4.13
Conductivity (µS/cm)	545.93	274.20	372.07
Total d issolved solid (ppm)	596.40	293.57	401.23

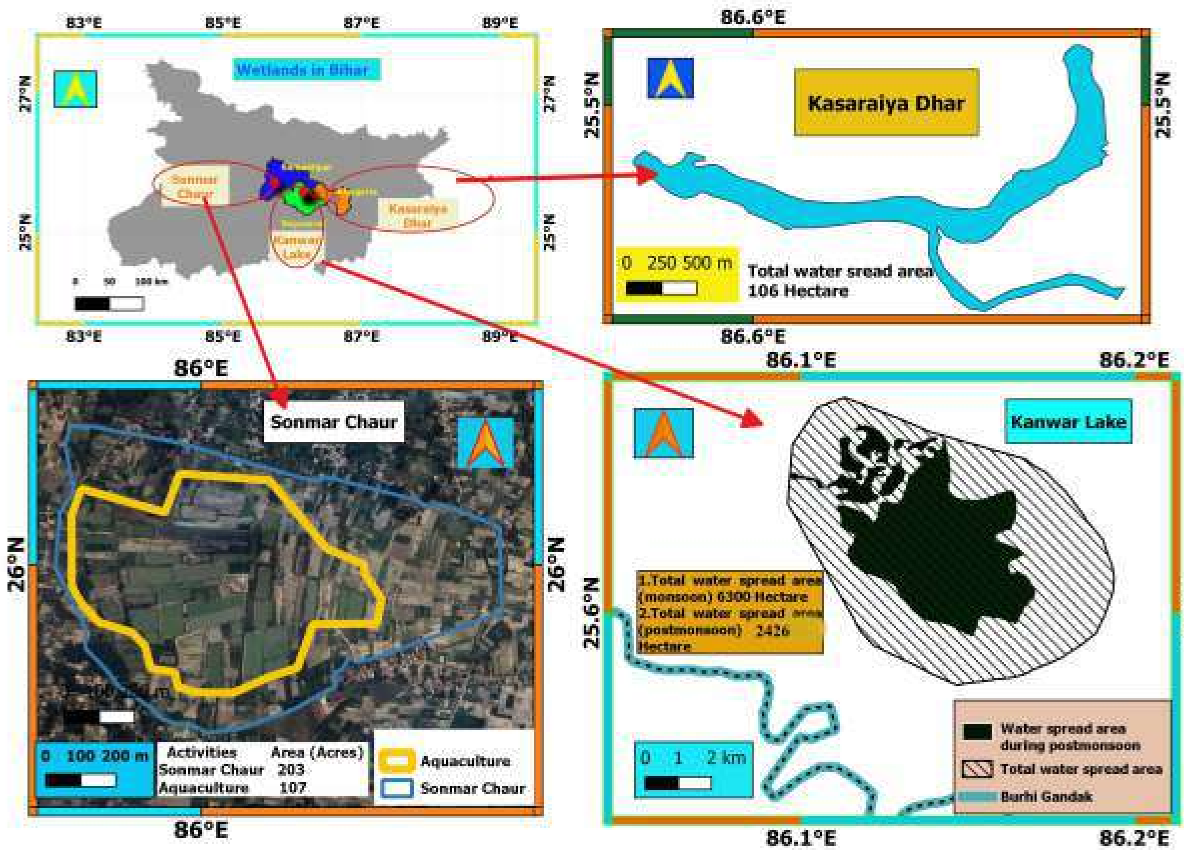


Fig 16.6 Delineated wetlands for fisheries management in Bihar

Modelling on temperature-driven responses in Azolla growth

Kasariya Dhar is a perennial wetland, which is infested with floating aquatic weeds. To observe the growth pattern under the climatic variables on Azolla (*Azolla pinnata*), an experiment was conducted in FRP tank with capacity of 500 L water. For the nutrient supply to Azolla, a mixture of 10 kg of soil, 1.5 kg of cow dung and 20 g NaH_2PO_4 was kept in the bottom of the tanks in triplicate manner. The experiment was started with 100 g of Azolla in each tank, and carried out for six months under the environmental temperature. At every 15 days interval, water temperature and weight of Azolla were observed in the morning hour during the study period. Polynomial regression model was applied to find out temperature-driven responses in Azolla growth rate (Table 16.2). Result indicated that the growth rate in Azolla increased with increase in water temperature; however, the growth rate decreased after water temperature reached at 30°C (Fig 16.7a). A significant positive correlation (r=0.62) was observed between water temperature and growth rate of Azolla (Fig 16.7b).

Table 16.2 Summary of polynomial regression analysis

Parameters	Estimate	Standard error	t value	Pr(>|t|)	p-Value
Intercept	143.69	62.7745	-2.289	0.02929*	<0.05
Temperature	18.51	6.1063	3.031	]0.00499 **	<0.001
Temperature	-0.33	0.1367	-2.388	0.02343 *	<0.05
R^2	0.48	-	-	-	
Adj R^2	0.45	-	-	-	

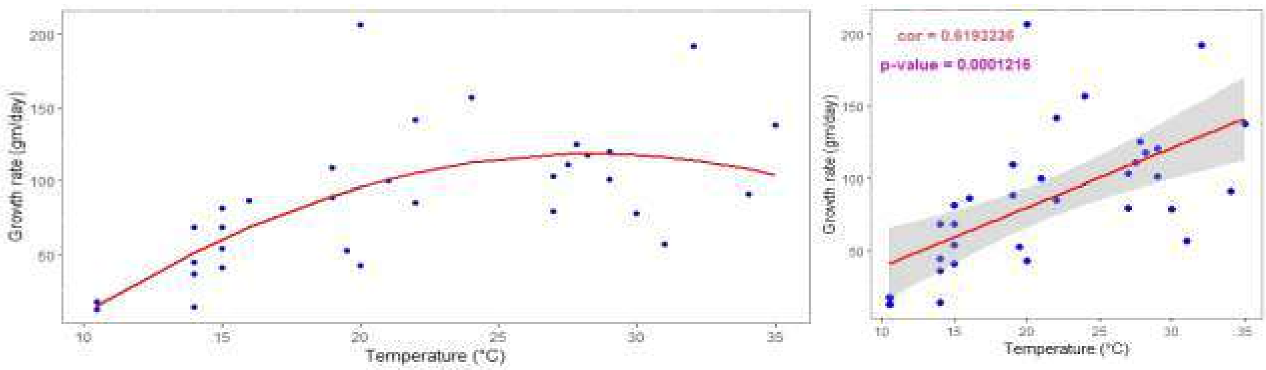


Fig 16.7 (a) Graph showing the effect of temperature on growth rate of Azolla, and **(b)** correlation plot between temperature and growth rate

Study on the microplastic ingestion in fish growth

An experiment was conducted to observe the effect of microplastic ingestion in grass carp (*Ctenopharyngodon idella*) for 35 days during 2024-25. The average weight of each grass carp was 10 g. This experiment was carried out in 5 L glass tank. The treatments included three types of microplastics: polypropylene in T1, polyethylene in T2 and low-density polyethylene (LDPE) in T3. Fish was fed with 5% of body weight, where microplastic was mixed at the rate of 1 ppm in each treatment. One control was also maintained. The highest weight loss was found in LDPE (35%) as compared to the control, while the highest amount of microplastic was found in the fish gut (58%) (Fig 16.8).

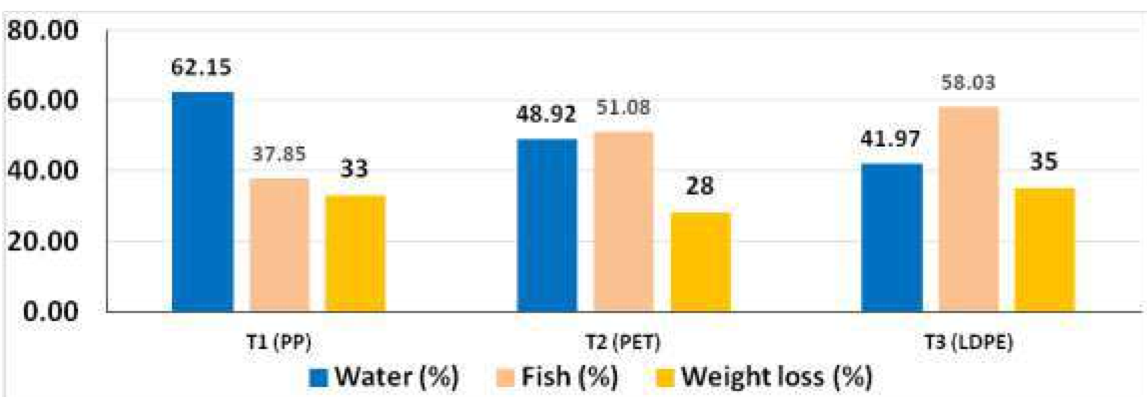


Fig16.8 Observation on microplastic effect in fish

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17 Farm Mechanization

Development and evaluation of a solar-powered maize sheller

A solar-powered maize sheller was designed and developed to offer an eco-friendly and cost-effective solution for maize threshing (Fig 17.1). It aimed at enhancing the efficiency for shelling kernels from the cob especially by small and marginal farmers inhabiting in remote or off-grid areas. The system integrates renewable energy with agricultural mechanization to enhance productivity while reducing dependence on conventional electricity or fossil fuels. The maize sheller is powered by a 500-watt DC motor, chosen for its high efficiency and compatibility with solar photovoltaic (PV) systems. The power source comprises three solar panels of 335 Wp each, totaling 1,005 Wp, which supply electricity directly to the motor during the day (Fig 17.2 & Table 17.1) . To regulate energy flow and ensure system stability, a solar charge controller and a DC distribution system are incorporated. Additionally, a battery backup can be included in practical applications to store excess energy for use during non-sunny periods or at night. The maize sheller was field-tested and showed an effective processing capacity of around 200 kg per hour. The solar-powered setup ensured an uninterrupted power supply during daylight, adequately meeting the motor's energy requirements. Further performance evaluation is ongoing.

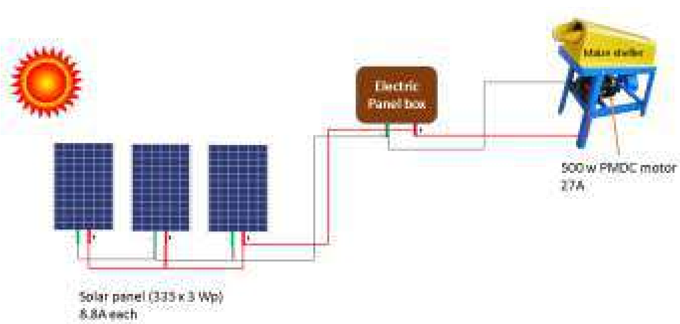

Fig 17.1 Schematic diagram of Solar powered maize sheller

Fig 17.2 Developed solar operated maize sheller

Table 17.1 Solar Panel specification

Maximum Power Output	335 W
Type	Polycrystalline
Usage/Application	Home
Model	ALP 335W
Maximum Power Voltage Vmp	38.08 V
Product Warranty	144 months
Short circuit Current Isc	9.43 A
Maximum Power Current Imp	8.80 A
Net Weight (in kg)	21 kg
Dimensions (in cms)	198.6x100.1x3.5 cm (HxLxW)
Brand	Luminous
Open circuit voltage voc	46.02 V

Energy flow, carbon balance and water footprints of dominant cropping systems under different agro-ecological regions of eastern India

Twenty-one major rice-based cropping systems across seven states in eastern India (three systems per state) were evaluated for energy patterns, carbon balance and water footprint. Data were collected from four states: Odisha, Jharkhand, Bihar, and West Bengal. In Odisha, energy ratios were calculated as follows: rice-rice (7.06), rice-green gram (6.05) and rice-fallow (6.14). In Jharkhand, the energy ratios were: rice-fallow (7.63), rice-mustard (8.24), and rice-potato (6.45).

18 Socio-economic Studies and Transfer of Technology

Climate resilient agriculture programme

Under the project *climate resilient agriculture* (CRA) Programme, climate resilient crop varieties and production technologies were demonstrated at the farmer's field in Harikisanpur, Dalsagar, Churamanpur, Ramobariya and Balapur villages of Buxar district. In 2024, a total of 1468 acre area was covered under farmers' participatory demonstration. The details are given in the Table 18.1. These demonstrations benefitted 1376 farmers (consisting of 1112 male and 264 female farmers in the adopted villages under CRA). Additionally, long term experiments were also continued and carried out at KVK Buxar farm.

Productivity enhancement through CRA interventions

In *Kharif* season, line transplanted rice variety 'BPT 5204' combined with interventions, such as water harvesting, field bunding, green seeker based nutrient management and alternate wetting and drying system, led to 15% increase in rice productivity compared to traditional practices in non-CRA areas in Buxar district (Table 18.2). The raised bed method of maize cultivation (cv. Kaveri Profit) was introduced as one of the CRA interventions, resulting in a yield increase of 29.33% compared to the flat bed method. The introduction of line-sown bajra during the *Kharif* season proved to be a highly favored among the farming communities, as this crop could withstand drought conditions. Additionally, it also offered fodder for their livestock. Line sowing of bajra (cv. LG-70401) recorded 35.22% yield advantage over the traditional broadcasting method.

Table 18.1 Area coverage and beneficiaries under CRA Programme during 2024-25

Season	Target area (acre)	Area covered (acre)	No. of beneficiaries
Rabi 2023-24	623	623	716
Summer 2024	250	250	233
Kharif 2024	595	595	427
Total	1468	1468	1376

Table 18.2 A comparison of crop productivity under CRA and Non-CRA

Seasons	Crop	Productivity (q/ha)		% increase over non-CRA
		CRA	Non CRA	
Kharif	Rice	52.06	45.24	15.08
	Bajra	35.40	23.18	35.22
	Maize	56.44	43.64	29.33
Rabi	Wheat	48.60	42.91	15.96
	Lentil	18.04	12.34	25.80
	Chickpea	22.34	17.42	28.24
	Mustard	16.82	12.79	20.31
Summer	Mungbean	15.23	11.86	32.90

In *Rabi* 2023-24, the ZT practice in wheat, lentil, chickpea and mustard gained popularity due to reduced fuel consumption and labor requirement. The use of ZT in wheat (cv. HD 2967) resulted in 16% higher yield compared to traditional broadcasting method. Similarly, the grain yield of lentil (cv. IPL 220), chickpea (cv. Pusa 3043) and mustard (cv. PM 30) under ZT demonstrations were 20-28% higher than that under conventional broadcasting methods. Additionally, ZT summer moong (cv. Samrat and IPM 2-14) recorded an average grain yield of 15.23 q/ha, i.e., 32.90% increase over the local variety.

Profitability under CRA interventions

Significantly higher profitability under all CRA interventions was observed than that under conventional farming systems across all the crop seasons owing to higher productivity. The line sown rice along with CRA production technologies resulted in a net profitability of 17.67% compared to puddled transplanting. This improvement could be ascribed to the use of quality seeds, timely sowing, efficient water management and balanced fertilizer application (Fig 18.3). The raised bed *Kharif* maize with high yielding hybrid varieties achieved a profitability of Rs 85250/ha, a 24.23% increase over traditional method of maize cultivation in non-CRA areas. The line sowing method for bajra resulted in a net return of Rs 52718/ha with an increase in profitability of 43.29%. Similarly, during the *Rabi* season, the ZT approach for wheat achieved a profitability boost of 21.49% with a net return of Rs 96240/ha compared to traditional broadcasting method. A similar trend was observed in other *Rabi* crops with increases in profitability for ZT lentil, chickpea and mustard ranging from 25% to 30%. Among the *Rabi* crops, ZT wheat recorded the highest profitability (Rs 96240/ha) followed by ZT chickpea (Rs 89282/ha). Despite experiencing water stress in summer, ZT moong yielded Rs 43154/ha with CRA interventions (Fig18.1).

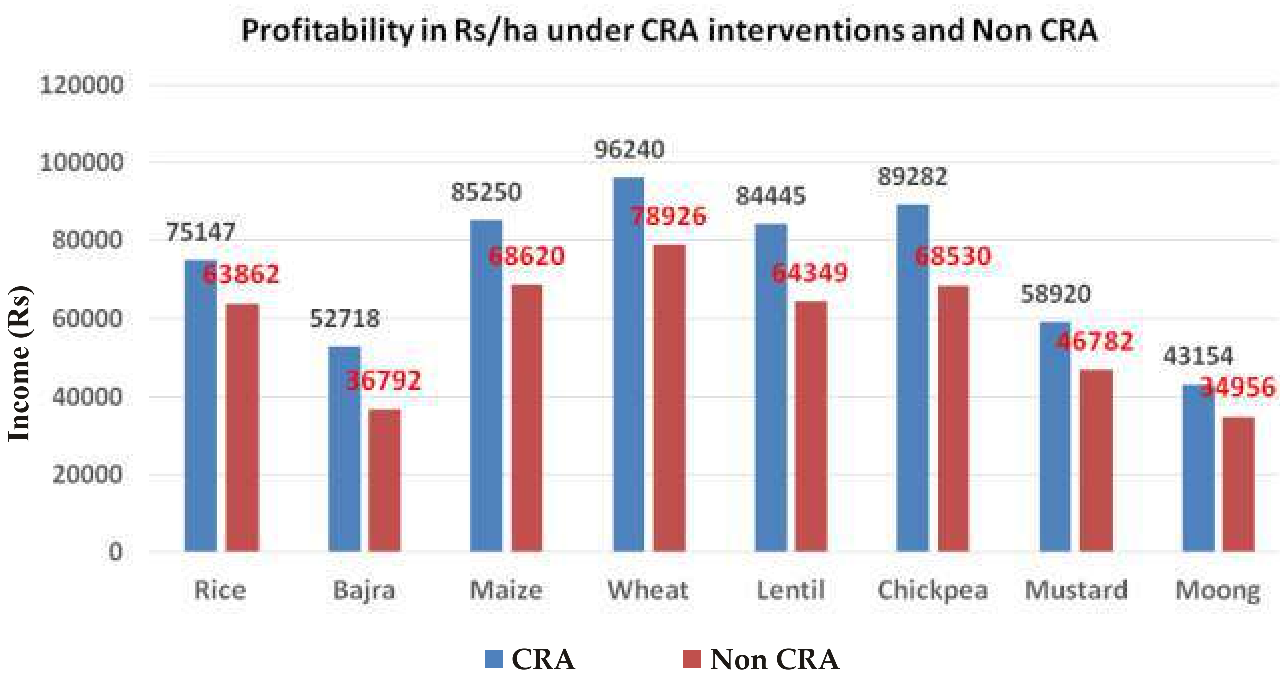

Fig 18.1 Profitability under CRA interventions

Crop diversification under CRA Programme

Crop diversification was introduced as a key component of CRA Programme. As a part of this initiative, area of maize, bajra and other millets were increased by reducing the rice area during the *Kharif* season. Similarly, wheat area was also reduced in the succeeding *Rabi* season by enhancing the cultivation of other *Rabi* crops such as chickpea, lentil and mustard. The impact has been evident from expansion of CRA interventions including crop diversification into neighboring non-CRA villages. During 2023-24, the average area covered by other field crops (other than rice and wheat) in non-CRA villages in comparison to CRA villages was 12, 29, 17, 14, 16 and 25 percents respectively under RB maize, RB Bajra, ZT chickpea, ZT lentil, ZT mustard and ZT moong (Table 18.3). This indicated that CRA interventions in the fields are gradually adopted by non-CRA farmers.

Capacity building and other activities in CRA programme

Capacity building has been a crucial component in CRA programme. A total of 4011 beneficiaries participated under various capacity building programmes organized under CRA. The details are mentioned in Table 18.4.

Identification of promising cropping systems and residue management

The CRA programme also focuses on identifying the best cropping system based on profitability, productivity and existing climatic situations. During the year 2023-24, the top three cropping systems identified in Buxar were maize-chickpea-moong followed by rice-wheat-moong and rice-chickpea-moong. The maize-based cropping system showed slightly higher profitability than the rice-based cropping system besides requires considerably less water than rice-wheat system. The details are mentioned in Table 18.5. A total of 42 tones of straw bales and 22 quintals of biochar were produced at KVK Buxar farm; this assisted in the management of crop residue after the harvest of rice and wheat. The custom hiring centers developed at KVK Buxar generated, a total revenue of Rs 2.12 lakh was generated during the year. Additionally, 150 acres of land in adopted CRA villages were levelled using a *laser land leveler*.

Table 18.3 Crop diversification other than rice and wheat in non-CRA villages

S. No.	Crops	Interventions	% of area covered in non-CRA villages*
1	Maize	Raised-bed planting	12
2	Bajra	Raised-bed planting	29
3	Chickpea	Zero tillage	17
4	Lentil	Zero tillage	14
5	Mustard	Zero tillage	16
6	Moong	Line sowing	25

*The percentage coverage was evaluated based on the area covered at non-CRA villages compared to the area covered at CRA villages

Table 18.4 Capacity building under CRA programme organized at Buxar

S. No.	Details of the programme	No. of events	Male	Female	No. of beneficiaries
1.	Training programmes	42	1895	584	2479
2.	Field days	5	392	158	550
3.	Exposure visits	9	834	148	982
Total		56	3121	890	4011

Table 18.5 Most profitable cropping systems in Buxar

Cropping system	Profitability (R s/ha)
Maize-chickpea-moong	217686
Rice-wheat-moong	214541
Rice-chickpea-moong	207583

Sustainable improvement in livelihood of scheduled caste community in Meskaur and Sirdala blocks of Nawada district, Bihar

A project entitled "Sustainable improvement in livelihood of scheduled caste community in Meskaur and Sirdala blocks of Nawada district, Bihar", funded by the *Department of Science and Technology* under "Science for Equity Empowerment and Development" (SEED) scheme, has been initiated since February 2024 in collaboration with KVK, Nawada and an NGO 'Kaushalya Foundation'. The major objective of this project relates to improving the existing livelihood of farmers and other members of the scheduled caste (SC) community in four selected villages (Akri Pandey Bigha and Kopin from Meskaur, and Janhaul and Chougaon from Sirdala blocks) of Nawada district. A total of 200 SC farmers from four villages (50 from each village) were adopted for technology interventions related to agriculture and livestock.

Participatory technology demonstrations at Nawada

In *Kharif* 2024, an improved rice variety 'Rajendra Sweta', groundnut variety 'Girnar-5', maize variety 'Shaktiman 5', pigeonpea variety 'IPA 203' and fodder sorghum variety 'UPMC 503' were introduced in selected villages through participatory field demonstrations (Table 18.6).

In rice, the variety 'Rajendra Sweta' with 16.2% higher yield provided better return to the farmers owing to its fine grain quality than the local variety. 'Rajendra Sweta' was, therefore, identified as the promising variety of rice in the project area. It is evident from the Table 18.6 varietal interventions produced high yield, fetching higher profits to the farmers. The SC farmers effectively utilized sorghum as the fodder for their livestock.

FLDs of climate resilient rice varieties

A total of four FLDs involving four climate resilient high-yielding rice varieties, namely 'Swarna Samriddhi Dhan', 'Swarna Unnat', 'Swarna Purvi Dhan-2' and 'Swarna Shreya', were conducted at progressive farmers' field at Nawada. A total of 10 kg seeds of each variety were provided to the farmers along with comprehensive technical support. A Rice field day was also organized on 27th of October 2024 at the village before final harvesting of these FLD plots, during which feedback from farmers about the performance of demonstrated rice varieties was collected (Fig 18.2). Results showed that the average yield of 'Swarna Purvi Dhan-2' (5.1 t/ha) was the highest followed by 'Swarna Unnat' (4.91 t/ha), 'Swarna Samriddhi Dhan (4.73 t/ha) and 'Swarna Shreya' (4.43 t/ha). Despite the high yield potential of 'Swarna Samriddhi Dhan', the yield was lower due to the occurrence of false smut. All these varieties provided approximately 20-40% higher yield than those of the local varieties.

Table 18.6 Performance of different crop varieties under *Kharif* demonstration at Nawada, Bihar

S. No.	Crop and variety	No. of field demonstrations	Average yield in demonstration plot (t/ha)	Average yield under farmers' practice (t/ha)	% increase in yield
1	Paddy (Rajendra Sweta)	129	4.3	3.7	16.2
2	Groundnut (Girnar-5)	70	2.1	1.9	10.5
3	Maize (Shaktimaan-5)	30	5.4	4.6	17.4
4	Sorghum (UPMC 503)*	50	3-4 cuts	--	-

*Sorghum was utilized as fodder grass for livestock with 3-4 harvests

Distribution of seed and planting materials for field demonstrations

During *Kharif* and *Rabi* seasons, seeds of crop varieties, and planting materials were distributed to SC farmers of adopted villages in Nawada as per details given in Table 18.7.

Fig 18. 2 A training program for SC farmers organized at KVK Nawada

Livestock based technology interventions

To improve the livelihood security of SC farmers, a total of 50 'Black Bengal' goats (40 female and 10 male) and 800 chicks were distributed to 58 marginal farmers of SC community. Prior to this, these farmers received training in goat and poultry rearing as well as animal health management (Fig 18.3).

Development of zero hunger and zero technology gap village through innovative interventions

Under the aegis of ICAR-RCER (Patna) and ATARI (Patna), a joint project - *Development of Zero Hunger and Zero Technology Gap Village through Innovative Interventions* - was launched in August 2023. This ambitious initiative aimed to select a village in Bihar and develop it into a model of agricultural innovation with zero hunger and zero technology gap. *Chhotaka Dhakaich* village in Simri block of Buxar district was identified for the purpose. The technology interventions under the project were finalized under the following four themes:

Fig 18.3 Distribution of improved breeds of chicks and goats among SC farmers

Table 18.7 Most profitable cropping systems in Buxar

S. No.	Crops	Variety	No. of Demonstrations	Quantity (qt)
1	Paddy	Rajendra Sweta	129	3.00
2	Red gram	IPA 203	On bunds	0.50
3	Groundnut	Girnar 5	70	1.00
4	Wheat	Karan Vandana & HD 2967	76	5.00
5.	Chickpea	Swarna La kshami & Pusa 3043	120	2.00
6.	Mustard	Pant Sweta	50	0.24
7.	Chill seedlings (no.)	NS 1101	30	900
8.	Tomato Seedlings (no.)	Abhilash	30	900

- Sustainable intensification of rice-wheat cropping system using climate resilient varieties, zero tillage technology for *Rabi* crops and introduction of mungbean during summer.
- Nutri-garden technology for nutritional security of farm families.
- Livestock-based technologies and community-based animal health centre in the village.
- Diversified livelihood opportunities and capacity building of farmers and youth for livelihood improvement.

Process Model developed

It began with surveys using participatory rural appraisal (PRA), baseline studies and focused group discussion (FGDs) to identify existing constraints. Need assessment and social mapping were done to design targeted strategies. Various capacity building activities (training, demonstrations, exposure visits, awareness camps and gender sensitization workshops) were organized. The model is jointly implemented by ICAR-RCER (Patna), ATARI (Patna), KVK (Buxar) and village institutions with the active participation of farmers. The process model is depicted in Fig 18.4.

Participatory field demonstrations and its impact

In the *Rabi* season of 2023-24, technologies such as zero tillage wheat (cv. HD 2967) and line sown chickpea (cv. Pusa 3043) were demonstrated at farmers' field. The ZT wheat demonstrated a yield increase 13.3% compared to that of the locally broadcasted wheat, while the improved chickpea variety produced a 26% higher yield than that under farmers' practice (Table 18.8). To address hidden hunger linked to nutrition deficiencies, demonstrations of cabbage (K-1), cauliflower (C 6015) and onion (AFDR) were conducted, resulting in a significant increase in yield and income of farmers.

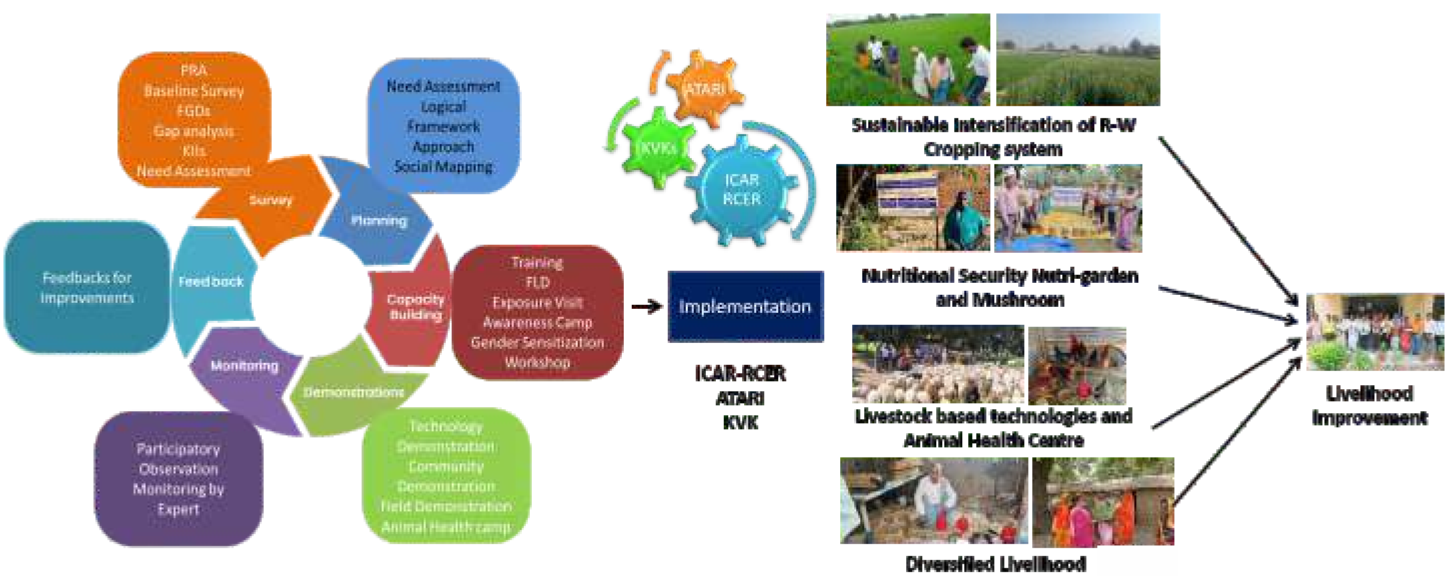

Fig 18.4 Process model for developing ZHZTG village

Table 18.8 Technology intervention and its impact on yield increase

S. No.	Technology interventions (Crop and variety)	No. of demo.	Yield (q/ha)		% increase in yield
			Demonstration	check	
1	ZT wheat (HD 2967)	36	44.3	39.2	13.35
2	Line sowing of chickpea (Pusa 3043)	41	17.59	14.22	26
3	Raised bed planting of Cauliflower (C 6015)	10	340.6	296.5	14.9
4	Onion (AFDR)	06	175	144	21.5
5	Raised bed planting of cabbage (K-1)	19	334.5	295	13.3

In the *Kharif* 2024, 73 demonstrations of high yielding climate resilient paddy varieties (Swarn Samridhi, Swarn Shakti and Swarn Unnat) were conducted in a total area of 21 ha on the farmers' field (Fig 18.5). Results revealed that 'Swarna Samridhi' had an average yield of 44.1 q/ha, reflecting a 20.8% increase in yield compared to the farmers' practice. Similarly, the variety 'Swarna Shakti' and 'Swarna Unnat' recorded average yield of 43.7 and 40.0 q/ha, respectively with percentage increases of 11-14 % over the farmers' practice

Fig 18.5 Rice field of adopted farmers

Intensification of rice-wheat cropping system by including summer moong

For sustainable intensification of rice-wheat cropping system, moong bean (cv. IPM 2-14) was introduced in the village on 5 ha area involving 32 farmers' fields during the year 2024 in summer season (Fig 18.6). Advancing the cultivation of green gram with a zero-tillage machine and improved variety resulted in an average yield of 10.35 q/ha. The importance of green gram as an additional crop and its significance in improving soil fertility has received farmers' special attention.

Fig 18.6 Green gram picking in adopted farmers' field

Nutri-garden for providing nutritional security

To contribute to the zero hunger mission, nutri-gardens were established at selected locations in the village. Nutri-garden kits containing seeds and seedlings of 14 vegetables and small implements such as *khurpi* and *watering can* were distributed to 26 farming men and women. They were also provided detailed guidelines on sowing, spacing, nutrient management and harvesting techniques through training and awareness programmes. 18 household set up nutri-garden, and started growing a variety of vegetables for their own consumption and selling to get monetary benefit.

Backyard poultry farming

Backyard poultry farming was introduced to 30 willing marginal farmers as it is considered a potential enterprise for women empowerment, nutritional and livelihood security. 'Vanraja' poultry breed (Fig 18.7), which is a dual-purpose bird (egg and meat), was introduced (5 each with 100 birds and 25 each with 20 birds) under a backyard system of rearing along with some poultry cages, starter feed and drinkers. It was observed that the average body weight of poultry increased significantly from almost 400 g at 4 weeks to 1.8-2 Kg at the age of 180 days. The farmers earned a good profit by selling these birds for meat purpose at the attractive price (> Rs 300/kg) as compared to broiler farming.

Capacity building programmes

Capacity building activities, such as training, field visit, awareness camp and sensitization, were conducted regularly for successful implementation of the project. The details are given in the Table 18.9

Fig 18.7 Backyard poultry by an women farmer

Table 18.9 List of trainings imparted to farmers

S. No.	Title	Date and place	No. of beneficiaries
1	Scientific cultivation of *Rabi* crops for improving farm productivity and food security	January 10 -12, 2024; ICAR RCER, Patna	13
2	Production techniques for mushroom farming	Nov 13-14, 2024; Chhotaka Dhakaich	25
3	Animal health camp and awareness programme	March 06, 2024; Chhotaka Dhakaich	100
4	Launch workshop *cum* farmers-scientists interaction meeting	March 12, 2024; Chhotaka Dhakaich	125
5	Farmers-scientists interaction for establishment and management of nutri-garden	October 23, 2024; Chhotaka Dhakaich	40

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

The project "Impact of e-NAM on improving marketing of agricultural produce in eastern India" was started in Bihar during 2024. In July 2020, the Bihar government launched *Bihar Agricultural Produce Value Addition System* (BAVAS) to strengthen the agricultural marketing ecosystem in the state. Out of 54 APMC mandis, BAVAS has initiated efforts to link 20 Mandis with better infrastructure with the e-NAM platform since 2023-24. The data from stakeholders revealed that currently 999 traders along with 5186 farmers and 225 FPOs are registered on e-NAM platform in the state. There have been few instances of high-volume trading in the 20 selected mandis of the state (Fig 18.8). However, comprehensive implementation of this scheme across the state will take some time. The major commodities traded on the e-NAM platform include rice, wheat, maize and various pulses among food grains. Potato and onion have emerged as the main vegetables, while mango, banana and litchi are the major fruits traded through e-NAM in the state.

Constraints in e-NAM implementation in Bihar

Currently, BAVAS serves as the nodal agency for implementation of e-NAM in the state. However, discussions with state-level coordinators revealed numerous obstacles in the implementation of the scheme in Bihar. The abolition of the APMC act in 2006 created an open market policy for traders. Government officials are unable to compel any traders to use e-NAM platform for trading of their produce. Additionally, farmers in Bihar remain unaware of these electronic marketing opportunities. There is a lack of basic infrastructure for the implementation of electronic trade in selected mandis, including digital entry, weighing, assaying, storage and kisan bhavan. Moreover, there is an acute shortage of manpower for e-NAM related activities. Moreover, there is a necessity for dedicated staff to manage activities related to e-NAM. Skilled manpower is required for the electronic trading of agricultural produce using software. A large-scale awareness campaign targeting both farmers and traders is required to increase the reach of e-NAM in the state.

Building resilience model for the vulnerable hotspots to climate change in smallholder dairy production system of Indo-Gangetic Plain Region of India using GIS and Fuzzy cognitive mapping approach

A detailed assessment and classification of climate risk hotspots were undertaken across the IGP with a specific focus on Bihar (Fig 18.9). The study analyzed three temporal scenarios, historical (1980–2022) and future projections (2023–2050) under representative concentration pathways (RCP) 4.5 and 8.5.

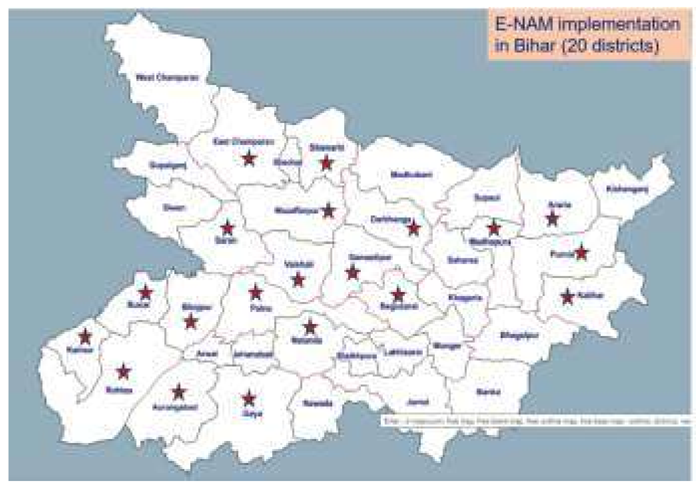

Fig 18.8 Districts of Bihar having e-NAM Mandis

In Bihar, Patna and Bhojpur districts were identified as highly vulnerable with a 99% confidence interval, while Buxar and Gaya were marked with a 95% confidence interval. To understand the ground realities, baseline surveys were carried out involving 200 farmers in each of these districts. These surveys, combined with GIS mapping and Fuzzy Cognitive Mapping (FCM), enabled a precise modelling of the socio-climatic vulnerabilities faced by smallholder dairy farmers in these regions.

The IGP, which spans only 15% of India's landmass, supports over 29% of the national livestock population and contributes more than 36% of India's milk production. However, this agriculturally vital region is increasingly vulnerable to the adverse

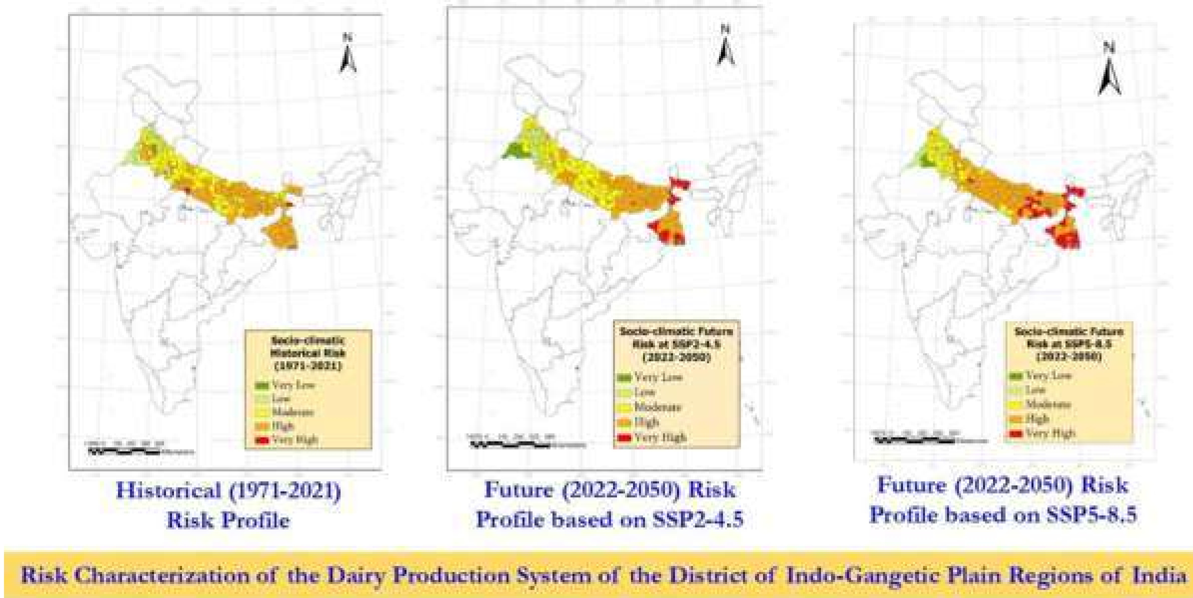

Fig 18.9 Mapping of the socio-climatic vulnerabilities faced by smallholder dairy farmers

effects of climate change. The project's spatial and temporal analysis, grounded in IPCC protocols, revealed that while only 1% of the IGP area (approx 4.4 lakh ha) fell into the "very high risk" category in 2021, this figure could escalate to 6.85% to 15.31 % by 2050 - an alarming increase of 25.76 to 63.09 lakh ha under SSP2-4.5 and SSP5-8.5 emission scenarios, respectively.

The number of hotspot districts across the IGP is expected to rise from 46 in 2021 to 56-57 by 2050, involving an additional 16.67 to 16.90 lakh ha of land. This data-driven insight calls for region-specific climate adaptation strategies to strengthen the resilience of dairy production systems in Bihar.

Assessing the impact of climate-resilient agricultural interventions in enhancing farmers' adaptive capacity in Bihar

With nearly 77% of its population engaged in farming activities, Bihar's agrarian economy is highly vulnerable to climate change impacts such as increased frequency and intensity of extreme climatic events. Recognizing the urgency of addressing these challenges, the Government of Bihar launched the *Climate Resilient Agricultural Programme* (CRAP) in 2019 with the objective to enhance farmers' adaptive capacity and resilience to climate change impacts through the adoption of climate-resilient agricultural practices. The survey questionnaire covered various aspects including socio-demographic profile, perception of climate change, agricultural practices, adaptive capacity and livelihood strategies. The Farmers climate perception index (CPI; Table 18.10) was developed by interviewing a total of 39 experts and farmers having a reliability score of 0.78 and SCV of 2.3068; this was further validated using appropriate statistical techniques.

Unlocking green gains: an assessment of voluntary carbon credit potential in Bihar

The global push for climate-smart agriculture has sparked interest in carbon credit programmes. These programmes incentivize farmers to adopt sustainable practices (eg., zero tillage) that reduce greenhouse gas emissions and enhance soil carbon sequestration. However, participation in carbon credit schemes remains limited. This study was conducted in the Buxar district of Bihar, focusing on villages practicing ZT under the CRA programme. Although India's voluntary carbon market is still in a nascent stage, particularly in agriculture, this study provides valuable baseline insights (Fig 18.10).

Table 18.10 Farmers climate change perception index components and scores

S. No.	Components	SCV	CA
1	Awareness about climate change	2.299	0.908
2	Perceived impact of climate change on agriculture	2.341	0.875
3	Adaptive capacity	2.290	0.754
4	Adoption of climate-resilient practices	2.264	0.687
5	Barriers to adaptation	2.282	0.892
6	Support from government and institutions	2.299	0.879
7	Perceived benefits of climate-resilient practices	2.367	0.726
8	Community and social networks	2.290	0.847
9	Climate change perception and knowledge	2.264	0.769
10	Perceived urgency and attitude towards climate action	2.367	0.795

SCV : Scale content validity, CA : Cronbach's Alpha

The analysis revealed (Fig 18.11) several key socio-economic factors influencing farmers' willingness to invest in carbon farming practices. Notably, years of farming experience positively correlated ($p<0.05$) with investment willingness, suggesting that experienced farmers could better understand the long-term agricultural benefits and the potential returns from carbon credit initiatives. Similarly, landholding size and each additional acre of operational land increased the probability of willingness to invest. This indicates that large farmers, who might anticipate greater cumulative returns from carbon credits, were inclined more to invest in carbon farming.

In contrast, age was negatively associated ($p<0.05$) with investment decisions, and annual household income showed an inverse relationship. This counterintuitive finding suggested that wealthier farmers have diversified income sources and are less dependent on the marginal benefits offered by carbon initiatives (Table 18.11).

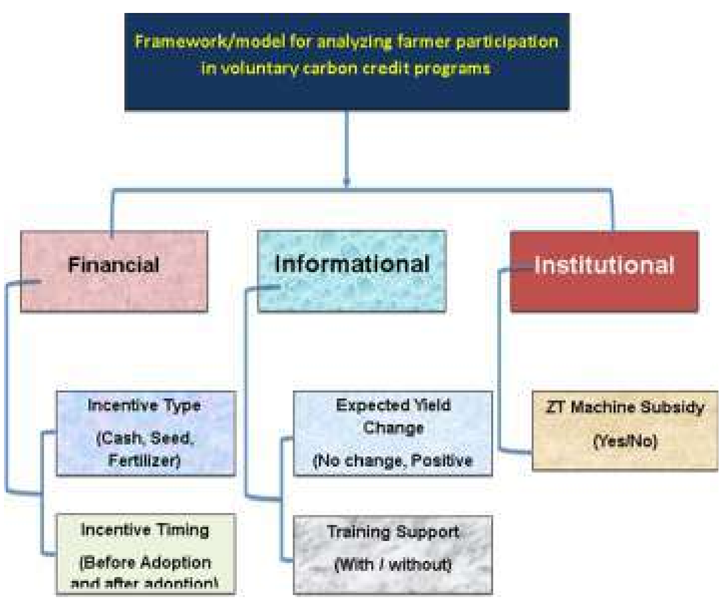

Fig 18.10 Model for analyzing the willingness of farmers' participation in voluntary carbon credit programmes

This study aimed to understand farmers' preferences for various support mechanisms offered under carbon credit programmes promoting ZT and other eligible carbon farming practices. Among the financial supports, incentive timing emerged as the most influential factor. In terms of informational support, both expected yield improvements and training support had significant effects. This underlines the importance of knowledge dissemination, practical demonstrations and hands-on training as part of any carbon credit initiative. Additionally, the preference for incentive type (cash vs. inputs) was highly heterogeneous, with the average coefficient being slightly negative. This implied that a one-size-fits-all approach would not work; farmers value choice, and programmes should ideally offer flexible incentive options aligned with individual preferences.

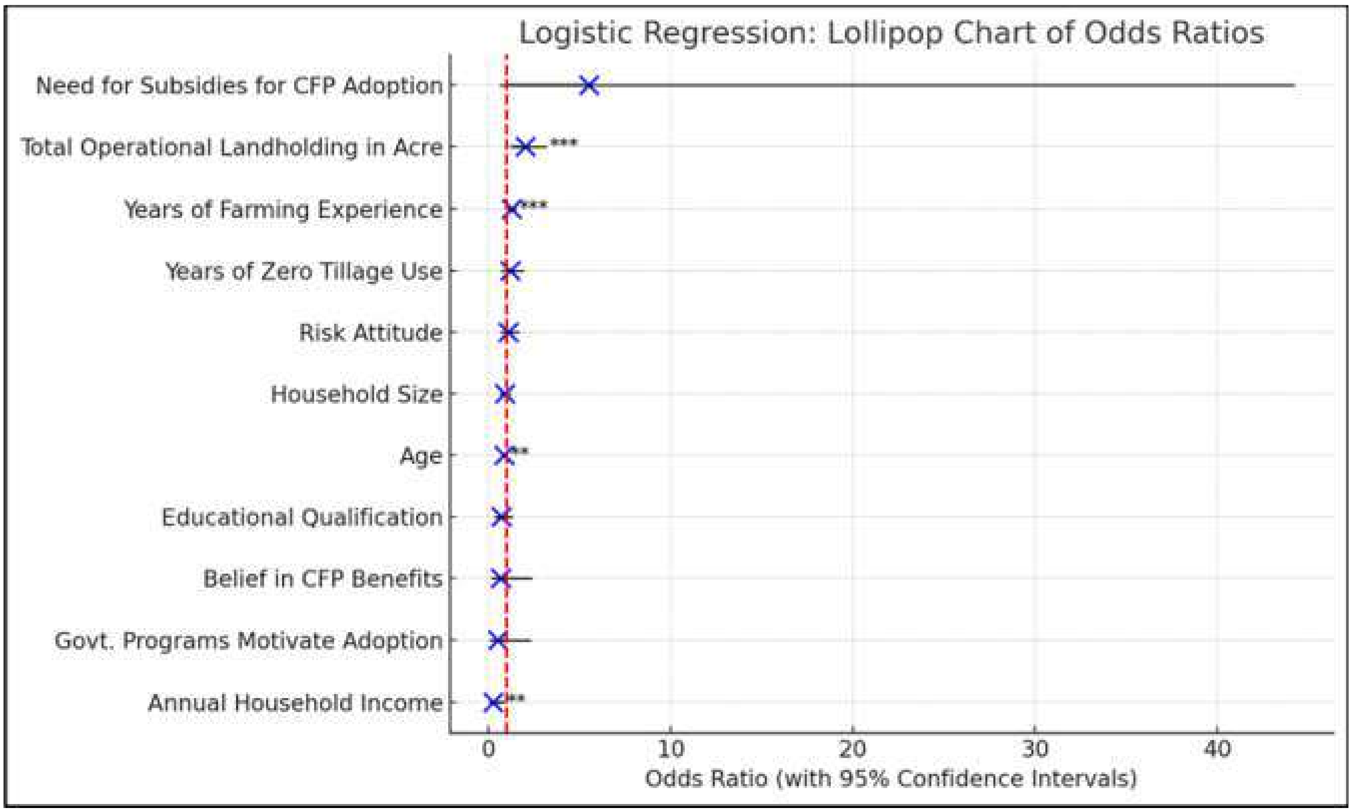

Fig 18.11 Key predictors influencing farmers' willingness to invest in carbon farming initiatives

Table 18.11 Factors influencing the willingness to invest in carbon farming practices

Variable	Significance	Interpretation
Age	$p < 0.05$	Older farmers are less likely to invest in carbon reduction
Farming experience	$p < 0.01$	More experienced farmers are more likely to invest
Annual household income	$p < 0.05$	Higher-income farmers are less likely to invest
Operational landholding	$p < 0.01$	Larger landholders are more likely to invest

Performance evaluation of aromatic rice germplasm in flood-prone regions of eastern India

A survey was conducted to identify and assess the performance of rice germplasm in flood-affected areas of eastern India during 2021-2023. The survey was carried out in four districts (Darbhanga and Madhubani in Bihar and Lakhimpur and Dhemaji in Assam), and a total of twenty-four aromatic rice germplasms were collected. These were grown at the main farm during 2023-2024. Data on morphological and yield characteristics, such as plant height, panicle length, panicle number, days to flowering and grain yield (t/ha), were recorded. The data were subjected to statistical analyses. The results indicated a significant positive correlation ($p < 0.05$) between panicle length and both plant height and days to flowering. In addition to this, grain yield also exhibited a significant positive correlation with plant height. Among the studied germplasms, 'Tulsiphul-2' exhibited the longest days to flowering (156.33 ± 5.50 days), followed by 'Katarni' (155.66 ± 6.65 days), while 'Marchadhan' took least number of days (135 ± 0.53 days) to flower. 'Kamod' recorded the tallest plant height (158 ± 3.23 cm), whereas 'Bhoga Joha' had the shortest (122.73 ± 2.60 cm) stature. 'Marchadhan' had the longest panicle length (29.93 ± 0.46 cm), while 'Katarni' had the shortest (23.86 ± 0.41 cm) panicle. In terms of grain yield, 'Satlakha Local' recorded the highest yield (2.65 ± 0.34 t/ha), while 'Goalporia Joha' was the lowest yielder (0.82 ± 0.04 t/ha). The 24 genotypes were grouped into two clusters; ten formed one cluster, while 14 were in the second cluster (Fig 18.12). The PCA biplot (Fig 18.13) revealed that plant height (PH), panicle length (PL) and grain yield (GY) dominated the first principal component, while days to flowering (DF) and panicle number (PN) dominated the second principal component. These two components together explained 57.39% of the data variability. Based on the results, 'Satlakha Local', 'Kanakjeera' and 'Kamod' emerged as the three most preferred germplasms for this region. After deposition, ICAR-NBPGR, New Delhi assigned unique IC numbers to all the 24 collections.

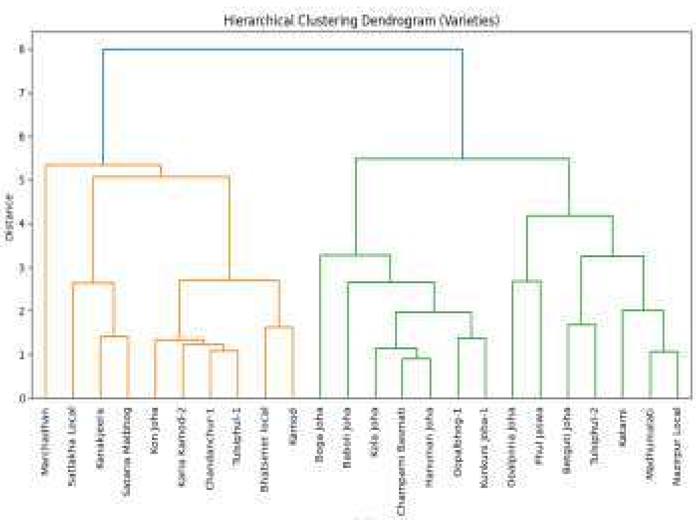

Fig 1812 Clustering of twenty-four selected aromatic rice germplasms in the eastern region

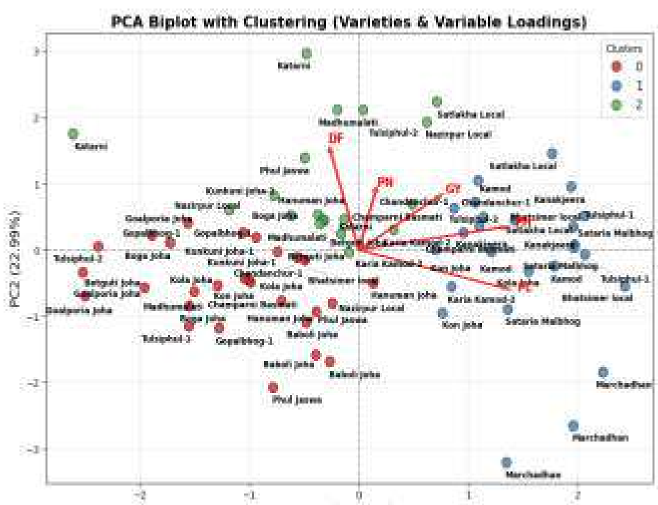

Fig18.13 PCA biplot analysis of aromatic rice germplasm in the eastern region

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

A dynamic factor analysis (DFA) model was developed to assess the common trend in total food grain production in the eastern states of India. Annual time series data on total food grain production (in '000' MT) for the period 2000 to 2023 were collected from the published source (Ministry of Agriculture and Farmers Welfare, Govt of India). The highest average food production was observed in WB [16,921.16 ± 1,630.26 ('000' MT)], while the lowest was in Jharkhand [3,693.38 ± 1,876.6 ('000' MT)] (Table 18.12). The best-fitted DFA model for the multivariate time series data was selected based on the minimum Akaike Information Criterion (AIC) values. The model with the parameters Q = "unconstrained", R = "diagonal and unequal", and a common trend (m = 2) was found to have the minimum AIC value of 328.65, making it the most suitable model for the food production data in the eastern states. Two common trends (Trend 1 and Trend 2) were observed across the seven states (Fig 18.14). Assam and Bihar were strongly associated with *Trend 1*, while states of Chhattisgarh, eastern UP, Jharkhand, Odisha and WB were found associated with *Trend 2* (Fig 18.15). Hence, all the seven states of the region could be grouped into two based on the growth in total food production.

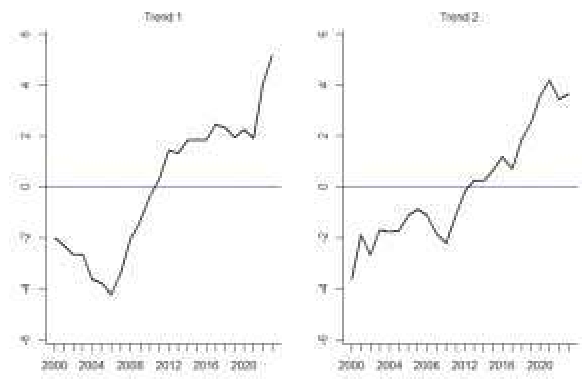

Fig 18.14 Two common trends of food production in the eastern states identified by DFA model during 2000 to 2023

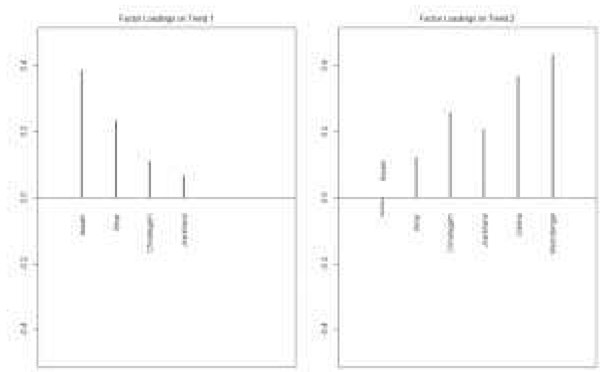

Fig 18.15 Factor loadings on two trends of food production in the eastern states identified by DFA model during 2000 to 2023

Indicators for assessing FPO sustainability

A Google form was developed and shared with 100 experts to gather their responses on a five-point scale regarding the relevance of various indicators and sub-indicators for assessing FPO sustainability. Based on expert feedback, 11 key sustainability indicators were finalized. Sub-indicators with a mean score above 4.12 were also selected. The finalized indicators and sub-indicators are presented in Table 18.13.

Table 18.12 Total food grain production ('000' MT) statistics in the eastern region of India

States	Assam	Bihar	Chhattisgarh	Jharkhand	Odisha	Eastern UP	West Bengal
Avg	4702.23	13409.88	6821.64	3693.38	7727.86	15907.55	16921.16
Std	825.87	3233.20	1925.26	1234.34	1440.52	2228.80	1630.26
Min	3060.0	7704.42	2901.3	1876.6	3573.7	12612.1	13815
Max	6259.4	21200.76	10893	6001.3	10125.2	20095.18	20307.56

Table 18.13 Indicators and sub-indicators of sustainability of FPO

S. No.	Indicators of sustainability of FPOs	No. of selected sub-indicators (score > 4.192)
1	Objectives of FPO	3
2	Participation in FPO	3
3	Coverage/size of FPO	3
4	Resilience (flexibility) in FPO	3
5	Compliance in FPO	6
6	Economic performance of FPO	8
7	Social benefits from FPO	3
8	Psychological benefits from FPO	3
9	Technical competence in FPO	4
10	Effectiveness of services provided by FPOs	5
11	Linkages developed by FPO	4

Table 18.14 Barriers in sustainability of FPO perceived by BOD members in Jharkhand (N=45)

Category of barrier	Barriers	Garret mean score	Rank
Technical	Less knowledge about how to strengthen FPO	60.96	5
	Less availability of appropriate technology	58.40	6
Infrastructure	Less facility of storage of produce	64.87	1
	Lack of processing facility	63.76	2
Financial	Members not willing to pay for FPO	63.02	3
	Government contribution not sufficient to promote FPO	57.91	8
Governance	Limited number of active members of BOD	61.89	4
	Lack of proper coordination in collective work	57.00	9
Input Supply	Longer time in getting license for selling inputs	58.09	7
	Sudden rise in demand of inputs on the onset of monsoon	53.62	10

Barriers to sustainability of FPOs in Jharkhand: Perceptions from FPO board members

Barriers affecting the sustainability of FPOs in Jharkhand, as perceived by members of *board of directors* (BOD), were identified, scored and categorized (Table 18.14). Technical barriers related to the adoption of technology, while infrastructural barriers covered gaps in storage and processing facilities. Financial barriers included issues around funding, capital and insurance. Governance-related barriers involved operational inefficiencies, poor coordination and limited participation. Input supply barriers stemmed from challenges in delivery, licensing, price surges and costly dealership structures.

Impact of interventions under farmer FIRST programme

The interventions carried out under the *Farmer FIRST Programme* (FFP) demonstrated a significant impact across multiple domains of farming. These included the crop-based module, horticulture-based module, animal husbandry-based module, enterprise-based module and farming system-based module. Each module was strategically designed to address local needs, enhance resource use efficiency and improve livelihoods. The following section presents the outcomes and tangible benefits realized by farmers through these targeted interventions.

Crop based module

Demonstration of climate resilient paddy varieties (Swarn Shreya, Swarn Unnat, Swarn Samridhi, Swarn Purvi-1, 2 &3, Swarn Shushak, and Swarn Sukha Dhan) were introduced in the FFP villages. Demonstrations were conducted on 105 farmers' fields, covering a total area of 26.60 ha. The average recorded yield was 41.11 q/ha in the demonstration plot, compared to 25 q/ha in the control plot. The average net income in the demonstration (demo) plots and farmers' practice was Rs 0.46 lakh/ha and Rs 0.09 lakh/ha, respectively.

Horticulture based module

Rainy season cultivation of tomato using bacterial wilt-resistant F1 hybrid 'Swarna Sampada' was demonstrated on 48 farmers' fields covering 2.88 ha area. The average yield achieved was 38.85 t/ha, significantly higher than 15 t/ha from traditional varieties. This resulted in a substantial net profit of Rs 7.32 lakh/ha for participating farmers, compared to only Rs 0.12 lakh/ha in control plots. Demonstrations on improved leguminous vegetables were conducted across several locations. Pencil bean variety 'HAFB 7' was grown in 55 farmers' fields over 0.48

ha, yielding 1.26 t/ha *vs.* 0.9 t/ha in traditional practices, with a net income of Rs 1.47 lakh/ha compared to Rs 0.98 lakh/ha. Cowpea variety 'Swarna Mukut', introduced as a diversification option to rainfed paddy, was demonstrated in 66 fields over 0.15 ha and recorded an average yield of 4.5 t/ha. Soybean variety 'Swarn Vasundhra' was demonstrated in 13 fields (0.0053 ha), yielding 3.84 t/ha in demo plots and 2.9 t/ha in control, with corresponding net incomes of Rs 1.09 lakh/ha and Rs 0.03 lakh/ha. Lima bean variety 'Swarn Poshan', demonstrated in 16 fields over 0.03 ha, produced 1.70 t/ha in demo plots (vs. 1.0 t/ha in control), with net income of Rs 3.8 lakh/ha (vs. Rs 0.053 lakh/ha). Dolicus bean variety 'HADB-32' was taken up in 26 fields over 0.65 ha, yielding 8.95 t/ha in demo and 4.8 t/ha in control plots, with a net income of Rs 1.15 lakh/ha and Rs 0.76 lakh/ha, respectively. Brinjal variety 'Swarn Shyamali' was demonstrated in 43 fields (2.8 ha), producing 51.81 t/ha compared to 15 t/ha in traditional plots, with a net profit of Rs 0.26 lakh/ha against Rs 0.12 lakh/ha. Potato varieties 'Kufri Lalit', 'Kufri Neelkanth' and 'Kufri Himalini' were demonstrated in 127 fields (2.57 ha), with yields of 27.65, 29.36, and 24.96 t/ha, and net incomes of Rs 4.78, 976 and 1.19 lakh/ha, respectively. 'Kufri Himalini' that showed 6-10 tubers/plant was appreciated for its yield, taste, color and size.

Animal based module

To improve the genetic potential of the pig population, seven T×D breeding boars were introduced into pig units in the adopted villages during 2024-25. Farmers using T×D boars reported 8–9 piglets per litter, with a net income of Rs 40,000 from 8 animals. In contrast, traditional breeding with local boars resulted in only 2-4 piglets per litter and a net income of Rs 10,000 from 2 animals. In addition, 325 kg of area-specific chelated mineral mixture was provided to 98 cows and 45 buffaloes (@ 50 g/day), and to 227 pigs, 396 goats, 470 poultry birds and 425 ducks (@ 5-10 g/day). The supplementation addressed region-specific mineral deficiencies in Jharkhand soils, which often led to imbalanced nutrition through local fodder. As a result, the average milk yield in cattle increased from 1.9 to 2.4 l/day, leading to a rise in net income from Rs 9,500 to Rs 13,900 per lactation. In goats, the average daily body weight gain improved from 39.23 g to 42.13 g, enhancing the net income per goat from Rs 10,800 to Rs 16,200.

Enterprise based module

To promote entrepreneurship in the adopted villages, capacity-building programmes on mushroom cultivation were organized. Following the training, 26 farmers initiated mushroom farming (Table 18.15), preparing a total of 1,150 bags (Fig 18.16, 18.17 and 18.18). This activity generated an additional net income of Rs 1.60 lakh in the project villages. Similarly, vermicomposting was encouraged through technology demonstrations using 14 vermibeds across 12 farmers' fields. Each vermibed (4.0 m × 2.0 m × 1.0 m) produced an average of 1,253 kg of vermicompost per batch, with three batches annually. Though the compost was used entirely on-farm, the activity resulted in potential savings of Rs 0.24 lakh/year/farmer, considering the market price of Rs 12 per kg for organic manure.

Fig 18.16 Harvested Oyster mushroom

Fig 18.17 Badi making from Oyster mushroom

Fig 18.18 Vermicomposting unit

Table 18.15 Performance of oyster mushroom production

Number of Demo units	Number of mushroom bags	Farmers benefitted	Quantity produced (kg)	Expenditure incurred (Rs)	Selling price (Rs/ kg)	Gross income (Rs.)	Net income (Rs)	B:C Ratio
26	1150	26	1125	42944	180	202500	159556	4.72

Farming system based module

To maximize land use and enhance farm income, multiple interventions were undertaken under natural resource management, homestead development and integrated farming modules. To address the issue of open grazing post-paddy harvest, galvanised iron fencing nets were installed in a group approach. This not only curtailed stray animal entry, but also enabled group farming and technology demonstrations. High-yielding varieties of wheat (DBW-187), bottle gourd (Swarna Sneha) and Arhar (IPA-203) were cultivated on 5.94 ha of previously fallow land (Table 18.16). In demonstration plots, wheat yielded 2.35 t/ha, and bottle gourd produced 17.04 t/ha, significantly boosting farm incomes and promoting productive *Rabi/Zaid* season cropping.

To enhance nutritional security at the household level, homestead gardens were promoted. A total of 246 saplings of improved varieties of mango (Amrapali, Malda, Langra and Mallika), litchi (Shahi and China), guava (L-49 and Allahabad Safeda) and papaya (Red Lady) were distributed among 15 farmers. Building on the region's existing agricultural practices, IFS was promoted to enhance profitability and sustainability. Based on survey findings, the IFS model combining field crops + vegetables + dairy + goat + poultry + mushroom was identified as the most promising. This model was demonstrated on 2.31 ha across 4 farmers' fields. The net annual income from this system reached Rs 3.07 lakh/ha, in contrast to Rs 0.60 lakh/ha from the more commonly practiced system (field crops + horticulture + vegetables + goat + backyard poultry), indicating the strong economic potential of well-integrated IFS model.

Agri-business incubation

Under the ABI Project, four entrepreneurs were admitted for incubation in 2024 (Table 18.17), focusing on innovations in nursery production, organic fertilizer development and herbal tea value addition across Jharkhand and Bihar.

Table 18.16 Performance of demonstrations under NRM based module

Technology demonstrated (Crop- variety)	No. of demo conducted	Area under demo (ha)	Yield (q/ha)			Economics of demos (Rs/ha)			
			Demo	Control	% Increase	Gross cost	Gross return	Net return	B:C Ratio
Wheat (DBW-187)	11	1.41	23.51	17.0	38.33	22182	51134	28951	2.31
Arhar (IPA-203)	17	0.54	20.11	17.21	16.85	47808	98363	50555	2.06
Gram (GNG-2144)	7	0.30	18.75	16.8	11.61	30887	40771	9884	1.32
Bottle gourd (Swarna Sneha)	10	0.09	409.19	121.56	236.46	219398	889781	670383	4.06

Table 18.17 Details of the programmes organized under ABI project

S. No.	Name of programme	Duration/date	No. of participants	Type of participants
1	Participation of entrepreneurs in a three days' training programme "ABIGROW 2.0" organized by ICAR NAARM, Hyderabad	Jan 22-24, 2024	5	Incubatees
2	Industry Meet - 2024: Bridging the gap between Industry and Institute	Sep 24, 2024	150	ABI Incubatee/ entrepreneur/ scientist
3	ABI incubatee mentorship programme	Dec 12, 2024	40	ABI Incubatee/ mentor/scientist

ABI incubatee mentorship programme

The ABI incubatee mentorship programme on "Mushroom Production and Processing" was organized at FSRCHPR, Ranchi in hybrid mode on December 12, 2024 (Fig 18.19). Seven incubatees from Jharkhand and Bihar participated in discussions on agribusiness incubation, entrepreneurship and technology adoption. Experts provided insights into conservation agriculture, nursery production, organic fertilizers and ITK-based health formulations. Incubatees were also guided on value chain management, legal compliance, licensing and financial planning for startups. The programme also highlighted the potential of value addition in wild fruits and local plants, encouraging entrepreneurs to explore opportunities in rural agribusiness. While interacting with incubatees, the advisory committee members and mentors highlighted the challenges in agri-business, and provided necessary guidance to incubatees.

Fig 18.19 ABI incubatee mentorship programme at FSRCHPR, Ranchi

IP management and technology commercialization

Registration of varieties with PPV and FRA

Table 18.18 lists 11 plant varieties registered under the *Protection of Plant Varieties and Farmers' Rights Authority* (PPV & FRA) along with their registration details.

Sequence Submitted to NCBI

Table 18.19 lists five sequence submissions to NCBI including mitochondrial, milk somatic cell and microbial sequences from mallard, buffalo, hybrid cattle, litchi stink bug and fall armyworm along with their publication details.

Table 18.18 Varieties registered with PPV&FRA during 2024

Registration no.	Name of plant variety	Submission date	Application granted/ registered** (annual fee submitted on)
REG/2019/134	Swarna Sneha (bottle gourd)	Aug 02, 2022	Feb 26, 2024
REG/2019/130	Swarna Yamini (bitter gourd)	Aug 02, 2022	Feb 26, 2024
REG2013/1094	Swarna Vijaya (tomato)	Dec 04, 2018	Jun 28, 2024
REG/2019/135	Swarna Sawani (ridge gourd)	Oct 18, 2019	Jul 04, 2024
REG/2018/597	Swarna Safal (faba bean)	Jul 04, 2018	Jul 04, 2024
REG/2012/107	Swarna Mani (brinjal)	May 22, 2014	Jul 05, 2024
REG/2012/108	Swarna Pratibha (brinjal)	May 22, 2014	Jul 05, 2024
REG/2012/109	Swarna Shyamli(brinjal)	Sep 07, 2019	Jul 05, 2024
REG/2012/384	Swarna Lalima (tomato)	Apr 27, 2015	Jul 05, 2024
REG/2012/385	Swarna Sampada (tomato)	Sep 07, 2019	Jul 05, 2024
REG/2014/2131	Swarna Mukti (fieldpea)	Oct 30, 2014	Jul 05, 2024

Table 18.19 Sequence submissions to NCBI and publication details

S. No.	Accession No.	Sequence
1.	OQ561754-OQ561760	Mitochondrial sequence of *Anas platyrhynchos* (mallard)
2.	PRJNA980004	Gut associated bacterial population in different developmental stage of litchi stink bug (*Tessaratoma javanica*)
3.	PRJNA979959	Microbial community of C-strain of *Spodoptera frugiperda*
4.	PQ031225	*Bacillus cereus* strain RCER G05 16S ribosomal RNA gene (partial sequence)
5.	PQ037632	*Bacillus thuringiensis* strain RCER G06 16S ribosomal RNA gene (partial sequence)
6.	PQ044599	*Pseudomonas* Sp. strain RCER G09 16S ribosomal RNA gene (partial sequence)
7.	PQ037636	*Psychrobacter alimentarius* strain RCER G07 16S ribosomal RNA gene (partial sequence)
8.	PQ044597	*Staphylococcus* Sp. strain RCER G08 16S ribosomal RNA gene (partial sequence)
9.	PQ008724	*Staphylococcus hominis* strain RCER 804 16S ribosomal RNA gene (partial sequence)
10.	PQ008725	*Bacillus thuringiensis* strain RCER 843 16S ribosomal RNA gene (partial sequence)
11.	PQ044601	*Klebsiella aerogenes* strain RCER G10 16S ribosomal RNA gene (partial sequence)
12.	PQ008594	*Staphylococcus* strain G01 759 16S ribosomal RNA gene (partial sequence)
13.	PQ008625	*Bacillus* (in: firmicutes) strain G02 759 16S ribosomal RNA gene (partial sequence)
14.	PQ044602	*Klebsiella aerogenes* strain RCER G11 16S ribosomal RNA gene
15.	PRJNA1080298	Milk somatic cell sequence of *Bubalus bubalis*
16.	PRJNA 1080306	Milk somatic cell sequence of *Bos indicus x Bos taurus* (hybrid cattle)

Memorandum of understanding signed

Table 18.20 lists 15 memorandums of understanding (MoUs) signed for technology transfer in agriculture, covering grafted tomato production, multi-tier cropping, planting material propagation and fruit fly traps. It includes details of contracting parties, signing dates and revenue earned through licensing fees and royalties.

Table 18.20 Details of MoU for commercialization of technologies

S. No.	Name of technology/ know-how	Name of contracting party	Date on which MoU signed	Revenue earned (in Rs)
1.	Large scale production of the grafted tomato plants on bacterial wilt resistant root stock of brinjal	Agri-ntrepreneur Growth Foundation, Pune	Mar 11, 2024	Technology license fee of Rs 10,000 + 2% royalty on sale of grafted plants for 10 years
2.	Large scale production of the grafted tomato plants on bacterial wilt resistant root stock of brinjal	Jivanmarshal Fed Farmer Producer Company Limited, Chakai Jamui, Bihar	Sep 24, 2024	Technology license fee of Rs 10,000 + 2% royalty on sale of grafted plants for 10 years
3.	Large scale promotion and scaling–up the technology of multi-tier cropping system for rainfed uplands through its network	Bhartiya Lok Kalyan Sansthan, Chutia Ranchi	Sep 24, 2024	Technology license fee of Rs 20,000+2% royalty per annum for 10 years
4.	Large scale planting material production of the peach variety 'Florda Prince'	Phal Udyog Nursery, Tatisilwai, Ranchi	Sep 24, 2024	Technology license fee of Rs 50,000+2% royalty per annum for 10 years
5.	Large scale planting material production of the peach variety 'Florda Prince'	Green Garden Enterprises, Ormanjhi, Ranchi	Sep 24, 2024	Technology license fee of Rs 50,000 + 2% royalty per annum for 10 years
6.	Large scale planting material production of the Bael variety 'Swarna Vasudha'	Green Garden Enterprises, Ormanjhi, Ranchi	Sep 24, 2024	Technology license fee of Rs 100,000+2% royalty per annum for 10 years
7.	Large scale planting material production of the peach variety 'Florda Prince'	Green Garden Landscape and Horticulture Pvt. Ltd, Angarha, Ranchi	Sep 24, 2024	Technology license fee of Rs 50,000 + 2% royalty per annum for 10 years
8.	Large scale planting material production of the Litchi variety 'Swarna Madhu'	Green Garden Enterprises, Ormanjhi, Ranchi	Sep 24, 2024	Technology license fee of Rs 100,000 +2% royalty per annum for 10 years
9.	Large scale promotion and scaling-up the technology of Multitier cropping system for rainfed uplands through its network	Maharashtra Prabodhan Seva Mandal, Nasik Maharashtra	Sep24, 2024	Technology license fee of Rs 20,000 + 2% royalty per annum for 10 years
10.	Large scale planting material production of the Bael variety 'Swarna Vasudha'	Phal Udyog Nursery, Tatisilwai, Ranchi	Sep 24, 2024	Technology license fee of Rs 100,000 + 2% royalty per annum for 10 years
11.	Large scale planting material production of the Litchi variety 'Swarna Madhu'	Phal Udyog Nursery, Tatisilwai, Ranchi	Sep 24, 2024	Technology license fee of Rs 100,000 + 2% royalty per annum for 10 years
12.	Mixed *para-pheromone fruit fly traps* for horticultural crops	Aditya Agro Crop Care, Ranchi	Oct 30, 2024	Technology license fee of Rs 1, 00,000 + 2% royalty per annum for 10 years
13.	Multi-tier cropping system for rainfed uplands of eastern India	Transforming Rural India Foundation, Ranchi	Oct 28, 2024	Technology license fee of Rs 1, 00,000 + 2% royalty per annum for 10 years.
14.	Multi-tier cropping system for rainfed uplands of Eastern India	Professional Assistance for Development Action	Oct 28, 2024	Technology license fee of Rs 1, 00,000 + 2% royalty per annum for 10 years.
15.	MoU for management education and research for the benefit of agriculture	YBN University Ranchi, Jharkhand	Sep 05, 2024	Rs 10,000 for 3-month duration, Rs 20,000 for 3-month duration (dissertation) and Rs 30,000 for 6-month duration (based on ICAR Norms)

Other collaborations

Other collaborations for technology commercialization are listed in Table 18.21, 18.22 and 18.23.

Table 18.21 Material Transfer Agreement

S. No.	Name of technology/ know-how	Name of contracting party	Date of Licensing
1.	*Swarna Sheetal* and *Swarna Ageti* (cucumber)	Baba Bhimrao Ambedkar University, Lucknow	July 09, 2024

Table 18.22 International collaborations

Research area	Collaborating institute/organization
Development of solar irrigation pump sizing tool	International Water Management Institute, New Delhi
UAV-based crop water stress assessment	University of Southern Queensland, Australia

Table 18.23 Other collaborations

Research area	Collaborating institute/organization
Impact evaluation of watershed development projects	National Bank for Agriculture and Rural Development, Ranchi
FPOs, IFS model, interspecific grafting, organic fruit systems and jackfruit value addition, exploring underutilized crops	Rashtriya Krishi Vikas Yojna, Govt of Jharkhand
Technology demonstrations on farmers' fields	Non-Governmental Organizations
Project activities/ trainings/ demonstrations under SCSP, RKVY, etc	Krishi Vigyan Kendras
Standardization of cultivation practices for custard apple	National Horticulture Mission, Government of Jharkhand
Honey testing	National Bee Board, Ministry of Agriculture &Farmers Welfare, Govt of India

Network project on conservation of lac insect genetic resources

A survey for the availability of natural occurrence of lac insect and their host plants was carried out in 55 blocks across seven districts of eastern UP, namely,_Deoria, Kushinagar, Maharajganj, Ballia, Ghazipur, Gorakhpur and Basti. Lac insects were observed in five blocks (under three districts) on its natural hosts: *Ficus rumphii* in Deoria Sadar (Deoria) and *Ficus religiosa* in Pharenda (Maharajganj) and in Basti, Gaur and Bahadurpur (Basti).

Participatory lac cultivation has been implemented in Hirmoti and Samukhia (Banka), Bengalgarh (Chandan) and Salayia (Katoriya) villages of Banka district. About 150 kg of brood lac was harvested from 38 palas (*Butea monosperma*) and 5 ber (*Ziziphus mauritiana*) trees in Hirmoti village from *Baishakhi* crop during July 2024. This entire 150 kg of brood lac was inoculated onto around 200 palas trees across all four sites in July 2024 to raise *Katki* 2024 crop, which yielded around 340 kg of brood lac during November 2024. In the first week of November 2024, entire 340 kg of brood lac was inoculated onto 230 palas trees and 2 ber trees across all four sites to raise the *Baisakhi* crop (2024-25). The initial settlement density was found to be satisfactory.

19 Krishi Vigyan Kendra

There are two Krishi Vigyan Kendras (KVKs) under the administrative control of ICAR RCER, Patna. These KVKs, one each at Buxar (Bihar) and Ramgarh (Jharkhand), play a crucial role in translating scientific research into practical applications by providing location-specific training, conducting FLDs and promoting modern agricultural technologies to farmers, extension workers and rural youth. Details of their activities and achievements are given below separately.

KRISHI VIGYAN KENDRA, BUXAR

Training programme for practicing farmers

The KVK organized a total of 68 training programmes for practicing farmers of the Buxar district, which aimed at upgrading their knowledge and skills in modern farming techniques. A total of 2,214 farmers (including 429 farmers from SC community) participated in these trainings, details of which are given below in Table 19.1.

Training programme for rural youth

Need-based seven training programmes were organized for skill enhancement to 265 rural youth (227 male and 38 female) of Buxar district to generate income and self-employment through local resources. The main objective of this training programme was to equip rural youth with short-term, skill-based training in agriculture and allied sector to enhance their employability and promote self-employment.

Training programme for extension functionaries

The KVK regularly conducted training programmes for the practicing farmers of Buxar district with the objective of enhancing their knowledge and skills in modern agricultural practices. These trainings were designed to help farmers achieve higher yields at low cost by adopting improved technologies suited to various farming conditions. During the reporting period, a total of 68 training programmes were organized, benefiting 2,214 farmers (including 429 farmers of SC community).

Technology assessment

On farm testing (OFT): The details are given in Table 19.2.

Table 19.1 Training programme for practicing farmers (*Discipline wise*)

S. No.	Domain	No. of participants						Grand total		
		Other			SC					
		M	F	T	M	F	T	M	F	T
1	Soil & water conservation	388	0	388	77	37	114	465	37	502
2	Plant protection	675	31	706	113	56	169	788	87	875
3	Plant breeding	1687	98	1785	273	156	429	1960	254	2214
	Grand total (A+B+C)	1687	98	1785	273	156	429	1960	254	2214

M: male, F: female, T: total, SC: scheduled caste

Table 19.2 Achievements on technologies assessed (On farm testing)

S. No.	Thematic areas	Title of the OFT	Technologies assessed under various crops (cereal crop production) No. of the technologies (Technology interventions)	No. of trials	No. of locations	Final recommendation
1.	Integrated nutrient management	Assessment of nano urea on yield and economics in rice crop	**TO1:** 50% of RDN & 100% PK + nano urea @4ml/l water (single spray at 35 DAS) **TO2:** 75% of RDN & 100% PK + 2 spray of nano urea at (35 DAS) and 45 DAS @ 4 ml/l water	01	10	Application of 75% of RDN & 100% P & K + 2 spray of nano urea at (35 DAS) and 45 DAS @ 4 ml/l water were found promising to increase no. of tiller/plant (19-27), and grain yield (51.50 qt/ha) with B-C ratio of 2.87 as compared to farmers practice.
2.	Integrated pest management	Manage-ment of brown plant hopper through insect growth regulator (IGR) and chemical insecticide.	**TO1:** IGR (Buprofezine) 25 SC @ 200 ml ai (800 ml ha) *fb* Buprofezin 22.0% + Fipronil 3% SC @ 110+15 ai (500 ml)/ha **TO2:** Chlorantraniliprole 0.50% + Thiamethoxam 01% w/w GR @ *ai* 30+60 (6 kg/ha)	01	10	Spray of Chlorantraniliprole 0.50 % + Thiamethoxam 01 % w/w GR @ ai 30+60 (6 kg/ha) was found better to control the BPH infestation and damage as well as infestation of rice stem borer at maturity stage with grain yield 52.8 q/ha with B-C ratio of 2.83 in comparison to farmers practice.
3.	Integrated disease management	Assess-ment of fungicides for the manage-ment of sheath blight of rice	**TO1:** Spray of Propiconazole 13.9% + Difenoconazole 13.9% EC @500 ml/ha **TO2:** Spray of Thifluzamide 24 SC @ 1 ml /l of water (45 days after transplanting)	01	10	Spray of Thifluzamide 24 SC @ 1 ml /l of water (45 days after transplanting) controlled the damage of sheath blight; found economical than other treatments with grain yield of 51.40 q/ha with B-C ratio of 2.77 as compared to farmers practice.
4.	Nutrient use efficiency	Assess-ment of nano urea on yield and economics in rice crop	**FP:** RDF (100:40:20)Kg/ha **T1:** 50% of RDN & 100% PK + nano urea @ 4ml/l water (single spray at 35 DAS) **T2:** 75% of RDN & 100% PK + 2 spray of nano urea at (35 DAS) and 45 DAS @ 4 ml/l water	01	10	Application of 75% of RDN & 100% PK + 2 spray of nano urea at (35 DAS) and 45 DAS @ 4 ml/l water in rice crop improved nitrogen use efficiency in rice-wheat cropping system and reduced the excess application of urea with grain yield of 51.80 q/ha & B-C ratio of 2.87.
			Total	4	40	

Achievements of frontline demonstrations

The KVK conducted 24 frontline demonstrations (FLDs) on cereal crops across 1,075 farmers' fields, covering an area of 436.8 ha. The primary objective was to showcase the potential of improved varieties along with advanced agronomic practices and technologies in rice, wheat, bajra and maize to enhance cereal production and productivity. As a result of these efforts in 2024, yield increases of 13.64% in cereals, 25.62% in oilseeds, and 11.56% in pulses were recorded. In horticultural crops, FLDs led to yield enhancements, ranging from 16.46% to 48.80%, indicating significant potential for improved practices.

In the oilseeds, the KVK conducted two FLDs on mustard and sesame, covering 50 ha area involving 85 farmers, with a focus on promoting the adoption of the improved variety 'Pusa Mustard 30' among the farmers of Buxar district. For pulses, five demonstrations on pigeonpea, lentil, chickpea, vegetable pea and moong bean were carried out on 135.6 ha, benefitting 285 farmers. Two demonstrations were conducted on okra and cow pea that led to production increase by 12.38 and 19.5 percents, respectively. Further details are mentioned in Table 19.3.

Cluster frontline demonstration (CFLD) on pulses and oilseeds

CFLD on pulses (funded under NFSM) and oilseeds (funded under National Mission on Oilseeds and Oil Palm) were conducted to promote the adoption of scientific management practices for pulses and oilseed crops among the farmers to enhance their productivity. The details are given in Table 19.4

Table 19.3 Details of FLDs conducted during the year 2024

S.No.	Crop category	No. of FLD	Area (ha)	No. of beneficiaries	Yield in Demo (q/ha)	Yield in check (q/ha)
1.	Cereals	14	436.8	1075	49.15	43.25
2.	Oilseeds	02	50	85	15.10	12.02
3.	Pulses	05	135.6	285	27.02	24.22
4.	Horticultural crops	02	2	36	141.5	121.5
5.	Livestock	01	60 Unit (20 chicks per unit)	60	125 eggs/annum	84 eggs/annum
	Grand total	24	624.4 ha + 60 Unit	1541	-	-

Table 19.4 Details of CFLD on pulses and oilseeds

S. No.	Crop season	Name of crop	Area (ha)	No. of farmers	Details of technology demonstrated	Details of existing farmer practice	Yield (q/ha) at farmer's field	Yield obtained in demonstration (q/ha)		
								Max	Min	Mean
1	Rabi (23-24)	Mustard	60	196	Line sowing of Var. PM -30 with seed treatment	Broadcast untreated seed of Varuna	13.7	15.5	12.8	14.15
2	Rabi (23-24)	Lentil	20	62	Line sowing of Var. IPL 220 with seed treatment	Broadcast ing, no seed treatment	10.50	13.80	11.20	13.10
			80	248	-	-	-	-	-	-

Extension and training activities under FLD programme

1. Organized field days on popularization of mustard var. PM 30 among 100 farmers at Pawani village in the Buxar district to promote HYV of mustard for higher production in timely sown.
2. Conducted a training on INM, and organized a field day on ZT wheat at Jamuaon village in Block Itarhi in district Buxar among 103 farmers.
3. Conducted a training programme on IPM in chickpea crop among 30 farmers, and organized a field day among 100 farmers on ZT chickpea at Churamanpur village in Buxar district to increase cropping intensity and soil health improvement through inclusion of pulses in rice wheat cropping system.

Seed production at KVK farm

The KVK produced 234.4 quintals of quality seed of cereals (rice & wheat) and oilseed (mustard) crops as per the need of the district farmers, and provided these seeds to 3322 farmers of the district including 374 and 75 farmers, respectively from SC and ST community. The KVK also produced 500 quality slip/sapling of hybrid Napier for year-round green fodder availability for dairy cattle, and provided them to over 55 farmers.

Production of planting materials

The KVK produced 22550 planting materials of vegetable and fruits crop, and provided these to 614 farmers (including 136 SC and 20 ST farmers) of the district to popularize new high yielding varieties of vegetables and fruits.

Extension/outreach activities

The KVK organized various kinds of 1641 extension activities among 9843 farmers including 8107 males and 1336 females of the district 'Buxar' to create awareness, information on modern agriculture welfare Govt. scheme, and popularize crop varieties released by Honorable PM Govt. of India to showcase the agriculture technologies, celebration of various days pertaining to farmers welfare.

Entrepreneurship/startup support

The KVK facilitated Mr Manoj Kumar Singh to found *Vishwamitra Honey* at his native village 'Rasen'. Registered under FSSAI (Lic. No. 20421041000003), the enterprise engages in honey processing using both micro and macro filtration techniques. Currently, the enterprise involves 25 members, and generates an annual income of 15-17 lakh. The KVK has provided training, exposure visits and marketing platforms *via* FPOs; this resulted in significant growth of his enterprise. Mr Manoj, who was previously unemployed and economically weak, is now a recognized entrepreneur with elevated social status. Presently, the enterprise operates with over 500 beehives, processing 15-17 tonnes of honey annually under the brand *Vishwamitra Honey*.

Out-scaling of natural farming

Under the out-scaling of natural farming initiative in Bihar, the KVK has been actively promoting sustainable agricultural practices across rice-wheat, rice-chickpea, rice-lentil and maize - potato cropping systems. A total of six activities, comprising 3 training programs, 2 demonstrations and 1 awareness campaign, were conducted. These efforts engaged 249 participants including 43 females. The details are given in Table 19.5.

Fig 19.1 Vishwamitra honey

Table 19.5 Training and demonstration for out-scaling of natural farming initiative in Bihar

Name of activity	No. of activities organized	No. of participants	Participants (Male)						Participants (Female)		Total
			Gen	OBC	SC	ST	Others	Total	Gen	OBC	
Training	03	137	101	-	1	-	-	101	29	-	29
Demons-tration	02	12	12	-	-	-	-	12	-	-	-
Awareness	01	100	36	42	15	0	0	93	-	7	7
Total	06	249	149	42	15	-	-	206	29	7	36

OBC: other backward caste, Gen: General category, SC: scheduled caste, ST: scheduled tribe

Visit of dignitaries/ team/ committee to the KVK Buxar

Dr SK Chaudhari

Dr SK Chaudhari, Deputy Director General (Natural Resource Management) visited the KVK along with Dr Anup Das, Director, ICAR RCER Patna, on January 20, 2024. The visit included a field inspection of NICRA project activities at the adopted village Kukurah. Dr Chaudhari reviewed ongoing demonstrations, viz., water harvesting structures, weed management, water-saving through mulching, zero tillage, paddy straw incorporation and integrated backyard poultry and goatery, aimed at enhancing livelihood security for marginal and underprivileged women farmers. Dr Chaudhari interacted with all the subject matter specialists and KVK staff, and provided useful suggestions.

Dr SK Chaudhari inaugurated the implement shed at KVK Buxar (Fig 19.2) constructed under the CRA Programme in the presence of Director, ICAR RCER Patna. He also visited key demonstration sites including the Long-Term Cropping System Experimental Plot, Natural Farming Seed Hub, and solar-based irrigation systems. Dr Chaudhari chaired the Farmers-Scientists Interaction-cum-Exhibition on "Climate Resilient Agriculture Technologies & Natural Farming" and distributed power sprayers to SC farmers under the SCSP scheme. Dr Anup Das commended KVK Buxar's efforts and highlighted the importance of water-use efficiency through "Per Drop More Crop" and the use of drone technology for chemical applications.

Visit of QRT Team

A quinquennial review team (QRT), comprising the chairman, Prof SK Chakraborty (former Vice Chancellor, UBKV, Cooch Behar, WB), members (Dr AK Patra and Dr S Rayzada) and member secretary (Dr Kamal Sharma), visited KVK Buxar to assess its progress over the past five years (Fig 19.3) . The team reviewed various initiatives including the IFS model, custom hiring centre, CRA Programme, long-term cropping system demonstration, seed hub and processing unit. They also visited the CRA-adopted village Dalsagar, and interacted with farmers like Jitendra Kushwaha and Smt Usha Devi, who showcased raised bed maize intercropped with coriander, zero tillage wheat, chickpea and lentil. The team appreciated the KVK's efforts in crop residue management through straw balers, laser land leveling and farmer capacity building through trainings and exposure visits.

Fig 19.2 Dr SK Chaudhari inaugurating implement shed and distributing inputs to SC farmers

Fig 19.3 Glimpses of QRT team visit at KVK Buxar

Participation in Viksit Bharat Sankalp Yatra

KVK Buxar played an active role in the Viksit Bharat Sankalp Yatra (VBSY) across Buxar district, reaching over 100 panchayats through extensive outreach efforts aimed at raising awareness and ensuring the saturation of various Government of India welfare schemes. Covering all the 142 panchayats of the district, the Yatra successfully disseminated information on key government initiatives even in the most remote areas. As part of the campaign, several on-the-spot services were offered, including Krishak Vaigyanik Vartalap, diagnostic services, PM Ujjwala Yojana enrolment, MY Bharat volunteer registration and distribution of Ayushman Bharat cards. The Yatra witnessed enthusiastic participation from farmers and citizens, who actively engaged with various government schemes, and were encouraged to exercise their rights and avail the benefits entitled to them.

Vocational training programme on "mushroom production"

The KVK organized three training programmes on "mushroom production: A source of income generation" each for two days in SC dominated villages, *viz*., Nathpur, Hukaha and Gurudas Mathia under the district 'Buxar' to create awareness on nutritional security and income generation through cultivation of oyster mushroom. The participants were provided skill training and input support to start mushroom cultivation to enable them to take it in their regular diet. There were 104 participants including 16 males.

Fig 19.4 Glimpses of Viksit Bharat SankalpYatra

Organization of Kisan Mela

The KVK organized a two days Kissan Mela during March 12-13, 2024 with a theme of "Integrated Farming System: A source of self-employment" for making awareness and showcasing the benefits of IFS for small and marginal farmers especially belonging to SC community of the district. The Kissan Mela was inaugurated by Dr Anup Das, Director, ICAR RCER Patna as a chief guest. A total of 355 comprising 167 male and 188 female including 280 SC farmers participated in the KissanMela.

Field day on ZT wheat and chickpea under CRA Programme

A field day on ZT wheat (Var. HD 2967) and chickpea (var. GNG 2299) was organized at Churamanpur village of block 'Buxar' to create awareness among farmers on resource conservation technology for sustainable agriculture. There were 23 male and 4 female participants in the field day.

Exposure visit of school students

The KVK facilitated exposure visits of 78 students of Cambridge Senior Secondary School, Buxar and 37 students of DAV Public school, Buxar at KVK Farm Buxar, respectively on 14.05.2024 and 25.01.2024. The KVK showed live demonstration of drone technology and its application in agriculture. The student visited various agri demonstration units, *viz*., IFS model, custom hiring centre, seed processing unit, demonstration of mini sprinkler at long term experimental plot of CRAP, various farm machinery, apiculture unit, and the like, and interacted with the scientist/SMS of the KVK regarding agricultural education, career in agriculture and allied sector and the job opportunity.

Fig 19.5 Exposure visit of school students

Live telecasting of PM-Kisan Samman Nidhi Programme

The KVK organized live telecasting of 16th and 17th installments of PM-Kisan Samman Nidhi released programme at KVK Buxar on 28th of February, 2024 and 18th of June, 2024, respectively. A kisan goshthi programme on the occasion of release of 16th installment release of PM-Kisan Samman Nidhi was also organized in the auspicious presence of Shri Ashwini Kumar Choubey, Hon'ble MoS (Govt of India), to make awareness on summer season crops, which was participated by over 200 farmers.

Fig 19.6 Live telecasting of PM-Kisan Samman Nidhi Programme

KRISHI VIGYAN KENDRA RAMGARH

With a strong commitment towards farming community, KVK Ramgarh actively implements a wide range of field-level initiatives designed to transfer cutting-edge agricultural knowledge and technologies directly to farmers' fields. Key interventions include OFTs, FLDs, cluster frontline demonstrations (CFLDs), skill-enhancing training programs, exposure visits, and the like. Through these dynamic efforts, the KVK equips farmers with the practical skills and scientific insights needed to boost productivity, embrace sustainable practices and enhance income generation. By bridging the gap between research and rural application, the KVK has become a catalyst for transformation enabling farmers to overcome local challenges and make measurable strides in their agricultural ventures. From raising crop yields through improved agronomic practices to fostering eco-friendly farming systems, it continues to make a profound and lasting impact on rural livelihoods. A brief snapshot of the centre's achievements is provided below.

On-farm trials

1.Assessment of organic inputs for papaya cultivation

Problem diagnosed	Low fruit yield due to poor nutrient management.
Final recommendation at micro level situation	Apply 2 kg vermicompost (VC), Ghanjeeva amrit and liquid formulation of non-edible oil cake (500g/plant in 5 split drenching applications). This integrated organic nutrient management approach enhances soil fertility, boosts plant vigor and significantly improves fruit yield and quality in papaya, offering a sustainable alternative to chemical inputs (Fig 19.7).

Fig 19.7 Papaya cultivation

2. Assessment of biomass mulching in mango

Problem diagnosed	Low fruit yield due to poor floor/surface and nutrient management in mango.
Final recommendation at micro level situation	Biomass mulching with *Tephrosia* @ 1 kg dry biomass/m² canopy spread for better moisture conservation, nutrient management, and enhanced yield with improved profitability (Fig 19.8).

Fig 19.8 Biomass mulching with Tephrosia in mango

3. ***Effects of rubber mat flooring on subclinical mastitis in crossbred cows***

Problem diagnosed	Mastitis, lameness, more standing time, lower body condition score and low milk yield
Final recommendation at micro level situation	Concrete flooring with rubber mat recommended for crossbred cows under semi-intensive systems to reduce subclinical mastitis. This practice significantly lowers somatic cell count, improves milk yield, reduces lameness and enhances overall animal comfort. It is more effective than traditional kuccha or plain concrete flooring. Suitable for small and marginal farmers aiming to improve herd health and productivity (Fig. 19.9)

Fig 19.9 Flooring with rubber mat

4. Effect of shelter management on lactating crossbred cows during summer

Problem diagnosed	Painting, low DM intake, reduced milk yield especially in summer season.
Final recommendation at micro level situation	For small/marginal farmers with limited investment capacity, six-inch paddy straw bedding with bamboo structure over asbestos roofing recommended as an effective, low-cost summer shelter management practice to improve milk yield and cow comfort.

5. ***Assessing effectiveness of extension methods for dissemination of commercial Cauliflower vegetable production technologies***

Problem diagnosed	Low cost effective approach of extension methods.
Final recommendation at micro level situation	Group contact method (demonstration, lecture, participatory discussion/training with same content related to cauliflower production technology) appeared as the most effective extension method in the district as per farmers as well as extension personnel perceptions.

Front line demonstrations: Details are given in the Table 19.6.

Table 19.6. Details of FLDs conducted and their coverage

S. No.	Crop	Name of the technology demonstrated	No. of farmers	Area (ha)	Yield (q/ha)		% increase
					Demo	Check	
1	Rice	Medium duration and drought tolerant variety 'IR64 drt 1'	125	30	42.25	36.40	16.07
2		Medium duration and drought tolerant variety 'CR Dhan 320'	95	25	52.60	38.65	36.10
3		Medium duration and Drought tolerance Cv. Swarna Samridhi Dhan	62	20	53.92	45.07	19.63
4		Medium duration and drought tolerant variety 'Swarna Sukha Dhan'	15	5	44.2	38.30	15.4
5	Finger millet	'BBM 10'	55	10	15.30	12.44	22.10
6	Wheat	'DBW 222'	12	5	--	--	--
7	Wheat	'DBW 187'	12	5	--	--	--
8	Chickpea	'Birsa Chana-3'	--	10	12.46	10.20	22.15
9	Bottle gourd	Powdery mildew and downey mildew tolerant variety 'Swarna Sneha'	35	05	208.20	169.70	23.00
10	Brinjal	Bacterial wilt resistant variety 'Swarna Shyamali'	40	05	438.00	351.00	24.78
11	Tomato	Bacterial wilt resistant variety 'Swarna Sampada'	35	05	620.50	535.30	15.88
12	Sweet potato	'Shree Bhadra'	10	2	265.32	183.33	44.72
13	Chilli	'Swarna Praphulya'	20	2	--	--	--
14	Cowpea	Bush type variety 'Swarna Mukut'	20	2	100.00	84.00	15.00
15	Bitter gourd	'Swarna Yamini'	15	2	194.00	171.00	13.45
16	Sponge gourd	Early flowering and fruiting variety 'Swarna Sawani'	20	2	164.00	142.00	15.49
17	Ridge gourd	'Swarna Manjari'	15	2	156.00	138.00	13.04
18	Vegetable pea	'HAEP-2'	10	2	96.40	76.20	26.51
19	Faba bean	'Swarna Safal'	20	5	180.00	150.00	20.0
20	Poultry	'Kadak Nath'	25	500	1.4 kg	1.1 kg	27.27
					96 eggs	61 eggs	57.37
21	Poultry	'Sonali'	75	1500	2.81 kg	1.2 kg	134.16
					175 eggs	60 eggs	191.66
22	Duckery	'Khakhi Campbell'	25	500	178 Eggs	65 eggs	173.84

Details of CFLDs on pulses and oilseeds crop under NFSM and NMOOP: Details are given in the Table 19.7

Table 19.7 Details of CFLDs on pulses and oilseeds

S. No.	Crop	Technology	Area (ha)	No of beneficiaries			Village covered
				Male	Female	Total	
01	Lentil	Pusa Ageti 4717 + seed treatment + foliar spray of NPK 19:19:19 + need based insecticide	20	41	48	89	*Chitarpur, Sondeeha, Jamsingh, Budhakhap & Vyang*
02	Chickpea	KPG 59 + seed treatment with Rhizobium + foliar spray of NPK 19:19:19 + need based insecticide	20	41	22	63	*Vyang, Kudrukhurd, Gargali, Uchringa & Bongasuri*
03	Pigeonpea	IPA 203 + seed treatment with Rhizobium + foliar spray of NPK 19:19:19 + need based insecticide	50	112	196	308	*Jobla, Udlu, Pandatad, Tilaiya, Arabasti & Chotkachumba*
04	Mustard	BBM1 + seed treatment + foliar spray of NPK 19:19:19 + need based insecticide	40	46	54	100	*Sondiha, Chitarpur, Jamsingh, Galgali & Budhakhap*
05	Linseed	Priyem + seed treatment + foliar spray of NPK 19:19:19 + need based insecticide	20	51	37	88	*Sondeeha, Jamsingh, Gargali, Jatratand & Budhakhap*
06	Groundnut	K1812 + timely sowing + line sowing(30 cm ×10 cm) + seed rate @ 27kg/demo + seed treatment with Beeja amrit @250 ml/l + interculture opration two times with cycle hoe weeder 20-25 DAS and 35-45 DAS + INM, IPM (Dashparni) @25-30ml/l and Indoxacarb 15.8 EC@ 0.5ml/l	60	103	89	192	*Sarlakhurd, Chatak, Budhakhap, Lodhma, Sandi & Tilaiya*
07	Sesame	Variety 'GT-6' + line sowing + spacing 30 cm ×10 cm + seed rate @1.5 kg/ demo/ 0.25ha + seed treatment through Beeja amrit @100 ml/kg seed	40	69	77	146	*Lodhama, Sandi, Tilaiya, Budhakhap, Patratu, Kodi & Sangrampur*
		Total	250	585	411	986	

Fig 19.10 Performance of different oilseed and pulses crop under CFLD

Training programme and extension activities

Table 19.8 Details of the training programme organized by KVK Ramgarh

S. No.	Type of training	No. of trainings	No. of Beneficiaries		
			Male	Female	Total
1.	Training programme for practicing farmers	90	1613	2113	3726
2.	training programme for rural youth	23	329	286	615
3.	training programme for extension functionaries	27	402	461	863
	Total	140	2344	2860	5204


Fig 19.11 Glimpses of training programme for practicing farmers

Table 19.9 Details of extension activities organized by KVK Ramgarh

Nature of Extension Activity	No. of activities	Total		
		M	F	Total
Kisan Mela organized	01	235	368	603
Kisan Mela participated	04	1610	3369	4979
Field Day	08	125	244	379
Krishak Choupal	01	27	34	61
Kisan Ghosthi	10	350	429	779
Workshop	03	292	411	703
Group discussion	12	73	93	166
Lectures delivered as resource persons	11	125	148	273
Advisory Services	62	321	405	726
Scientific visit to farmer's field	56	311	382	693
Farmers' visit to KVK	-	477	790	1267
Diagnostic visits	22	35	78	113
Exposure visits	04	82	78	160
Animal health camp	03	65	83	148

Table 19.10 Interaction/Live telecast programme of Hon'ble PM

S. No.	Date of event	Name of event/programme	Participants			
			Farmers	Staffs	VIP/Others	Total
1	28.02.2024	PM Live telecast	210	4	1	21
2	18.06.2024	PM Live telecast	106	3	-	109
3	11.08.2024	PM Live telecast	34	7	3	44
4	05.10.2024	PM Live telecast	40	4	-	40

Training and awareness programmes during Viksit Bharat Sankalp Yatra

KVK Ramgarh played a pivotal role in the Viksit Bharat Sankalp Yatra organised across the Ramgarh district from December 5, 2023 to January 12, 2024. The Yatra successfully covered all panchayats of the district, ensuring inclusive outreach and engagement with the farming community. During the campaign, 60 training programmes and 65 awareness sessions were organised, emphasizing the key agricultural themes such as: soil health management and soil sampling techniques, natural and organic farming practices, nutritional gardening for household food security, millet production and its role in nutrition and climate resilience and use of drone technology in modern agriculture. These sessions were designed to enhance the knowledge and skills of farmers, farm women, rural youth, extension personnel, stakeholders, and officials aligning with the broader goal of sustainable agricultural development.

Fig 19.12 Interaction during Viksit Bharat Sankalp Yatra

Farmer fair *cum* farmer scientist interaction and agricultural exhibition

Fig 19.13 Glimpses of farmer fair *cum* farmer scientist interaction

On January 27, 2024 KVK Ramgarh in collaboration with NABARD, organised a farmer fair *cum* farmer scientist interaction and agricultural exhibition. The event began with the ICAR song and a ceremonial lamp lighting by Mr Jaiprakash Bhai Patel, Hon'ble MLA of Mandu, and Mr Subhash Chandra Garg, Regional DGM of NABARD. Mr Jayant Sinha, Hon'ble MP of Hazaribagh, graced the occasion virtually as the Chief Guest. The event witnessed participation of over 550 farmers, including members of FPO governing bodies. Additionally, 50 Scheduled Caste and Scheduled Tribe farmers were provided with small agricultural tools.

Live telecast of PM Samman Nidhi

KVK Ramgarh organized live telecasts of the PM-Kisan Samman Nidhi on February 28 and June 18, 2024, during which Hon'ble PM Shri Narendra Modi addressed and interacted with farmers nationwide. In conjunction with the telecasts, farmer-scientist interaction programmes were held, focusing on key topics such as rice fallow cultivation of pulses and oilseeds, Integrated Farming Systems (IFS), Integrated Nutrient Management (INM), and nursery management of horticultural crops. The event on February 28, witnessed participation from 80 farmers, while the session on June 18 was attended by 130 participants.

Fig 19.14 Glimpses of live telecast of PM Samman Nidhi

Green Initiative: Plantation Drive at KVK Ramgarh

In a vibrant initiative to promote sustainable agriculture and environmental conservation, Hon'ble MLA of Mandu, Mr Jaiprakash Bhai Patel, inaugurated a plantation drive at the premises of

Fig 19.15 Plantation Drive at KVK Ramgarh

Krishi Vigyan Kendra, Ramgarh. His visit also marked the inauguration of the Farmer Fair cum Farmer-Scientist Interaction and Agricultural Exhibition. During the event, Mr Patel encouraged farmers to embrace innovative seeds, modern agricultural technologies, and natural farming practices to boost productivity while preserving ecological balance. The plantation drive symbolized a collective step towards a greener future, reflecting the integration of environmental responsibility within agricultural progress.

Certificate course on INM

The KVK organised a fifteen-day certificate course on INM from February 29 to March 11, 2024. The training aimed to enhance the knowledge of 40 input dealers and rural youth on sustainable nutrient management practices. Inaugurated virtually by Dr Anup Das, Director of ICAR-RCER, Patna, the programme highlighted the importance of technology in boosting agricultural productivity and farmer income. Participants were trained in efficient fertilizer usage, bio-fertilizer application, soil health management, and quality control of bio-fertilizers. The significance of micro-nutrients in improving crop yield and soil fertility was also emphasized. This training equipped participants with practical knowledge and skills, enabling them to promote sustainable agriculture.

Visit of Director General and Secretary, DARE

The Director General of ICAR and Secretary of DARE, Dr Himanshu Pathak accompanied by the Directors of ICAR-NISA, ICAR-IIAB, and other dignitaries, visited KVK Ramgarh. He commended the KVK team for their impactful initiatives in promoting sustainable agriculture and supporting farmer welfare. During the visit, he toured various demonstration units showcasing practical agricultural models and technologies. He offered

Fig 19.16 Dr Himanshu Pathak addressing farmers

insightful suggestions to further improve the effectiveness of these units for the benefit of local farmers. The Director General also interacted with farmers undergoing training in the IFS, encouraging them to adopt diversified farming approaches for better resilience and income generation.

Training programmes on IFS

The KVK organized two three-day skill development training programmes on IFS under its extension initiative 'PRAYAS', supported by ICAR-IIAB, Ranchi. The first training, held from February 28 to March 1, 2024, targeted Scheduled Caste (SC) farmers under the Scheduled Caste Sub-Plan. A total of 35 participants, primarily women from Udlu village, received both theoretical and practical training on IFS models such as agro-forestry, agro-

Fig 19.17 Glimpses of training programmes on IFS

horticulture, and livestock-based systems to promote sustainable livelihoods. The second programme, organized from March 4-6, 2024, focused on tribal farmers from Lodhma village under the Tribal Sub-Plan. Around 30 participants were trained in seedling production, pig and goat farming, and basic marketing techniques. These initiatives aimed to empower marginalized communities through knowledge and skill-building in modern agriculture.

Exposure visits of tribal farmers

On March 13, 2024, fifty tribal farmers participated in an exposure visit to FSRCHPR and BAU, Ranchi, under the Tribal Sub-Plan (TSP), aimed at enhancing their understanding of modern agricultural practices. At BAU, Kanke, the farmers visited piggery and goatery units and attended a session on commercial pig farming, gaining insights into improved livestock management techniques. At FSRCHPR, they explored innovative technologies such as drip irrigation, poly mulching,

Fig 19.18 Exposure visit of tribal farmers

multi-tier orchards, and protected vegetable cultivation-methods particularly beneficial for optimizing resources in rainfed areas. The farmers also had interactive sessions with the Director of ICAR-RCER, Patna, the Head of FSRCHPR, and subject experts, who motivated them to adopt integrated farming systems for higher productivity and income. These visits offered practical exposure to scientific approaches and empowered tribal farmers with the knowledge and confidence to implement sustainable, resource-efficient farming methods, contributing to livelihood improvement and agricultural resilience in their communities.

Farmers awareness programme cum animal health camp

On March 18, 2024, KVK Ramgarh, conducted a farmers' awareness programme *cum* animal health camp at Udlu village under the Scheduled Caste

Sub-Plan. The event aimed to promote advanced agricultural and livestock management practices like mulching, drip irrigation, vaccination importance, and prevention of common animal diseases. Subject experts shared practical knowledge to help farmers improve productivity and animal health. The programme witnessed active participation from over 200 farmers, with a significant number of women attendees, highlighting the vital role of women in agriculture. Through demonstrations and discussions, participants gained valuable insights into sustainable farming techniques and scientific livestock care.

Fig 19.19 Farmers awareness programme *cum* animal health camp

Exposure visit of Scheduled Caste (SC) farmers

On March 19, 2024, an exposure visit was organized for 40 Scheduled Caste (SC) farmers under the Scheduled Caste Sub Plan (SCSP) to ICAR-RCER, Patna. The objective was to upgrade their knowledge and skills in modern agriculture and animal husbandry practices. During the visit, farmers explored various facilities, including the IFS, goat, dairy, duck, and poultry units, fish hatchery, nutri garden, and seed production sites. This hands-on exposure provided valuable insights into efficient and sustainable farming techniques. A major highlight was the farmer-scientist interaction session, chaired by Dr Anup Das, Director of ICAR-

Fig 19.20 Farmers visiting experimental field at RCER Patna camp

RCER, Patna, which focused on the role of poultry, duckery, goatery, and integrated crop systems in enhancing income and resilience. To support dairy farmers, milk cans were distributed during the valedictory session. The programme aimed to empower SC farmers with practical knowledge and tools for improved livelihoods.

Pre *Kharif* workshop

A one-day pre *Kharif* workshop was organized on May 6, 2024, in the presence of Dr KD Kokate, Chairman of the Research Advisory Committee (RAC), ICAR-RCER, Patna, and Dr Anup Das, Director of ICAR, Patna, along with other dignitaries. Dr Sudhanshu Shekhar, Head of KVK, welcomed the guests and shared insights into the ongoing initiatives aimed at farmer welfare. Two technical bulletins authored by KVK were released during the inauguration. The guests visited research plots and plantations, offering valuable feedback on the innovative systems observed. Dr Kokate interacted with farmers from various villages and encouraged them to adopt scientific farming practices. Dr Das recommended the Dobha technique for drip irrigation and water harvesting. The workshop emphasized cost-effective agriculture and income enhancement. Progressive farmers like Hari Mahato and Sunita Devi actively participated. Later, Dr Kokate and Dr Das visited

Armadag and Kodi villages in Patratu block, where they observed seedling production and an innovative intercropping model of watermelon in mango orchards. Impressed by KVK's grassroots efforts, Dr Kokate offered practical suggestions and praised the center's role in promoting sustainable agriculture and empowering the local farming community.

Farmers scientist interaction

A farmer scientist interaction under the Scheduled Caste Sub Plan was held at KVK. The event was inaugurated by Dr SK Chakraborty, Chairman of the QRT, Patna, alongside other distinguished guests. The programme featured the release of three

Fig 19.21 Glimpses of pre *Kharif* workshop

technical bulletins authored by KVK. The review team inspected various units, including technology demonstrations, intensive horticulture, and animal husbandry units, while reviewing KVK's achievements from 2018 to 2023. Dr Sudhanshu Shekhar, Head of KVK, highlighted the center's work in agriculture and related fields. The review team praised KVK's efforts and stressed extending agricultural techniques to more farmers. Progressive farmers shared their experiences, including Baleshwar Mehta, who discussed year-round cauliflower cultivation. Experts emphasized fingerling production, organic farming, and strategic marketing. The event also featured the

Fig 19.22 Glimpses of farmer scientist interaction

planting of fruit trees and the distribution of sewing machines to women farmers and battery-operated sprayers to SC farmers.

Ek Ped Maa Ke Naam (Plant # 4 # Mother)

KVK Ramgarh organized a special plantation drive under the theme "Ek Ped Maa Ke Naam", honoring motherhood and promoting environmental conservation. As part of this meaningful initiative, 2000 mango saplings were planted across multiple locations, including the KVK campus at Udalu and Lodma village. The programme aimed to create awareness about tree plantation, ecological balance, and the importance of dedicating trees to our mothers as a symbol of gratitude and love. Local farmers, women, youth, and community leaders actively participated, making the event a heartfelt and sustainable tribute to motherhood.

Fig 19.23 Plantation drive under "Ek Ped Maa Ke Naam"

Rabi workshop

On November 24, 2024, KVK organised a *Rabi* workshop, aiming to promote sustainable agriculture and enhance farmers' incomes through integrated approaches. Dr Anup Das, Director ICAR RCER, emphasized the adoption of the IFS to ensure resource optimization and income diversification. He advocated for the use of organic manure and chemical fertilizers based on Soil Health Card recommendations to maintain soil health. He also encouraged farmers to adopt allied activities such as goat rearing, poultry, tailoring, and tractor-based services to create additional income opportunities. Highlighting conservation practices, Dr Bikas Das advised on minimal tillage, zero tillage machinery, drip irrigation, and rainwater harvesting to boost productivity sustainably. Dr Das stressed on enhancing income through value chain development, especially by cultivating high-value crops like sweet corn, broccoli, jackfruit, mango, pomegranate, and mahua. He also recommended using wastelands for planting gooseberry, tamarind, and bamboo, and selecting crops based on soil type. Dr Vishal Nath discussed the potential of growing off-season vegetables using limited resources and shared insights on forming farmer organizations and marketing techniques to secure better prices.

Fig 19.24 Dignitaries during *Rabi* workshop

RAWE programme

The Rural Agricultural Work Experience (RAWE) programme was conducted at KVK Ramgarh for BSc Agriculture students. This programme emphasized practical exposure in areas such as organic/natural farming, INM/IPM, Integrated Farming Systems, and protected vegetable cultivation. Students engaged in field activities like PRA, poultry, duck, and goat farming, along with hands-on training in nursery management, fruit tree pruning, canopy management, and soil sampling. A strong focus was placed on market-led extension and value chain management. The programme significantly enhanced the students' practical skills, scientific understanding, and preparedness for professional roles in agriculture.

Fig 19.25 Students engaged in field experiment

Drone demonstration

A drone demonstration was held on September 6, 2024 at Udalu village, showcasing advanced agricultural technology in rice cultivation. Farmers and scientists gathered to witness how drones can enhance farming practices, particularly in pest control, and precise pesticide and micronutrient spraying. The demonstration highlighted the efficiency of drones in reducing labor, saving time, and ensuring optimal use of resources. Participants expressed enthusiasm about adopting this technology to boost productivity and sustainability in rice farming. The event concluded with a Q&A session, where experts addressed farmers' queries and emphasized the importance of integrating technology into traditional farming methods.

Animal health and vaccination camp under Scheduled Tribes (ST) and Schedule Cast Sub Plan scheme (SCSP)

The KVK organized two impactful livestock health programmes under the Scheduled Tribes and SCSP scheme to improve animal well-being and promote scientific farming practices. on 22 July 2024, a similar PPR vaccination camp in Udalu village benefited another 500 goats and raised awareness on disease

Fig 19.26 Farmers and scientists during drone demonstration

prevention and livestock management. More than 55 farmers, including women, actively participated in these camps, reflecting growing awareness and enthusiasm. These efforts significantly contributed to improving animal health, enhancing farmer knowledge, and supporting sustainable rural livelihoods in Ramgarh. A kisan seminar *cum* Animal Health and Vaccination Camp was held on 26 July 2024 in Lodhama village, Ramgarh block, where over 500 goats were vaccinated against Peste des Petits Ruminants (PPR) a highly contagious viral disease. Medicines including dewormers, antibiotics, mineral mixtures, and vitamin supplements were also distributed. KVK Head Dr

Fig 19.27 Glimpses of animal health and vaccination camp

Sudhanshu Shekhar addressed farmers on the importance of timely vaccination, deworming, and rearing practices for advanced cattle breeds, pigs, and poultry. Napier grass plants were distributed to promote sustainable fodder cultivation using pond resources.

Promotion of direct seeding of rice for climate-resilient farming

KVK Ramgarh organized a Field Day in Lodhma village to promote climate-resilient farming practices, with a special focus on Direct Seeding of Rice (DSR). The event saw the participation of key agricultural scientists, including Dr NP Mandal, Head of the Central Rainfed Upland Rice Research Station, Hazaribagh, as chief guest, and experts Dr Amresh Chandel and Sarvesh Shukla from the International Rice Research Institute (IRRI), Varanasi. Dr Mandal emphasized the urgent need for climate-smart agriculture, encouraging farmers to adopt DSR using Zero Tillage Technology as a sustainable alternative to traditional transplanting methods. He highlighted how this approach can reduce water dependency and labour costs while increasing resilience to erratic rainfall. Dr Chandel explained effective weed management in DSR systems. Dr Shekhar highlighted that early harvesting through DSR creates opportunities for farmers to grow *Rabi* crops like pulses, oilseeds, and lentils, thereby boosting productivity and soil fertility. The event included a visit to farmer Sangeeta Devi's field, where participants observed the successful cultivation of Swarn Shreya and CR Dhan 320 varieties under DSR, showcasing the practical benefits of this innovative technique.

Schedule Caste Sub Plan (SCSP)

The Schedule Caste Sub Plan (SCSP), implemented by KVK Ramgarh, has significantly uplifted the socio-economic status of Scheduled Caste (SC) farmers in Udlu village through sustainable agriculture and integrated livelihood initiatives.

Fig 19.28 Glimpses of field day

The programme focused on enhancing productivity, income, and food security using scientific interventions and climate-resilient farming practices. Over 425 farmers benefited from 14 capacity-building programmes covering integrated farming systems, soil health, water conservation, and livestock-based livelihoods such as piggery, poultry, and goat farming. Women farmers were actively engaged, ensuring inclusive participation and empowerment. To improve agricultural productivity, 386 farmers received quality inputs including high-yielding seeds, drought-resistant crop varieties, bio-fertilizers, vegetable seedlings, and small farm tools. These inputs, coupled with training in organic practices and modern techniques, helped reduce drudgery and improve farm efficiency. Livelihood enhancement was further supported through the promotion of integrated farming models combining horticulture with livestock, benefitting 90 households. Interventions like rainwater harvesting, drip irrigation, and agroforestry improved soil moisture by 20%, reduced water dependency, and increased resilience to drought. A major highlight was the integrated pig-based intervention. By introducing improved crop varieties and piggery units, average annual household income rose from Rs 44,685 to Rs 1,34,000, a remarkable 199.87% increase. The initiative stands as a replicable model for empowering SC communities through targeted agricultural development.

Tribal Sub Plan (TSP)

The Tribal Sub Plan (TSP), effectively implemented by KVK Ramgarh in Lodma village, Jharkhand, has significantly contributed to the advancement of sustainable agriculture among tribal communities. The programme focused on enhancing farm productivity, improving livelihoods, and ensuring food security through targeted scientific interventions. A total of 20 capacity-building programmes were conducted, benefitting over 612 tribal farmers. These trainings covered critical areas such as climate-resilient agriculture, soil health management, and water conservation practices. To support these efforts, 386 farmers received high-yielding and drought-tolerant seeds, improved vegetable varieties, fruit saplings, and bio-fertilizers to boost crop yield and farm income. Techniques like rainwater harvesting, drip irrigation, mulching, and agroforestry helped improve soil moisture retention by 15%, contributing to better crop health and reduced dependency on erratic rainfall. One of the most notable outcomes of the TSP was its economic impact. The average net annual income of beneficiary families increased from Rs 42,648 to Rs 81,255 . A significant 90.52% rise following the introduction of improved crop varieties, fruit plants, poultry, and small farm tools. Overall, the TSP has empowered tribal farmers in Lodma village by fostering resilient and diversified farming systems. The initiative stands as a replicable model for holistic rural development in tribal-dominated regions.

Natural Farming

In 2024, KVK Ramgarh promoted natural farming practices in the district, marking a significant advancement in sustainable agriculture. The programme encompassed 18 awareness sessions engaging 2,500 participants and 14 training programmes with 1,422 participants, effectively enhancing farmers' knowledge and adoption of eco-friendly farming techniques. Additionally, KVK conducted 13 crop demonstrations on over 20 acres, featuring key crops such as Rice (Swarna Shreya and CR Dhan 320), Cowpea (Swarna Harita), Bottle gourd (Swarna Sneha), Sponge gourd (Swarna Prabha), Bitter gourd (Swarna Yamini), Ground nut (K 1812), Chili (Swarna Praphulya), Mustard (PM-30), Ridge gourd (Swarna Manjari), Pigeon pea (IPA-203), Niger (BN 1), Finger Millet (BBM 10) on more than 20 acre area. A field day in adopted villages attracted 62 participants, showcasing practical applications of natural farming. These efforts have been instrumental in equipping farmers with the skills and resources necessary for implementing sustainable agricultural practices, thereby fostering an environmentally conscious approach to farming in the district.

Fig 19.29 Glimpses of Natural farming demonstrations

District Agromet Advisory Services:

The release of 26 e-bilingual Agromet Advisory Bulletins by the District Agro-Meteorological Unit (DAMU), KVK-Ramgarh, under ICAR-RCER, Patna, has made a remarkable impact on agricultural outreach and decision-making across Ramgarh district. Leveraging ICT tools, these bulletins have effectively reached over 293 stakeholders and nearly 4350 progressive farmers, enhancing access to timely and region-specific agricultural guidance. Covering vital topics such as crop planning, harvesting techniques, agronomic practices and animal husbandry & poultry. The advisories have become a trusted source of actionable information. Their popularity stems from their local relevance, timeliness, and bilingual format, which ensures inclusivity across diverse linguistic groups in the district. These bulletins have empowered farmers to adopt climate-smart practices, improve resource efficiency, and make informed decisions aligned with changing weather patterns and seasonal requirements. The continued success of the Agromet Advisory service underscores KVK Ramgarh's commitment to innovative extension services, ensuring that scientific knowledge translates into practical benefits for farmers, contributing meaningfully to the region's agricultural growth and prosperity.

Fig 19.30 Farmers at the Agro-Meteorological Unit

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

The *Participatory Research Application for Year-round Income and Agricultural Sustainability* (PRAYAS) project, which focuses on year-round income and agricultural sustainability, has been implemented across seven eastern states (Bihar, West Bengal, Assam, Jharkhand, Chhattisgarh, Odisha and eastern Uttar Pradesh) of India. It has significantly contributed to enhancing of farm productivity, sustainability and rural livelihoods. The project adopted a participatory approach, combining capacity building, input support, demonstrations and infrastructural interventions, with a strong focus on SC and ST farmers. During the year, 41 training programs (36 short-term and 5 long-term) were organized, which benefited 1,724 farmers. In addition, 14 FLDs, 6 awareness camps and one on-farm trial (OFT) facilitated hands-on learning and exposure to climate-resilient and sustainable agricultural practices (Table 20.1). The program provided significant input support by distributing over 17 tonnes of seeds (covering cereals, pulses and vegetables), 8,290 fruit plants, more than 31,000 napier slips and mushroom spawn and bio-fertilizers to more than 2,500 farmers. Additionally, farmers were given poultry chicks, small livestock, animal feed, medicines and small to medium-scale farm equipment to diversify their income and enhance food and nutrition security. Infrastructure, such as nurseries, seed farms and irrigation support, was established along with promotion of IFS, nutri-gardens and natural farming practices across 156 sites. Veterinary services, artificial insemination and animal health camps were implemented to enhance livestock health and productivity. Through this integrated and inclusive approach, PRAYAS has strengthened the adaptive capacity of smallholder farmers, improved resource-use efficiency and laid the foundation for sustainable and climate-resilient agriculture across the vulnerable regions of Eastern India.

Table 20.1 Activities in and beneficiaries under PRAYAS

Activities	Unit	Qty	No. of beneficiaries
Training programs of 1 - 3 days duration	no.	36	1582
Training programs of 4 - 10 days duration	no.	5	142
On farm trials	no.	01	10
Front line and other demonstration	no.	14	44
Awareness camps/exposure	no.	06	465
Input distribution			
Seeds (paddy, sorghum, ragi, horse gram, maize and moong)	kg	11257	959
Seeds (okra/pea/Frencebean/soybean/tomato/ brinjal/chilli/sorghum fodder,etc	kg	3113.99	834
Seeds (root and tuber crops, bitter guard, pumpkin, bottle guard, cucumber, radish, vegetable seed kits comprising BAU-90, IIVR-100PKTS)	no.	444	401
Nursery plants (mango, lemon and guava)	no.	8290	552
Cutting slips, suckers etc, Napier slips	packets	31035	237
Mushroom spawns/ bio-fertilizers	Packets	700	275
Small animal (pig/sheep/goat)	no.	82	29

Poultry chicks/duckling	no.	3228	292
Small equipments (up to Rs 2000): spade/sickle/plastic mulching sheet/v ermin bed/irrigation delivery pipe/ pick-axe/ bucket and m ug	no.	1116	571
Medium equipments/machinery (up to R s 25000): battery operated sprayer, tarpaulins, pressure cooker, cow mat, power weeder and brush cutter	no.	574	580
Large equipments/machinery (More than Rs 25000)	no.	01	--
Infrastructure/ civil work/pond	no.	01	02
Establishment of plant nursery/seed farm/hatchery	no.	1	1
Land development/ reclamation/c onservation	ha	1	13
Micronutrients	kg	3	35
FYM/vermicompost	t	95	65
Plant protection chemicals	kg	7	60
Plant growth promoter	kg	--	--
Animal feed	t	46.35	271
Animal fodder	t	--	--
Animal medicines	doses	120	40
Any other (specify): tarpaulin (58), training kits (50), irrigation pipe, drying net	--	263	263
Animal health camps	no.	19	611
Artificial insemination/vaccination	no.	01	163
Veterinary services (hospitalization, on -site treatment, PD, surgery, etc)	no.	20	15
Promotion of agri -entrepreneurship	no.	3	22
Promotion of IFS, IOFS, natural farming, nutri -garden, kitchen garden, orchards , etc	no.	55	156
Distribution of literature	no.	1000	120
Any other (specify)/jute bag	no.	--	2000

21 Training and Capacity Building

The employees of ICAR RCER regularly undergo training and capacity-building programs to stay updated with the latest advancements and techniques in their respective fields. Below are the details of the employees who participated in training programs during the year 2024.

Table 21.1 Proportion of employees undergone training

Category	Total no. of employees	Number of trainings planned for each category during 2024-25	Number of employees who underwent training during Jan-Dec 2024	% Realization of the training planned
Scientist	59	15	14	93.33
Technical	45	12	10	83.33
Administrative and Finance	28	--	2	--
Skilled supporting staff	21	--	--	--
Total	**153**	**27**	**26**	**89.16 (WM)**

WM: Weighted mean

Table 21.2 HRD fund allocation and utilization (Rs in Lakh)

BE-2024-25 for HRD	Actual expenditure up to December 2024	% utilization
2.41	2.41	100.00

Training/exposure visit/workshop etc organized by ICAR RCER, Patna

- An exhibition-*cum*-demonstration of "Agri-drone technology" was organized during January 1-2, 2024 at Kharsawan, Saraikela, Jharkhand.
- A training-*cum*-demonstration programme on "Application of agro-chemicals in rabi crops through drone technology" was organised during January 8-12, 2024 in Buxar district under the Agri-drone project.
- A three-day farmers' training on "Scientific Cultivation of Rabi Crops for Improving Farm Productivity and Food Security" was organised during January 10-12, 2024.
- An awareness-*cum*-demonstration programme on "Application of agro-chemicals in rabi crops through drone technology" was organized during January 19-22, 2024 in Buxar and Varanasi districts under the Agri-drone project.
- An awareness-*cum*-demonstration of drone technology was organised at KVK Ramgarh on January 27, 2024 under the Agri-drone project.
- Two trainings on "Integrated Farming System for Livelihood Security of Farmers" were organized each on January 18, 2024 with 44 participants, and February 2, 2024 with 30 participants, both supported by ETC Hehal, Ranchi.
- Three trainings on "Modern Techniques of Fruits and Vegetable Cultivation" were organised during February 12-14, February 19-21, and February 26-28, 2024 with 25 participants in each and were sponsored by PRADAN, Khunti (Jharkhand).
- A "National Conclave on Sustainability -

Productivity and Green Growth" was organised on February 13, 2024 at ICAR-RCER, Patna.

- Two awareness-*cum*-demonstrations on "Application of agro-chemicals in rabi crops through drone technology" were organised each on during February 14-15 and February 24-25, 2024 in Nalanda and Sheikhpura districts under the Agri-drone project.
- One-day awareness-*cum*-farmers interaction programme for dissemination of agricultural technology was organized on February 25, 2024 at Mangratoli, Nuagaon, Sundargarh, Odisha.
- One-day training on "Production Technology of Oyster Mushroom" was organised on February 26, 2024 with 60 participants under AICRP on Mushroom.
- A training programme on "Improved Farming Technologies for Augmenting Livelihood" was held during February 29 - March 1, 2024 at KVK Buxar under Scheduled Caste Sub-Plan (SCSP).
- A training on "Improved Mushroom Production Technique" was organized during February 29 - March 1, 2024 with 25 participants, under AICRP on Mushroom.
- A training programme on "Integrated Farming System for Livelihood Security" for SC farmers of Odisha under SCSP fund was organized during February 29 - March 2, 2024.
- Three IFS training on "Integrated Farming Systems (IFS)" on February 28, February 29, and March 4, 2024 under SCSP, Jharkhand.
- An awareness-*cum*-demonstration programme on "Application of agro-chemicals in rabi crops through drone technology" was held during March 2-3, 2024 in villages of Mirzapur / Varanasi district of Eastern UP under the Agri-drone project.
- Three trainings on "Modern Techniques of Fruits and Vegetable Cultivation" were organised during March 3-6, March 11-13 and March 18-20, 2024 each with 25 participants, sponsored by PRADAN, Khunti (Jharkhand).
- A training programme on "Improved Mushroom Production Technique" was organised on March 4, 2024 for 40 participants, supported by AICRP on Mushroom.
- A three-day farmers' training programme on "Integrated Farming System for Livelihood Improvement and Nutritional Security" was held during March 6-8, 2024 at KVK Buxar under SCSP.
- A training on "Enhancing Prosperity of Tribal Farmers through Animal and Fisheries-based Farming Systems" was organized at Ramnagar, West Champaran on March 16, 2024 under TSP.
- A sensitization-*cum*-workshop on "Natural and Green Farming" was jointly organized by ICAR-RCER and ATARI, Patna on March 22, 2024.
- A training on "Off-season and Improved Production Techniques of Fruit and Vegetables" was organised during March 22-26 2024 with 25 participants, sponsored by ATMA, Deoghar (Jharkhand).
- An exposure visit-*cum*-awareness programme on "Scientific Method of Crop Cultivation and Animal Husbandry" under the SCSP scheme was organised for farmers of Basantpur, Ballia, Uttar Pradesh on March 23, 2024.
- Two trainings on "Recent Advances in Integrated Fish Farming System" funded by the Government of Bihar, were organised during June 10-14, 2024 with 32 participants from Saran district and August 26-30, 2024 with 30 participants from Darbhanga district.
- A five-day training on "Improved Mushroom Cultivation Technique and Value Addition" was held during June 17-21, 2024 with 25 participants was organized under AICRP on Mushroom.
- A one-month students' skill development

training programme on "Land and Water Management Techniques in Agriculture" for B.Tech. (Agri. Engg.) students was organised during July 1-31, 2024, sponsored by Dr. RPCAU, Pusa, Samastipur, at ICAR-RCER, Patna.

- A master training programme on "Improved Cultivation Practices in Horticultural Crops" was organised during July 8-19, 2024 with 14 participants, sponsored by YBN University, Ranchi (Jharkhand).
- A training on "Production Technology of Oyster Mushroom" was held on July 8 and September 22-23, 2024 with more than 50 participants in each, under AICRP on Mushroom.
- A training on "Enhancing Food, Nutritional and Livelihood Security of Marginal and Small Farmers in Jharkhand through Need-Based Agricultural Technologies" was organised on July 16, 2024 with 50 participants, under the Farmer FIRST Programme.
- A training on "Sustainable Integrated Farming System" was held on July 16, 2024 with 50 participants under the Farmer FIRST Programme.
- A master training programme on "Soil Testing and Fertilizer Recommendations" was held during July 16-30, 2024 with 10 participants, supported by Jharkhand Rai University, Ranchi (Jharkhand).
- Two awareness - *cum* - demonstrations programme on "Application of agro - chemicals in kharif crops through drone technology" were organized on August 16 and September 25-27, 2024 at various village in Buxar district under the 100-day targets of NRM Division.
- The 19th Parthenium Awareness Week was organized during August 16-22, 2024.
- A training-*cum*-demonstration programme on "Application of agro-chemicals in kharif crops through drone technology" was held during September 4-6, 2024 in Ramgarh district.
- A training programme on "Advances in Integrated Aquaculture" was organised for 30 farmers of Bhagalpur district during September 9-13, 2024 under the Department of Fisheries, Bihar.
- A training programme on "Recent Advances in Integrated Fish Farming System" funded by the Government of Bihar, was organised during September 9-13, 2024 for 30 farmers from Bhagalpur district.
- An awareness-*cum*-demonstration on "Application of agro-chemicals in kharif crops through drone technology" was organised on September 11, 2024 at Telhara village, Nalanda district under SCSP.
- An interactive meeting and agricultural technology assessment with tribal farmers and input distribution were organised during September 12-14, 2024 at Ramnagar and adjoining villages of West Champaran.
- A three-day training on "Millets Production and Processing under Climate Change Scenarios" was organised during September 16-18, 2024 for 30 farmers.
- A training programme on "Scientific Perspectives on Coarse Cereals - Production and Processing" was organized during September 16-18, 2024 at ICAR-RCER, Patna.
- A three-day orientation training programme titled "Ready, Skilled and Grow" for newly recruited technical and administrative personnel was held during September 17-19, 2024 at ICAR-RCER, Patna.
- One-day agri-industrial meet was organized at ICAR-RCER, Patna on September 24, 2024.
- An interaction meeting on "Direct Seeded Rice" was organised on September 24, 2024 at ICAR-RCER, Patna.
- An exposure visit for farmers from Lakhisarai

district (ATMA) was organized on October 1, 2024 at ICAR-RCER, Patna.

- A specialized training on "Custard Apple Cultivation in Jharkhand: Ways and Forward" was held during October 7-9, 2024 with 65 participants, funded by NHM, Jharkhand.
- A training on "Establishment and Management of Custard Apple Based Production Systems" was organised during October 7-9, 2024 with 27 participants, under the Promotion of Commercial Custard Apple Cultivation in Jharkhand (NHM).
- A large-scale training and demonstration on "Scientific Cultivation of Potato" was organized on October 8, 2024 with 207 participants, under the Farmer FIRST Programme.
- A training on "Techniques on Phenotypic Characterization in Sheep" was held during November 25-26, 2024 with 5 participants, sponsored by Animal Genetics Resources of Jharkhand (NBAGR, Karnal, Haryana).
- One-day farmers' training on "Production, Profitability and Livelihood Improvement through Crop Diversification" was held in West Champaran district on November 26, 2024.
- A three-day training programme for extension functionaries on "Production, Profitability and Livelihood Improvement through Crop Diversification" was organized in West Champaran district during November,27-28, 2024.
- A training on "Recent Advances in Integrated Aquaculture" continued with a batch of 30 farmers from Munger district during December 2-6, 2024.
- A one-day training programme on efficient soil and water management techniques for crop production was held on December 5, 2024 at ICAR-RCER, Patna.
- An awareness-*cum*-demonstration on "Application of agro-chemicals in rabi crops through drone technology" was organised on December 6-7, 2024 in villages of Jamui district under SCSP.
- An orientation programme for strengthening FPOs was organised on December 19, 2024 with 25 participants, supported by the RKVY project.
- A training programme titled "Mushroom Divas" was organized under AICRP on Mushroom at FSRCHPR, Ranchi on December 23, 2024.

Animal health camps organized

- Two "Animal Health Camps" were organized under the Farmers' FIRST Project, one each on July 16 & July 18, 2024 at Namkum, Ranchi.
- A "Animal Health Camp" was organised at Nalanda (Rajgir) on July 31, 2024.
- A "Animal Health Camp" was organised at Jehanabad on August 8, 2024.
- A "Animal Health Camp" was organised at Jamui district (Jumui, Gidhaur, Khaira, Jhajha and Sikandara blocks) during September 10-11, 2024
- A "Animal Health Camp" was organised at Bhagalpur district (Bihpur, Naryanpur, Jagdishpur, Nathnagar and Pirpainti blocks) during October 15-17, 2024

Field day/Kisan goshthi/Mass awareness programme

- A field day on "CRA, IFS, lablab bean trials and crop diversification" was organized on February 9, 2024 at ICAR-RCER, Patna.
- A field day-*cum*- awareness programme organised for SC farmers at Dhipuji Jan Pam Village, Kamrup (M), Assam on February 26, 2024.
- A field day *cum* awareness programme organised for tribal farmers at Rewa Maheshwar village of Dimoria district, Kamrup (M), Assam on March 15, 2024.
- A field visit was organized with XX Research

Advisory Committee members under the Farmer FIRST Programme at Pindarkom, Ranchi on May 8, 2024.

- A *farmers-scientists interaction* was organised for Chotaka Dhakaich village, Simri, Buxar, Bihar on May 9, 2024.
- A field visit with the Fourth Quinquennial Review Team (QRT) was organised under the Farmer FIRST Programme at Pindarkom, Ranchi on June 8, 2024.
- A field day programme on "Jalvayu Anukul Krishi Mausam Sevaye" was organized on June 27, 2024 at Gopapur village, Naubatpur, Patna.
- A mass awareness programme was held on the occasion of the 101st Foundation Day of ICAR-NISA, Namkum, Ranchi on September 20, 2024.
- A *farmers-scientists interaction* was organised for SC farmers in Sirdala of Nawada district, Bihar on October 29, 2024.
- An awareness programme was organised for SC farmers in Meskaur of Nawada district Bihar on November 29, 2024.
- A field day on "महत्वपूर्ण गौण दलहनी सब्जी फसलों का उत्पादन, बीजोत्पादन एवं मूल्य संवर्धन" was organised under RKVY, Jharkhand at FSRCHPR, Ranchi on December 18, 2024.

Training attended by the employee during 2024

- Ajit K Jha, RS Pan, P Bhavana, Reena K Kamal, Reshma Shinde, and Victor Thingujam participated in the "IP Awareness Week" organized by the IP & TM Unit, New Delhi, in virtual mode during June 5-11, 2024.
- Banda Sainath attended a training programme on "Developing Competency in Econometrics" organized by ICAR-NAARM, Hyderabad during July22-26, 2024.
- Banda Sainath participated in a workshop-*cum*-training programme on "Developing Simulation Model of Technology Diffusion (TechSIM), Adoption and Impact for Forecasting using Techno-Socio-Economic-Ecological Factors" organized by NRRI, Cuttack during September 30 - October 5, 2024.
- Dhiraj Kumar Singh and Rohan Kumar Raman participated in a "Pedagogy Development Programme on Enhancing Pedagogical Competencies for Agricultural Education" organized by NAAS, New Delhi during April 29 - May 3, 2024 at NASC Complex, New Delhi.
- Jaipal S Choudhary attended a training programme on "Enhancing Pedagogical Competencies for Agricultural Education" organized by the National Academy of Agricultural Sciences, New Delhi, held at NAAS, New Delhi during April 1-5, 2024.
- Kirti Saurabh and Saurabh Kumar attended an "International Training on Soil and Root Health" organized by CIMMYT, Turkey during March 31- April 05, 2024.
- Meenu Kumari and Reshma Shinde attended the two-week short course on "Remote Sensing & GIS Applications in Forestry & Ecology" at NE-SAC, Umiam, Meghalaya, during December 2-13, 2024.
- P Bhavana and Meenu Kumari completed a MOOC on "Artificial Intelligence in Agriculture" organized by ICAR-NAARM, Hyderabad in virtual mode during March 1-31, 2024.
- Rachana Dubey attended the course "GHG Emissions in Rice Systems: Basics of Mechanisms and Standards for Measurement", held during November 25-29, 2024 at the International Rice Research Institute (IRRI), Los Baños, Laguna, Philippines.
- RS Pan attended a one-day training and demo for onboarding BSPCs N to B module of the SATHI portal organized by MA&FW, MoA, Government of India in virtual mode on March 1, 2024.
- RS Pan participated in the training on

"Community Resource Management for Changing Climate Scenario" organized by MANAGE, Hyderabad and KSNUAHS, Shivamogga in virtual mode during March 13-15, 2024.

- Ved Prakash participated in a seven-day training programme on "Python" during August 2-8, 2024 organized by ICAR-IASRI, New Delhi.
- Ved Prakash participated in a 21-day training programme on "Development of AI-based Android Applications in Agriculture" during March 5-25, 2024 organized by ICAR-IASRI, New Delhi.
- Ved Prakash participated in a five-day training programme on "Nature Positive Farming in View of Climate Change and Food Security" during February 19-23, 2024 organized by ICAR-Indian Institute of Farming Systems Research, Modipuram, Meerut, UP.
- Victor Thingujam attended a two-week short course on "Remote Sensing & GIS Applications in Forestry & Ecology" organized by the Forestry and Ecology Division of the North Eastern Space Applications Centre, Department of Space, Government of India, held at Umiam, Meghalaya during December 2-13, 2024.
- Victor Thingujam attended the National Training Programme on "Marketing and Value Chain-based Strategies for Agroforestry Products in India" organized by Rani Lakshmi Bai Central Agricultural University, Jhansi in collaboration with MANAGE, Hyderabad, held in virtual mode during May 27-31, 2024.

Poster and oral presentation at the conference

- A Upadhayaya, B Sarkar and A Das presented a paper on "Role of Information, Technology and Management in Attaining Sustainable Agriculture" in the 1st National Conference on Agriculture, Technology and Management (NCATM-2024) held on November 15, 2024 at CIMP, Patna.
- Abhishek Kumar presented a poster entitled "Soil Health Resilience and Pest-Predator Continuum for Sustainable Cropping Intensification under Conservation Agriculture in Rice Fallow System" in the Global Soils Conference 2024 held during November 19-22, 2024 at NASC Complex, New Delhi.
- Akram Ahmed, Amitav Dey, Saurabh Kumar, Rohan Kumar Raman, A Upadhayaya, Anup Das, et al. presented a paper on "Exploring Diara Lands of the Gandak River: Mapping, Understanding Cropping Strategies, and Addressing Agricultural Challenges" in the International Conference on "Advanced Agricultural Technologies for Self-Reliant Farmers and Developed India" held on February 11, 2024 at RPCAU, Pusa.
- Arti Kumari, A Upadhayaya, P Jeet, and A Das presented a paper on "Hydrological Behaviour Studies through Morphometric Characteristics of Panchane Watershed in Harohar Sub-basin, India" in LNSWSEC-2024 held during June 20-22, 2024 at Dehradun.
- Arti Kumari, A Upadhayaya, P Jeet, K Saurabh, V Prakash, and A Das presented a poster on "Estimation of Evapotranspiration and Stage-wise Crop Coefficients for Transplanted Puddled Rice in the Middle Gangetic Plains Using a Modified Non-Weighing Lysimeter" in the Global Soils Conference 2024 held during November 19-22, 2024 at NASC Complex, New Delhi.
- Banda Sainath presented a poster on "Differential Access, Heterogeneous Effects: Exploring the Caste Disparities in Agricultural

Information Access and Use in India." in the International Conference on "Agricultural Economists" held at New Delhi during August 2-7, 2024.

- BK Jha presented a paper titled "Resource Management by Precision Farming and Crop Geometry for Higher Productivity, Water Use Efficiency and Water Productivity in Cucurbits" in the Global Soils Conference 2024 held during November 19-22, 2024 at NASC Complex, New Delhi.
- Deokaran presented a research paper on "Effect of raising bund height around rice field on water management, growth, yield, and economics" in the International Conference held on February 11, 2024 at KVK, Piprakothi, Motihari, Bihar, organized by DRPCAU, Pusa, Samastipur, Bihar.
- Dhiraj Kumar Singh presented on the topic "Opportunities for Profitable Marketing and Export of Organic Makhana" in the National Conference on "Next Generation Agriculture-Organic and Natural Farming Pathways: Extension Strategies & Approaches" at Jabalpur, Madhya Pradesh during January 28-30, 2024.
- Manibhushan presented a research paper entitled "Development of Decision Support Tool for Farming System Using Structured Query Language to Get Optimum Income" in the VIth International Conference in Hybrid Mode on "Innovative and Current Advances in Agriculture and Allied Sciences (ICAAAS)" during July 15-20, 2024 at Cong Doan Vietnam Hotel, Hanoi, Vietnam through online mode, organized by the Society of Scientific Development in Agriculture and Technology, Meerut (U.P.).
- Meenu Kumari delivered an oral presentation on "Anthocyanin Pigmented Edible Podded Pea: An Approach Towards Biofortification" in the National Seminar on "Technological Innovations in Vegetable Production under Changing Climate Regime" at ANDUA&T, Ayodhya, UP during February 24-26, 2024.
- MK Dhakar presented a paper on "Enhancing High-Density Litchi Orchard Productivity through Sustainable Water Management" in the Progressive Horticulture National Symposium (PHNS-2024) on "Horticulture in Himalayas" at HNB Garhwal University, Srinagar Garhwal, Uttarakhand during October 17-19, 2024.
- Pawan Jeet, A Upadhayaya, Arti Kumari, Ajay Kumar, PK Sundaram, and A Das presented a poster on "Change Point Detection and Trend Analysis of Precipitation and Temperature over Sakri River Basin" in the National Conference on LNSWSEC-2024 held during June 20-22, 2024 at Dehradun, organized by IASWC and IISWC.
- Pawan Jeet, Arti Kumari, A Upadhayaya, A Das, and Ajay Kumar presented a poster on "Land Use/Land Cover Change Impact on Surface Water Availability in Sakri River Basin" in the Global Soils Conference 2024 held during November 19-22, 2024 at NASC Complex, New Delhi.
- Pushanayak, A Upadhayaya, S Senapati, C Sinha, and Prateek presented a paper on "A Comparative Water Management Study to Understand the Kosi River Flowing from Mount Everest for Improved Human Livelihoods" in NCATM-2024 held on November 15, 2024 at CIMP, Patna.
- Rakesh Kumar orally presented a paper entitled "Effect of Integrated Weed Management Practices and Nutrient Management on Weed and Yield of Millets under Rainfed Agroecosystem" in the International Conference on "Climate-Smart Weed Management for Global Food Security" held during November 28-30, 2024 at BHU, Varanasi, Uttar Pradesh.
- Rakesh Kumar presented a paper on "Effect of

POU1F1 Gene Polymorphism on Growth Traits in Assam Hill Goats" in the International Seminar on "Attaining and Retaining Youth in Agriculture" held during October 13-15, at Mahender Nath Singh School, Panchdamiya, Vaishali, Bihar.

- Rakesh Kumar presented a paper on "Impact of NGF Gene Polymorphism on Growth Traits in Black Bengal Goats" in the 8th International Conference on "Recent Trends in Advancement of Agriculture, Horticulture, Livestock and Allied Sciences" (RTAAAS-2024), held during November 21-22, 2024 at SGRRU, Dehradun.
- Ramkewal presented a paper on “Inquisition on different dates of transplanting on the occurrence and intensity of rice leaf folder (*Cnaphalocrocis medinalis* Guenée) in Central Uttar Pradesh” in the International Conference on “Agriculture and Allied Sciences: Recent Advances and Innovative Approaches for Climate Smart Agriculture”, held on November 25-26, 2024, in collaboration with the Department of Entomology and Agricultural Zoology, Institute of Agricultural Sciences, Banaras Hindu University (BHU), Varanasi.
- Reena Kamal delivered an oral presentation on "Morphometric, Production, and Behavioural Traits of Native Chicken of Hill & Plateau of Jharkhand, India" during the 7th International Conference on Global Approaches in Agricultural, Biological, Environmental, and Life Sciences for a Sustainable Future (GABELS-2024), held at Buddha Hall, D.A.V. College (Tribhuvan University), Kathmandu, Nepal, during June 8-10, 2024.
- Reena Kamal presented a paper titled "A Study on the Phenotypic Characteristics and Productivity of Chotanagpuri Buffalo Breed" in the National Symposium on Futuristic Approaches for Animal Health, Management, and Welfare: Challenges and Opportunities, organized by the College of Veterinary Sciences & Animal Husbandry, BAU, Ranchi on November 29-30, 2024.
- Reena Kamal presented a paper titled "Phenotypic Characterization and Behavioural Traits of Native Chicken of Chotanagpur Plateau, Jharkhand" in the XVIII Annual Convention of Indian Society of Animal Genetics and Breeding organized by Bihar Veterinary College, BASU, Patna, during November 21-22, 2024.
- Reshma Shinde presented a paper (online) titled "Phosphorus Fraction Dynamics in Acidic Soil Amended with Organic Sources in a Maize-French Bean Cropping System" in the International Conference on GABELS-2024, held at Tribhuvan University, Kathmandu, Nepal during June 8-10, 2024.
- Reshma Shinde presented a paper titled "The Impact of Co-Application of Nitrogen and Microbial Cultures on Crop Residue Decomposition, Maize Yield, and Soil Properties" in the Global Soils Conference 2024 at NASC Complex, New Delhi during November 19-21, 2024.
- Santosh Kumar participated and presented an oral research paper on "Morpho-Physiological, Biochemical, and Anatomical Responses of Rice Genotypes under Stage-Specific and Multi-Stage Drought in Rainfed Areas of Eastern Indo-Gangetic Plains" in the 3rd Indian Rice Congress-2024 organized by ARRW during December 5-7, 2024 at ICAR-NRRI, Cuttack, Odisha.
- Santosh S Mali presented a paper titled "Harnessing Solar Energy for Sustainable Water, Energy, Food, and Environmental Nexus (WEFE)" in the International Workshop on the Water-Energy-Food-Ecosystems Nexus organized during September 1-7, 2024 at ICC Sydney, Australia.
- Santosh S Mali presented a paper titled "Solar Irrigation Pump Sizing Tool" in the Global

Science-Policy Forum on Socially Inclusive Solar Irrigation Systems during April 24-26, 2024 at Kathmandu, Nepal.

- Santosh S. Mali presented a paper titled "Crop Water Stress Mapping in Large Farms Using Multispectral UAV Imageries for Precision Irrigation Planning" in the 9th Asian Regional Irrigation and Drainage Conference and Exhibition organized during September 1-7, 2024 at ICC Sydney, Australia.
- Shanker Dayal participated and delivered an oral presentation on "Transcriptome Profiling for Identification of Differentially Expressed Genes in Buffalo Suffering from Mastitis" at the ISAGB National Conference held during November 21-22, 2024 at Bihar Veterinary College, BASU, Patna.
- Shanker Dayal presented the progress of the Black Bengal Field Unit, ICAR-RCER, Patna in the 22nd Annual Review Meeting of AICRP on Goat Improvement held during October 15-16, 2024 at CSK-HPKV, Palampur, Himachal Pradesh.
- Sonaka Ghosh presented a paper on "भारत में फसल उत्पादन के लिए कुशल कृषि प्रौद्योगिकीयां" in a Hindi Workshop under the theme "समृद्ध कृषि द्वारा विकासित भारत" held at ICAR-RCER, Patna on September 26, 2024.
- Sonaka Ghosh presented a research paper on "Effects of Tillage and Herbicide on Weed Interference and Crop Yield in a Direct-Seeded Rice-Wheat-Greengram System" in the ISWS Biennial Conference at BHU, Varanasi during November 28-30, 2024.
- Sonaka Ghosh presented research on "Effects of Conservation Agriculture on Soil Carbon Sequestration and Greenhouse Gas Emissions" in the Global Soils Conference 2024 held during November 19-22, 2024 at NASC Complex, New Delhi.
- Ved Prakash presented a paper in the 6th International Conference on "Cutting-edge Solutions in Science-Agriculture, Technology, Engineering, and Humanities (CSATEH-2024)" held during August 24-26, 2024 at Kumaun University, Nainital.
- Ved Prakash presented a paper in the International Conference on "Climate Change & Agroecosystems: Threats, Opportunities & Solutions (INAGMET-2024)" held during February 8-10, 2024 at BHU, Varanasi.
- Ved Prakash presented a paper in the International Conference on "Agrivoltaics and Sustainability in Farming" held on September 19, 2024 at Agriculture Engineering College, TNAU Coimbatore, in collaboration with Teesside University, UK.
- Victor Thingujam presented a paper titled "Agroforestry for Sustainable Agriculture and Rural Development" in the National Seminar on Sustainable Agriculture, Rural Development and Future Food Security in India organized by Palli Siksha Bhavana, Visva-Bharati, and AESSRA, during March 1-2, 2024 at Sriniketan, West Bengal.
- Victor Thingujam presented a paper titled "Variation of Curcumin Content with Plant Growth and Development in Rhizomes of *Curcuma caesia* Roxb." in the National Seminar on Nature and Environmental Issues organized during September 6-7, 2024 at College of Horticulture, CAU, Bermiok, Sikkim.

22 IARI Patna Hub

The Indian Agricultural Research Institute (IARI) Patna Hub under ICAR-Research Complex for Eastern Region (ICAR RCER) continues to foster academic excellence, professional exposure and holistic development among its students. Presently, the hub nurtures 38 *undergraduate* (UG) students (comprising 17 in their first-year and 21 in their second-year), 2 *M Tech* scholars in *Soil and Water Conservation Engineering* (SWCE) and 3 *Ph D* scholars (2 in *SWCE* and 1 in *Agronomy*). Throughout the academic year 2024-25, students participated in a wide range of academic, exposure, extra-curricular, awareness and interaction (Fig 22.1) activities to enrich their educational experience and personality development.

Academic Activities

A strong emphasis was placed on fostering academic growth through various important events:

- *Board of Studies* meetings were organized for both the M Tech and Ph D programs, presided over by senior leadership including Dr Anup Das (Director, ICAR RCER) and Dr Anjani Kumar (Director, ICAR-ATARI, Patna).
- The Deeksharambh Program was conducted to formally induct newly admitted students into the academic framework, introducing them to institutional ethics, academic structure, curriculum and research *cum* career opportunities.
- Interaction meetings with eminent dignitaries, such as Dr Trilochan Mohapatra (Chairperson, PPV&FRA), Dr RK Samanta (former Vice-Chancellor, BCKV, Kalyani), Dr ML Jat (Secretary, DARE and DG, ICAR) and Dr US Gautam (former DDG, Agricultural Extension, ICAR), enriched the students with valuable insights pertaining to agricultural research, extension and innovation.

Exposure visits

To bridge the gap between classroom learning and practical field experience, exposure visits for the students were organized. Students visited leading institutions, *viz.*, National Research Centre on Litchi (Muzaffarpur), Doordarshan Kendra (Patna), Bihar Animal Sciences University (Patna) and ICAR-Central Potato Research Institute (Patna). Practical

Fig 22.1 Students with Dr ML Jat, Secretary (DARE) and Director General (ICAR) in the Deeksharambh program

organized at the experimental fields in the Main as well as Sabajpura Farms of ICAR RCER to let them observe and practice field experiments and farming innovations.

Extracurricular and motivational activities

Beyond academics, several activities were conducted to ensure students' emotional, cultural and personal development. The *Rakshabandhan* celebration in association with *Brahma Kumaris* encouraged spiritual and motivational learning. Participation in the *Cultural Workshop* and *Youth Day* sports competitions helped foster teamwork, leadership and creativity among students. In addition, students also took part in national observances including *Independence Day* and *Teachers' Day*, where they showcased their talents and leadership skills.

Special interactions and academic exchanges

To promote cross-learning and academic collaboration, students participated in the cultural evening as part of the *National Workshop on Greening Rice Fallow Areas*. Interaction sessions were organized with RAWE UG students from UAS Bangalore, enhancing inter-institutional academic exchanges. Students also interacted with IAS probationers, leading to their exposure to governance perspectives. In addition, students also took part in discussions with

Table 22.1 Achievements by IARI Patna Hub students in various competitions

S. No.	Event/organizer	Name of the student	Achievement
1.	Bhashan pratiyogita	Miss Mannat	Second prize
2.	Infographic competition	Miss Ambika Swargiary	Appreciation prize
3.	Inter-hub online photography contest (*Theme: Aesthetic IARI - Showcasing the Beauty of IARI Hub*)	Mr Ashish Kumar	First prize

Table 22.2 Highlights of the key events at IARI Patna Hub (2024)

S. No.	Date	Event	Remarks
1.	05.06.2024	World Environment Day	Special lectures by Dr Anita Raj (DFO) and Dr Prakash Jha (Mississippi University, USA)
2.	10.06.2024	Board of Studies Meeting (M Tech and PhD)	Presided over jointly by Dr Anup Das and Dr Anjani Kumar
3.	30.07.2024	Veterinary Clinical Complex Visit, BASU, Patna	Exposure visit to veterinary healthcare
4.	06.08.2024	Visit to Doordarshan Kendra, Patna	Interaction with program executive Mr Vivek Azad
6.	16.08.2024	19th Parthenium Awareness Week	Awareness campaign on invasive weeds
7.	19.08.2024	Interaction Meeting	Insights from Dr RK Samanta and Dr US Gautam
8.	20.08.2024	Rakshabandhan Celebration with Brahma Kumaris	Motivational address and celebration
9.	05.09.2024	Teachers' Day Celebration	Felicitation of faculty by students and organization of sports events
10.	23.10.2024	Interaction with Dr M L Jat, Secretary, DARE and DG, ICAR	
11.	15-30.10.2024	Deeksharambh Program	Orientation program for newly joined UG students; Course leader: Banda Sainath (Scientist)
12.	21.11.2024	Interaction Meeting	Talk by Dr Trilochan Mohapatra (Chairman, PPV&FRA, New Delhi)
13.	03.12.2024	Agricultural Education Day	Address by Dr RC Agarwal (DDG Education)
14.	05.12.2024	World Soil Day	Visit to ICAR-CPRI, Patna
15.	26-30.12.2024	Cultural Workshop	Organized by Dr Supriya Das

members of the *Board of Studies* and various chairmen (of other committees) during which academic and administrative concerns for the betterment of students' academic journey were addressed.

Achievements and key events

Students participated in various competitions, and achieved distinction by winning various prizes (Table 22.1). Highlights of the key events are provided in the Table 22.2.

Fig 22.2 Award-winning photograph in the Inter Hub photography competition [Courtsey: Mr Ashish Kumar, Second year UG student (2023-27)]

Exposure Visits

Fig 22.3 Educational trip to NRC on Litchi (Muzaffarpur)

Fig 22.4 Visit to Veterinary Clinical Complex, BASU, Patna

Fig22.5 Practical sessions at Sabajpura Farm of ICAR RCER

Fig 22.6 Cultural Workshop (2024)

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23 Events Organized

The ICAR RCER organized various events of broad institutional and famers' interest. The major events organized by the institute are as follows:

24th Institute Foundation Day

To commemorate its successful journey and institutional establishment, ICAR RCER celebrated its 24th Foundation Day on February 22, 2024, alongside an Agriculture Fair. The inaugural session was graced by Hon'ble Governor of Bihar, Shri Rajendra Vishwanath Arlekar, who formally inaugurated the programme by lighting the ceremonial lamp and extended his congratulations to all institute personnel (Fig 23.1). In his address, the Governor emphasized the importance of adopting natural farming practices, cautioning that excessive use of chemical inputs is degrading soil health and polluting the environment. He further highlighted that natural farming not only lowers production costs but also enhances agricultural output. He further urged for the holistic development of farmers to realize the vision of a developed India by 2047.

Dr Suresh Kumar Chaudhari (DDG NRM), the special guest of the program, emphasized on adopting climate-friendly farming techniques and highlighted the research and extension work being done by various institutions of ICAR. Dr Chaudhari delivered the Foundation Day lecture on "Suitable soil and water management for achieving sustainable development goals". In the lecture, he highlighted the importance of agriculture in making India a 5 trillion economy. Earlier, Dr Anup Das, Director of the institute, provided a brief overview of the institute's key achievements and contributions, along with the significance of the institute for fostering agricultural innovation in eastern India.

At this occasion, selected farmers, media persons, and employees (including retired ones) of the institute were also honored. In the technical session, Dr Anjani Kumar (Director, ATARI, Patna), Dr KG Mandal (Director, MGIFRI, Motihari), Dr Bikash Das (Director, NRC on Litchi, Muzaffarpur), Dr RK Jat (In-Charge, BISA), and scientists from the institute also participated and put forth their views. In addition, a farmer-scientist interaction meeting was also organized in which farmers shared their problems with scientists, and experts from different fields provided solutions for the same. Around 30 exhibition stalls were also set up by the government, private, and farmer organizations during the foundation day farmers' fair. During the occasion, a live demonstration for application of drone technology in farming was showcased.

Tribal Farmers' Conclave

ICAR RCER, Patna, successfully organized Farmers' Fair cum Tribal Farmers' Conclave during February 21-23, 2024. The event brought together over 500 tribal farmers, including members of Santhal, Munda, Oraon, Gond, and other tribal communities, and their representatives from across seven states. The conclave served as a vibrant platform for cultural exchange and knowledge-sharing. It featured captivating traditional dance performances by the Gond tribe of Bihar and the Santhal tribe of Jharkhand, celebrating the rich cultural heritage of tribal India (Fig 23.2). Tribal Farmer Producer Organizations (FPOs) showcased a wide range of indigenous agricultural products, underlining the value of traditional knowledge and sustainable farming practices. The event also honored exemplary tribal farmers for their significant contributions to conservation of biodiversity and ecological stewardship. By blending cultural celebration with agricultural innovation, the Tribal Farmers' Conclave highlighted the resilience, wisdom, and self-reliance of indigenous farming communities, reaffirming their vital role in shaping a sustainable agriculture.

Fig 23.1 Chief Guest Shri Rajendra Vishwanath Arlekar, Hon'ble Governor (Bihar) inaugurating the institute Foundation Day on February 22, 2024

Fig 23.2 Glimpses of Tribal Farmers' Conclave

Hon'ble Governor of Jharkhand and Agriculture Minister visits the exhibition stall of institute

Hon'ble Governor of Jharkhand, Sri CP Radhakrishnan, and Hon'ble Minister of Agriculture and Farmers Welfare, Shree Arjun Munda, visited the ICAR RCER, FSRCHPR, Ranchi exhibition stall during the "Shahid Kisan Mela" on January 01, 2024. The event also witnessed the esteemed presence of Dr Trilochan Mohapatra, former Secretary, DARE and DG, ICAR, who explored the innovative agricultural displays at the stall.

Fig 23.3 Hon'ble Governor of Jharkhand, Hon'ble Minister for Agriculture and Farmers Welfare, and Dr T Mahapatra, former Secretary DARE and DG, ICAR at the exhibition stall of the institute.

Union agriculture minister visits exhibition stalls of institute

The Regional Agricultural Fair was organized on February 02, 2024, at KVK Khunti, where Shri Arjun Munda, Hon'ble Minister for Agriculture and Farmers Welfare, and Dr Himanshu Pathak, Secretary DARE & DG ICAR, visited the institute's exhibition stall. They also actively participated in the live demonstration of agricultural drone spraying organized by ICAR RCER, highlighting advancements in modern farming technologies.

Hon'ble Shri Ramnath Thakur, Union Minister of State for Agriculture and Farmers' Welfare visited the institute

Hon'ble Shri Ramnath Thakur, Union Minister of State for Agriculture and Farmers' Welfare visited ICAR RCER, Patna on October 28, 2024. The Hon'ble Minister interacted with the scientists of the institute and discussed on various important projects/ programme being carried out for farmers and other stakeholders. He urged everyone to go beyond their limits to contribute to the vision of Viksit Bharat@2047 with focus on the enhancement of the livelihood of Annadata. He stressed on making access to as many farmers as possible with innovative fish farming technology and also stressed on conducting research on increasing production at the lowest feasible cost. He urged scientists of the institute to work on technologies/ practices for enhancement of income of small and marginal farmers. As a part of the 'Ek Ped Maa Ke Naam' campaign, he planted a tree in the institute to spread the message about environmental protection. He also inaugurated the Biofloc unit built for fish farming in the institute (Fig 23.5).

Fig 23.4 Sri Arjun Munda, Union Minister for Agriculture and Farmers Welfare & Dr Himanshu Pathak, Secretery DARE and DG , ICAR at the exhibition stalls of the institute at KVK Khunti

Fig 23.5 Hon'ble Shri Ramnath Thakur Ji, inaugurating Biofloc unit at the institute

Quinquennial review meeting

The Quinquennial Review Team (QRT) conducted a comprehensive assessment of the institute research activities in accordance with ICAR guidelines. The evaluation covered the performance of the institute, its regional research stations, farms, KVKs, outreach programme, and institutional linkages. The review involved a detailed analysis of the institute's work in technology generation, production, protection, dissemination, and publication through consultations with domain experts, followed by collective discussions by the QRT across sectors. The QRT comprised eminent experts, including Prof SK Chakravarti, Former vice chancellor of Uttar Banga Krishi Viswavidyalaya and Ex-Director of ICAR CPRI, Shimla and ICAR CTCRI, Thiruvananthapuram; Dr AK Patra, Emeritus Scientist and Former Director of ICAR IISS, Bhopal; Dr Chandrahas, Dean, CoVAS, Kishanganj and Dr S Raizada, Former ADG (Fisheries), ICAR, New Delhi (Fig 23.6). The team undertook three visits in 2024: the first to ICAR RCER Patna and KVK Buxar (February 6-8, 2024), the second to FSRCHPR Ranchi and KVK Ramgarh (June 8-9, 2024), and the third to ICAR RCER Patna and NRC on Makhana, Darbhanga (June 24-26, 2024).

The team emphasized the need to strengthen research and outreach efforts on climate-resilient agriculture, including stress-tolerant crop varieties, site-specific farming modules, GHG management, and standardized carbon farming practices. They recommended continued documentation of local livestock and poultry breeds, and highlighted the need for year-round fodder production strategies to address the eastern region's 70% fodder deficit. In fisheries, they advised developing integrated wetland management models to enhance fish productivity through culture-based and participatory approaches. The QRT expressed complete satisfaction with the overall achievements and graded the Institute's performance as "Excellent".

Fig 23.6 Glimpses of the inaugural session on QRT meeting

Fig 23.7 Director, ICAR RCER presenting QRT report to DG, ICAR and DDG, NRM

Research Advisory Committee (RAC) meeting

The XX Research Advisory Committee (RAC) meeting of ICAR-RCER was held at FSRCHPR, Ranchi, during May 6-8, 2024, under the chairmanship of Dr KD Kokate. The meeting was attended by Dr Rajbir Singh, Assistant Director General (Agri. AF & CC), along with RAC members Dr Masood Ali, Dr Shivendra Kumar, Dr KN Tiwari, and Dr SD Singh. During the meeting, the RAC team visited experimental plots and farm facilities of FSRCHPR and appreciated the quality and relevance of the research works being carried out at the Centre (Fig 23.8). The committee reviewed research progress, visited experimental plots, and appreciated the institute's research works in crop diversification, integrated farming systems, and farmers' outreach. Stakeholder interactions highlighted the positive impact of technologies introduced under ABI, Farmers FIRST, SCSP, and TSP, with farmers acknowledging the institute's support in inputs and technical guidance. The committee reviewed research achievements presented by ICAR-RCER divisions and KVKs at Buxar and Ramgarh. Key recommendations included strengthening communication through social media, promoting nutrient-rich and climate-resilient crops, enhancing infrastructure, advancing agri-processing, wastewater management, natural farming, nano fertilizers, and mapping area-specific needs for rice fallows and conservation agriculture. The RAC expressed overall satisfaction with the institute's research, extension, and developmental efforts aligned with regional needs and climatic challenges.

Agri-industrial Meet

ICAR RCER, Patna along with its Research Centre, FSRCHPR, Ranchi; two KVKs at Buxar and Ramgarh, organized an 'Institute Industry Meet' on September 24, 2024 at ICAR RCER Main campus, Patna in order to bridge the gap between ICAR institutes and Agricultural Entrepreneurs in the eastern region of India. More than 35 entrepreneurs from Bihar, Jharkhand, Chhattisgarh, and Maharashtra participated in the meet and had an interaction with the scientists belonging to various agricultural disciplines.

Dr Anup Das, Director of ICAR-RCER, showcased key technologies ready for commercialization, including grafted tomatoes, climate-resilient rice varieties, improved fruits and vegetables, and multitier cropping systems, emphasizing their role in boosting productivity and generating employment in the eastern region. Shri VK Sinha, CGM of NABARD and chief guest, praised

ICAR's contributions to agricultural growth and stressed the need for affordable, sustainable technologies, reaffirming NABARD's support. Dr Bikas Das, Director of NRC on Litchi, highlighted the importance of skill-based training to bridge the gap between farmers' and consumers' prices. The event saw participation from several dignitaries representing major agricultural institutions.

During the event, 10 MoUs, with respect to different varieties, new technologies and models, were signed between ICAR RCER, Patna and different industries/ enterprises for a nominal cost of rupees six lakh as the major objective is to spread advanced technologies developed by the institute for ensuring sustainable development across the eastern region (Fig 23.9). During the occasion, an innovative entrepreneur Shri Shravan Kumar, narrated his story and his association with the Institute. A woman entrepreneur from Ranchi, Smt Albina Ekka informed that the support she received from the institute helped her in preparing and marketing of herbal medicine and the enterprise gives her an annual profit of Rs. 10 lakhs . The programme ended with vote of thanks by Dr AK Singh, Head, FSRCHPR, Ranchi.

Fig 23.8 RAC team with scientist of ICAR RCER Patna

Fig 23.9 MoUs signed during ICAR RCER industry meet

Deeksharambh 2024 event at IARI Patna Hub

Deeksharambh 2024, organized by The Graduate School, ICAR IARI, took place during October 15-28, 2024 at ICAR RCER Patna, in collaboration with ICAR IARI Patna Hub. The event was inaugurated by Dr Mangi Lal Jat, the Chief Guest, who highlighted the importance of innovation in agricultural sciences (Fig 23.10). The programme aimed at welcoming new students, featuring lectures, workshops, and interactive sessions to foster academic and research growth. It provided valuable insights into agricultural advancements, encouraging critical thinking and collaboration among participants. The event concluded with a ceremony honoring outstanding contributions, emphasizing ICAR IARI's commitment to academic excellence in agriculture.

Interaction programme with Dr Trilochan Mohapatra

An interaction programme was organized between scientists, students of IARI hub, Patna and Dr Trilochan Mohapatra, Chairperson, Protection of Plant Varieties & Farmers' Rights Authority, and Former Secretary, DARE and Director General, ICAR on November 21, 2024 at ICAR RCER, Patna. Dr DR Singh, Hon'ble Vice-Chancellor, Bihar Agricultural University, Sabour, Dr PK Rout, Principal Scientist, ICAR Headquarters, New Delhi also graced the occasion (Fig 23.11). Dr Trilochan Mohapatra, in his address, appreciated the efforts of new initiatives of ICAR Research Complex, Patna in research and education. In his long interaction with the scientists and students, he suggested for 'Blended Learning' approach to enhance the skill and knowledge of the students. Addressing the issues of agriculture in the eastern region, Dr Mohapatra informed that the region provides equal opportunities and challenges, with slow variety replacement rate and low technology adoption. He urged the scientists to look for the solution and change the scenario by infusing new

Fig 23.10 Glimpses of Deeksharambh 2024

thoughts and ideas. He also suggested for promotion of pulse in Tal area and best lentil variety in rice fallow area. He underlined that diversification is the key for enhancing income for farmers in the eastern region. To bring the change in the livestock sector, Dr Mohapatra insisted to give more momentum on goat breeding. He suggested the scientists to develop a breeder stock and form different sire lines within Black Bengal breed for producing superior progenies to be distributed among the farmers.

Institute innovation cell

The Institute Innovation Cell, established in 2023, was conceived to nurture intellectual curiosity, support innovative thinking, and foster a conducive environment for creativity and research within the institute. In its inaugural year, the Cell launched the Young Scientist Innovation Project (YSIP) initiative, inviting scientists under the age of 40 to submit original and impactful research ideas. From the proposals received, two promising projects were selected for initial funding support, with the potential to be scaled into full-fledged research initiatives based on their outcomes (Fig 23.12). In addition to supporting innovation-led projects, it plays a key role in cultivating a culture of scientific innovation and collaboration through regular interactions, meetings, and thematic sessions. These are enriched by the participation of eminent experts from diverse disciplines, offering valuable platforms for scientists and students to exchange ideas, receive mentorship, and stay abreast of emerging trends and advancements in science and innovation.

Fig 23.11 Dr Trilochan Mohapatra at ICAR RCER Patna

Fig 23.12 Dignitaries evaluating proposal for Young Scientist Innovation Project initiative

National conclave on sustainability, productivity, and green growth

The National Conclave on Sustainability, Productivity, and Green Growth was held on February 13, 2024, at ICAR-RCER, Patna, and was jointly organized by ICAR-RCER, the National Productivity Council, Bihar State Productivity Council, and Indian Potash Limited. The event witnessed active participation from over 100 stakeholders, including scientists, farmers, and officials from both public and private sectors (Fig 23.13).

Sri JK Singh, Regional Director, National Productivity Council, opened the event by highlighting the significance of sustainable productivity and the role of climate-smart interventions, policy support, and green growth strategies in driving agricultural transformation. Dr Rajeev Ranjan (IAS Retd.), Guest of Honour and Director, IPL Centre for Rural Outreach (ICRO), emphasized the relevance of government initiatives like the Amrit Internship Program and expressed concern over the growing challenges posed by climate change to green development. Dr Rameshwar Singh, Vice-Chancellor, BASU, Patna, stressed the need to enhance livestock productivity and reduce water usage per kilogram of meat and milk to mitigate methane emissions. He called for the efficient use of natural resources as a pathway to sustainable growth.

Dr Bikash Das, Director, NRC Litchi, highlighted the value of underutilized, local fruits and vegetables in promoting green growth by minimizing transport-related emissions. He advocated for adoption of green agronomic practices such as biomass mulching and zero tillage to enhance soil health and sustainability. Dr Anup Das, Director, ICAR RCER, Patna identified three core challenges in agriculture: Enhancing productivity per unit area, conserving natural resources, and promoting green growth. He proposed actionable solutions like improving nitrogen and water use efficiency, reducing greenhouse gas emissions, and encouraging practices such as customized fertilizer use, efficient irrigation systems, bio-fertilizers, and conservation agriculture, in line with national research priorities. Dr RK Jat from BISA-CIMMYT, Samastipur, provided insights into climate-resilient agriculture initiatives in India, further reinforcing the conclave's emphasis on sustainable and inclusive green growth.

Fig 23.13 Dignitaries at national conclave on sustainability, productivity and green growth

Interaction meeting with the scientists of IRRI and BMGF

An interaction meeting of scientists from International Rice Research Institute (IRRI), Philippines and Bill & Melinda Gates Foundation (BMGF), Washington, USA with team of scientists from ICAR Research Complex for Eastern Region, Patna was organized on issue of "Direct Seeded Rice" on September 24, 2024 (Fig 23.14). Dr Gary Atlin, Senior Program Officer, BMGF-India and the chief Guest of the programme in his address stressed on the development of weed-suppressing rice genotypes for weed management in Direct Seeded Rice. He also emphasized on the importance of genomic prediction technology for the rice breeding program at ICAR RCER, Patna. Dr Atlin appreciated the fruitful outcome of the collaboration with ICAR RCER Patna. Dr Sankalp Bhosale, Research Leader-Product Development & Varietal Development, IRRI, Philippines too appreciated the efforts of ICAR RCER, Patna in developing 11 climate resilient rice varieties which are being adopted by the farmers of the eastern region.

Fig 23.14 IRRI and BMGF team at ICAR RCER Patna

Workshop on cultural activities for the UG students

The Workshop on Cultural Activities for the UG Students, conducted from December 26-30, 2024 at ICAR-RCER, Patna, emerged as a highly successful and enriching program. Organized as part of the IARI - Patna Academic Hub initiative, the workshop aimed to integrate cultural literacy into higher education and enhance the creative expression of undergraduate students. The workshop was facilitated by Dr Supriya Das, Associate Professor and Head, Department of Bengali, Ramthakur College, Agartala, Tripura. With her deep academic insight and dynamic engagement style, Dr Das delivered a series of impactful sessions focusing on cultural identity, language appreciation, artistic expression, and the role of performing arts in personal and social development (Fig 23.15). Over the five-day duration, the workshop witnessed active participation from UG students who enthusiastically took part in activities such as classical and folk dance, music performances, drama, poetry recitation, and creative writing exercises. The program successfully contributed to fostering holistic student development, enhancing cultural consciousness, and strengthening the academic vibrancy at ICAR-RCER, Patna.

Weekly scientific seminar series at ICAR RCER, Patna

To foster a vibrant culture of continuous learning and scientific knowledge exchange, ICAR RCER, Patna, initiated a Weekly Scientific Seminar Series, held every weekend. This initiative became a significant academic platform for knowledge sharing, interdisciplinary dialogue, and professional development among scientists, technical personnel, and administrative staffs. Since its inception, the seminar committee successfully conducted over 40 sessions, featuring eminent speakers from various domains of agriculture and allied sciences. Experts from ICAR institutes, State Agricultural Universities (SAUs), CSIR organizations, and reputed academic institutions had actively participated both online and offline, enriching the discourse with their insights and experiences (Fig 23.16). The initiative reflects the institute's commitment to academic excellence, collaboration, and capacity building, supporting innovative and informed approaches in agricultural research and rural development.

Fig 23.15 Glimpses of workshop on cultural activities for UG Students

Fig 23.16 Glimpses of weekly scientific seminar series at ICAR-RCER, Patna

Republic Day and Independence Day celebration

ICAR RCER celebrated two significant national events in 2024-Republic Day on 26th January and Independence Day on 15th August-with great enthusiasm and patriotism. Both events were marked by flag hoisting ceremonies, cultural performances, and commemorations that highlighted the country's rich history and achievements. Both occasions served as a reminder of institute commitment to advancing agriculture for the welfare of the nation, fostering national unity, and contributing to the country's growth and development. These celebrations not only honored India's history but also inspired all members of the ICAR community to continue working towards a brighter and more prosperous future for the nation.

Fig 23.17 Director, ICAR RCER Patna, hoisting the national flag with pride and honor during Independence Day 2024

Participatory technology evaluation

Participatory technology evaluation was conducted to identify trait-specific lablab bean genotypes for eastern India, involving scientists, farmers, students, and interns. A total of 216 lablab bean lines, including checks, were evaluated based on visual acceptability, colour, texture, yield, disease resistance, pest resistance, and nutritional traits using a 1-5 scale (Fig 23.18). Purple-podded beans were preferred for their nutritional value, while high phenol content was favored for pest and disease resistance. Female farmers prioritized bold-seeded, desi-type beans with good taste and shorter cooking time, while students leaned toward green-colored varieties.

Fig 23.18 Participatory technology evaluation of lablab bean on January 25, 2024

Training/awareness programme

Two trainings *cum* awareness programme were organized under the project 'Building lentil growing community resilience by the development of climate smart lentil varieties through farmers' participatory interventions'. Over 30 lentil growers from nearby blocks of Patna district participated in each programme organized separately on March 07 and March 12, 2024. During each program, farmers observed the field performance of advance breeding lines of lentil, and were asked to practice selection of better genotypes for further evaluation (Fig 23.19). In the afternoon, an interactive session with participating farmers was held.

Global Campaign 'Ek Ped Maa Ke Naam' Plant4 Mother' in the farmers' fields

With a goal of expanding sustainable lifestyle practices in the Eastern region of India, ICAR-RCER, Patna organized a tree plantation event under Global Campaign # Ek Ped Maa Ke Naam # 'Plant4 Mother' in the farmers' fields in Sangrampur village under Bikram block of Patna district on September 05, 2024 under the leadership of Dr Anup Das, Director, ICAR-RCER, Patna. In the Mega event, a total of 178 farmers participated from Sangrampur and nearby villages. The Director in his key note address created awareness among the participating farmers on the gruelling effect of climate change and the need for mitigation and the role of trees in enhancing ecosystem services, rural livelihood, soil and water conservation, and enriched nutrition. During the programme, the farmers were provided with around 1230 tree plants of Mahogany, Teak, Mango, Jack fruit, Amla, Lemon etc. Under this programme a total of 6000 tree saplings were planted by the main institute, FSRCHPR, Ranchi and two KVKs in Buxar, Bihar and Ramgarh, Jharkhand.

Fig 23.19 Awareness programme and farmers assessing field performance of lentil lines.

Fig 23.20 Tree plantation program under 'Ek Ped Maa Ke Naam'

Brainstorming session on enhancing custard apple cultivation in Jharkhand

A brainstorming session on "Custard apple cultivation in Jharkhand: Ways and forwards" was organized on October 7, 2024, which brought together key experts and stakeholders to explore strategies for enhancing custard apple cultivation in the state. The session was chaired by Dr Bikash Das (Director, NRC on Litchi), Dr Vishal Nath (OSD, IARI Jharkhand), Sri MK Sinha (Director, Jharkhand State Horticulture Mission), and Dr AK Singh (Head, ICAR RCER, FSRCHPR Ranchi) (Fig 23.21). Discussions focused on the potentials of custard apple to boost Jharkhand's rural economy through adoption of custard apple-based production system and entrepreneurship models. Key topics covered included orchard establishment, nutrient management, propagation, canopy management, and plant protection. To provide hands-on learning, farmers visited Nandi Green Solution farm in Khunti, where they gained practical insights into advanced cultivation techniques. The event saw the active participation of 57 representatives from NGOs, KVKs, the Jharkhand Horticulture Department, Birsa Agricultural University, ICAR NBPGR, and progressive farmers, marking a significant step toward strengthening custard apple cultivation in Jharkhand.

Mass awareness programme on kisan drone

Under the Government of India-sponsored Agricultural Drone Project, a one-day awareness programme on applications of agricultural drones was organized by ICAR RCER, FSRCHPR, Ranchi, on March 6, 2024, in Kumekela village, Pathalgaon block, Jashpur district (Fig 23.22). The programme provided technical insights into drone technology and demonstrated its application in agriculture through field spraying. Experts highlighted the benefits of drones in modern farming, emphasizing their roles in reducing input costs, saving time, and increasing efficiency. It was also explained how drones can effectively be used for spraying nano urea, pesticides, and other agrochemicals, leading to reduced labour requirements and enhanced profitability for farmers. Additionally, the importance of drones in both horticultural and other crop production was also discussed.

World Intellectual Property Day

World Intellectual Property Day was celebrated by FSRCHPR, Ranchi, under the theme "IP and SDGs: Building our common future with innovation and creativity" on April 29, 2024. A Keynote Address was delivered by Prof. Sreenivasa Murthy, DPIIT-IPR Chair Professor, National University of Study and Research in Law, Ranchi, on "Copyright protection in

Fig 23.21 Brainstorming session on custard apple-based production systems

Fig 23.22 Mass awareness programme at Jashpur district in Chhattisgarh

the digital era: Issues and challenges". Dr AK Singh, Head, FSRCHPR Ranchi, welcomed the dignitaries and participants. Dr Murthy elaborated on the challenges to copyright laws in the digital landscape, particularly concerning social media, and introduced new technologies related to copyright protection. A total of 80 attendees from Headquarters, Patna, KVK Buxar, and KVK Ramgarh, FSRCHPR Ranchi, participated in the programme (Fig 23.23).

World Environment Day

The ICAR-RCER, FSRCHPR, Ranchi, observed World Environment Day on June 5, 2024, with a focus on "Land restoration, desertification, and drought resilience" under the slogan "Our land, our future". The event highlighted the importance of sustainable practices to combat land degradation. A *kisan goshti* was conducted, engaging farmers from Plandu village in discussions on sustainable land management. Importance of eco-friendly techniques, water conservation through rainwater harvesting, and the significance of crop residue management and organic fertilizers were deliberated. As part of the celebration, mango and litchi saplings were distributed to 25 farmers. More than 25 Kusum, tamarind and karanj saplings were also planted at the boundary area of the centre (Fig 23.24). Additionally, 300 plants were supplied to various institutions, including banks, telecom services, and training schools, to enhance green cover and environmental sustainability.

Fig 23.23 Glimpses of world intellectual property day celebrations at Ranchi centre

Fig 23.24 Distribution and plantation of plant saplings to farmers

World Soil Day

ICAR RCER, Patna, celebrated World Soil Day on December 5, 2024, with the theme "Caring for soils: Measure, monitor, manage," emphasizing soil and water health for sustainable agri-food systems. The event was attended by around 70 participants, including farmers, students, and scientists. The programme highlighted the significance of soil health management through soil testing, conservation agriculture, and balanced fertilization (Fig 23.25). Soil health cards and improved fertilizers like nano urea and Sagarika were distributed to farmers in Dulhin Bazar village. Dr Anup Das, Director, ICAR-RCER, Patna, stressed the importance of soil testing and conservation practices, while Dr AK Singh and Dr Ashutosh Upadhyaya provided insights on balanced fertilization and soil-water quality management. At the Ranchi Centre, 350 school students engaged in soil health awareness activities, while KVK Ramgarh and KVK Buxar hosted practical workshops for over 95 farmers, focusing on eco-friendly soil management. The multi-location event successfully promoted sustainable agricultural practices and soil conservation awareness.

International yoga day celebrated at FSRCHPR, Ranchi

The ICAR-RCER, FSRCHPR, Ranchi, celebrated the 10th International Yoga Day on June 21, 2024, under the theme "Yoga for self and society" and "Women empowerment." The event aimed to promote the significance of yoga in maintaining physical and mental well-being while fostering a healthier and stress-free lifestyle. A one-hour yoga session was organized with the active participation of around 40 personnel from the Scientific, Technical, and Administrative Cadre (Fig 23.26). The session was conducted by Swami Shivanand, a yoga instructor from the Art of Living Foundation, who guided the participants through various yoga postures and breathing exercises.

Hindi Pakhwada celebrated at ICAR RCER Patna and FSRCHPR, Ranchi

Hindi Pakhwada is a significant event, and the activities under this program commenced on September 13, 2024, engaging employees through various events. The 15-day event featured multiple competitions, including debate, essay writing, poetry recitation, vocabulary challenges, annual work evaluation, and a Hindi quiz, encouraging active participation and appreciation of the language. The valedictory function, held on September 30, 2024, was graced by Dr KK Bose, Ex-Head, Department of Hindi, St. Xavier's College, Ranchi, as the Chief Guest, and Dr Rinu Sinha, Head, Department of Hindi, Nirmala College, Ranchi, as the Special Guest (Fig 23.27). During the closing ceremony, the guests distributed prizes to the winners of various competitions. The event concluded with a Hindi workshop, leaving participants inspired to further embrace and promote the language.

Fig 23.25 Celebration of World Soil Day at ICAR RCER Patna and FSRCHPR, Ranchi

Fig 23.26 Participant performing yoga on the occasion of 'International Yoga Day'

Fig 23.27 Hindi workshop organised under Hindi Pakhwada

Swachhata Pakhwada and Special Swachhata Campaign 3.0

FSRCHPR, Ranchi, actively undertook the Swachhata Hi Sewa campaign (September 15, 2024 to October 02, 2024) and the Special Swachhata Campaign 4.0 (October 02, 2024 to December 31, 2024) to promote cleanliness, sustainability, and community engagement. Activities included cleaning drives, tree plantations, agricultural waste management (vermicomposting, wastewater recycling), and record disposal for efficient workspace management (Fig 23.28). Awareness programme on waste segregation was organized in Plandu village whereas a drawing competition and student rally were arranged at Immaculate Heart of Mary High School, Namkum, emphasizing hygiene awareness. The institute also observed Swachhata Pakhwada (December 16-31, 2024), beginning with a Swachhata Pledge, followed by systematic workspace maintenance, afforestation, and voluntary *Shramdaan* initiatives. Activities such as quiz competitions, Swachhata runs, and signature campaigns further promoted waste recycling and water conservation. Through these sustained efforts, ICAR RCER FSRCHPR Ranchi contributed to building a cleaner, greener, and more sustainable future, aligning with the national vision of Swachh Bharat.

Fig 23.28 Activities under Swachhata Hi Sewa campaign

Parthenium Awareness Week

Parthenium hysterophorus, locally called carrot weed, gajar ghas or congress grass, has been considered one of the most problematic alien invasive weeds, which is posing a serious threat to human beings and livestock besides deteriorating the environment and causing loss of crop productivity and biodiversity. Given the seriousness and magnitude of the threat posed by this weed, ICAR-RCER, Patna organized "19th Parthenium Awareness Week" during August 16-22, 2024, by involving Regional Centre in Ranchi and KVKs in Buxar and Ramgarh, to make farmers and general public aware about the menace of Parthenium and its management strategies. A wide range of activities including a brainstorming session on parthenium control measures were conducted to spread maximum awareness among scientists, administrative and technical staff, farmers, students, and farm workers (Fig 23.29). During the occasion, Dr Sonaka Ghosh Scientist, DLWM, delivered a lecture on "Strategies for *Parthenium hysterophorus* L. management".

Fig 23.29 Glimpses of Parthenium Awareness Week

Dr Sudhakar Pandey, ADG (VC) visited FSRCHPR, Ranchi

On February 19, 2024, Dr Sudhakar Pandey, ADG (Vegetable Crops), visited FSRCHPR, Ranchi. During the visit, he inspected the AICRP (VC) trials and seed production plots at the centre. He also engaged in an interactive meeting with the scientists, discussing ongoing research activities and advancements in vegetable crop development.

Fig 23.30 Dr Sudhakar Pandey, ADG (VC) in AICRIP experimental fields

24 Awards and Recognition

Awards and Recognition

1. FSRCHPR, Plandu, Ranchi received '**Performance Excellence Award 2022-23**' from the Agricultural Extension Division, ICAR, New Delhi for implementation of the Farmers First Programme.
2. FSRCHPR, Plandu, Ranchi received the award '**Top-performing centre in implementation of special programme on TSP-STC**' for research work done under AICRP on Fruits during 11th Group Discussion of ICAR - AICRP on Fruits held at NAU, Navsari during January 22-25, 2024.
3. FSRCHPR, Plandu, Ranchi received '**Second prize for promotion and implementation of policy for Official Language**' on March 08, 2024 during the Conference organized for promotion of regional official language at Siliguri, India.
4. Dr Anirban Mukherjee received '**NABARD Researcher of the Year 2023**' for excellence in Agricultural Extension from the President of Indian Union at IARI Convocation.
5. Dr Ujjwal Kumar received '**Extension Leadership Award, 2024**' from Department of Extension Education, BHU, Varanasi.
6. Dr Santosh Kumar was conferred '**NARES-IRRI Fellowship Award**' by the International Rice Research Institute for his valuable contribution to the One IRRI NARES Breeding Network.
7. Dr Rakesh Kumar received '**BASA Fellowship**' from Bihar Agriculture Science Academy, RPCAU, Pusa (Samastipur), Bihar.
8. Dr Sonaka Ghosh received '**ISWS Mrs A Anasuya Best Ph D Thesis Award**' from the Indian Society of Weed Science, Jabalpur (MP).
9. Dr Rohan Kumar Raman received '**Distinguished Scientist Award-2024**' from Agricultural and Environmental Technology Development Society (AETDS), US Nagar, Uttarakhand, India.
10. Dr MK Dhakar received '**Himadri Young Scientist Award 2023**' from the Indian Society of Horticultural Research and Development (ISHRD), Uttarakhand, India.
11. Dr P Bhavana received '**Special Recognition Certificate for distinguished services in academic activities of IARI Mega University Ranchi Hub**' in the year 2023-24 during 13th Foundation Day of ICAR-IIAB on October 09, 2024.
12. Dr Manibhushan received '**Scientist of the Year Award 2024**' for outstanding contribution in the field of Computer Science and Engineering from Society of Scientific Development in Agriculture and Technology (SSDAT), Meerut (UP) during VIth International Conference on ICAAAS during July15-20, 2024.
13. Dr Rajni Kumari was awarded **"Ram Singh Memorial National Animal Welfare Award 2024"** by Pashudhan Praharee, Ranchi for article on "One World One Health Prevent Zoonoses".

Best Paper/Poster/Presentation Awards

1. Dr A Upadhayaya received '**Best Research Paper Award for the year 2022**' during a Conference organized by the Indian Association of Soil and Water Conservationists at Dehradun during June 20-22, 2024.
2. Dr MK Dhakar received '**Best Oral Presentation Award**' during Progressive Horticulture National Symposium (PHNS-2024) on Horticulture in Himalayas at HNB Garhwal University, Srinagar Garhwal, Uttarakhand during Oct 17-19, 2024.
3. Dr Reena K Kamal received '**Best Oral Presentation Award**' for presentation of a paper 'Phenotypic characterization and behavioural traits of native chicken of Chotanagpur plateau, Jharkhand' during the XVIII Annual Convention

of Indian Society of Animal Genetics and Breeding organized at Bihar Veterinary College, BASU, Patna, Bihar during November 21-22, 2024.

4. Dr Reena K Kamal received '**Best Oral Presentation Award (2nd)**' for the paper "A study on the phenotypic characteristics and productivity of Chotanagpuri buffalo breed" in a National symposium on *Futuristic Approaches for Animal Health, Management and Welfare: Challenges and opportunities* organized by the college of veterinary Sciences & Animal Husbandry, BAU, Ranchi, Jharkhand during November 29-30, 2024.
5. Dr Akram Ahmed received '**Best Oral Presentation Award**' in the international conference on 'Advanced Agricultural Technologies for Self-Reliant Farmers and Developed India' held at KVK, Piprakothi on February 11, 2024.
6. Dr Sonaka Ghosh received '**Best Oral Presentation Award**' in the Technical Session on "Recent approaches for integrated weed management in rice and rice-based cropping systems" at the ISWS Biennial Conference on "Climate-smart Weed Management for Global Food Security" held at BHU, Varanasi during November 28-30, 2024.
7. Dr Ved Prakash received '**Best Oral Presentation Award**' in an international conference on *Agrivoltaics and sustainability in farming* organised at the Agriculture Engineering College and Research Institute, TNAU Coimbatore in collaboration with Teesside University, UK on September 19, 2024.
8. Dr Ved Prakash received '**Second Best Oral Presentation Award**' in the 6th International Conference on 'Cutting-edge solutions in science-agriculture, technology, engineering, and humanities (CSATEH-2024)' at UGC-HRDC hall, Kumaun University, Nainital, Uttarakhand during August 24-26, 2024.
9. Dr Dhiraj Kumar Singh received '**Best Oral Presentation Award**' in the National Conference on 'Next Generation Agriculture - Organic and Natural Farming Pathways: Extension Strategies and Approaches' organized at ATARI, Jabalpur during January 28-30, 2024.
10. Dr Rajni Kumari received '**Best Oral Presentation Award**' in the National Conference on Enhancing Farmer's income by livestock, poultry and aqua farming through sustainable and eco-friendly smart technologies and practices on the topic Complete mitochondrial genome of Maithili duck held during 28-29 February 2024, BVC, Patna.
11. Dr Rajni Kumari received '**Best Oral presentation Award**' in the VI International conference in hybrid mode on innovative and current advances in agriculture and allied sciences at Hanoi, Vietnam on the topic entitled "Comparative analysis of complete mitochondrial genomes of seven duck germplasms from Eastern India" during July 15-20, 2024.
12. Dr Rajni Kumari received '**Best Poster Presentation Award**' at XVIII National conference of Indian society of animal genetics and breeding on the topic Complete mitochondrial genome of Chhattisgarh and its phylogenetic analysis at BASU Patna during November 21-22, 2024.
13. Dr Rohan Kumar Raman received '**Best Oral Presentation Award**' in the International Conference on 'Advanced Agricultural Technologies for Self-Reliant Farmers and Developed India' held at Piprakothi (Bihar) on February 11, 2024.
14. Dr Rohan Kumar Raman received '**Certificate of Appreciation for Oral Presentation**' in the 74th Annual Conference of Indian Society of Agricultural Statistics on 'Harnessing Statistics and Artificial Intelligence for Sustainable and Smart Agriculture' at NM College of Agriculture, NAU, Navsari during February 2-4, 2024.
15. Dr Tanmay Kumar Koley received '**Best Oral Presentation Award**' in the 'National Conference on Managing Agro-Biodiversity in North Eastern India (NCMAN-2024)' organised by Indian

Society of Plant Genetic Resources at ICAR Research Complex for NEH Region Umiam, Meghalaya, during October23-25, 2024.

16. Dr Rakesh Kumar received the '**Best Presentation Award**' in the 3rd International Conference on Climate-Smart Nutri Sensitive Integrated Farming System for Gender-equitable Sustainable Agriculture: Prospects and Challenges (ICNSFS-2024) on the topic Molecular Characterization and phylogenetic insights of cattle Tick Rhipicephalus microplus from subtropical Mountainous terrain of Meghalaya, India, during Nov. 06-08, 2024, at ICAR-CIWA, Bhubaneswar, India.

17. Mr Banda Sainath received '**Best Oral Presentation Award**' in the International Conference on "Advanced Agricultural Technologies for Self-Reliant Farmers and Developed India" at Piprakothi (Bihar) on February 11, 2024.

Fig 24.1 Dr Anirban Mukherjee receiving '**NABARD Researcher of the Year 2023**' from the President of Indian Union for excellence in Agricultural Extension during IARI Convocation

Fig 24.2 Dr Rohan Kumar Raman receiving 'Distinguished Scientist Award-2024'

25 Intellectual Property and Scientific Assets

Technologies certified by ICAR: 10

- Agroforestry models for rehabilitation of coal mine affected areas in eastern plateau & hill region **(ICAR-NRM-RCER-Technology-2024-058)**
- Climate resilient model village developed at Gaya and Buxar districts of Bihar **(ICAR-AEXT-RCER-Model-2024-084)**
- Flood prone area identified as fruit hub in Bihar: A policy framework **(ICAR-AED-RCER-Policy-2024-019)**
- Innovative millet-based climate resilient cropping system for eastern India **(ICAR-NRM-RCER-Technology-2024-060)**
- Low cost non-weighing lysimeter for assessing nutrient leaching loss **(ICAR-NRM-RCER-Technology-2024-059)**
- Model for structural and functional analysis of makhana value chain model **(ICAR-AED-RCER-Model-2024-037)**
- Nutrigarden model addressing anemia and hypovitaminosis challenges of Eastern India **(ICAR-AEXT-RCER-Model-2024-040)**
- Strengthening export potential of farmer producer organizations (FPO) through One District One Product (ODOP): a conceptual model **(ICAR-AEXT-RCER-Policy-2024-085)**
- Technology for sustainable intensification of rice-fallow in Eastern India **(ICAR-NRM-RCER-Technology-2024-056)**
- Tephrosia biomass mulching technology for improving soil health and productivity of fruit orchard **(ICAR-NRM-RCER-Technology-2024-057)**

Varieties released: 03

- Swarna Purvi Dhan 4 (IET 29405), S.O. 4388 (E) dated October 8, 2024
- Swarna Purvi Dhan 5 (IET 29036), S.O. 4388 (E) dated October 8, 2024
- Swarna Lakshami (DBGC 3), S.O. 1560 (E), dated March 26, 2024

Patent granted: 01

- *A patent entitled "Composition and system for the preparation and analysis of fish feed enriched with curcumin"* (Patent No. IPC: A23K 50/80) was issued on January 26, 2024, by the President of the German Patent and Trademark Office, Germany

Copyright and design: 02

- *A copyright entitled* "Enhancing the crop resilience in challenging environments through nanotechnology" (L-148460/2024 dated 29.05.2024) was issued by the Government of India
- *A design entitled* "Developed design for Automated Dairy Cow Health Monitoring and Milking System with Machine Learning Integration" (Design number 6382814 dated 19.08.2024) was issued by the Government of India

NCBI accession number received: **11**

- Bacterial 16S rRNA gene sequence accession number (PQ031225, PQ037632, PQ044599, PQ037636, PQ044597, PQ008724, PQ008725, PQ044601, PQ008594, PQ008625 and PQ044602) received from NCBI, USA

26 Publication

Research papers

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

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सुधांशु शेखर, इन्द्रजीत, धर्मजीत खेरवार एवं सन्नी कुमार, 2024. "थनैला रोग" कृषि विज्ञान केन्द्र, रामगढ़, भा.कृ.अनु.प. का पूर्वी अनु. परिसर, पटना, बुलेटिन न. 220/RANCHI/85 झारखण्ड-825316

वीरेन्द्र कुमार यादव, प्रेम मोहन, अमृता सोनी, अणिमा प्रभा, बी. के.झा, पी.भावना, महेश कुमार धाकड़, विक्टर थिन्गुजम, इन्द्रजीत, सुधांशु शेखर, उज्जवल कुमार, अनूप दास "किसानो के लिए सरकारी योजनाए" भा.कृ.अनु.प. का पूर्वी अनु. परिसर, कृषि प्रणाली का पहाड़ी एवं पठारी अनुसंधान केंद्र, प्लांडू, रांची तकनीकी बुलेटिन न. E -225/Ranchi-109

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27 Personnel

Director	Dr Anup Das

Division of Crop Research
Dr Sanjeev Kumar, Principal Scientist (Agronomy) & Head
Dr AK Choudhary, Principal Scientist (Plant Breeding)
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Dr Rakesh Kumar, Senior Scientist (Agronomy)
Dr Rachana Dubey, Scientist (Environmental Science)
Dr Abhishek Kumar Dubey, Scientist (Plant Pathology)
Dr Manisha Tamta, Scientist (Agricultural Meteorology)
Dr Kumari Shubha, Scientist (Vegetable Science)
Dr Saurabh Kumar, Scientist (Agricultural Microbiology)
Dr Abhishek Kumar, Scientist (Agroforestry)

Division of Livestock & Fisheries Management
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Dr Amitava Dey, Principal Scientist (Animal Nutrition)
Dr Shanker Dayal, Principal Scientist (Animal Genetics & Breeding)
Dr Pankaj Kumar, Principal Scientist (Veterinary Medicine)
Dr PC Chandran, Principal Scientist (Animal Genetics & Breeding)
Dr PK Ray, Senior Scientist (Animal Pathology)
Dr Rajni Kumari, Senior Scientist (Animal Biotechnology)
Dr Jyoti Kumar, Senior Scientist (Veterinary Microbiology)
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Dr Dhiraj Kumar Singh, Sr Scientist (Agril Extn)
Dr Anirban Mukherjee, Scientist (Agril Extn)
Dr Rohan Kumar Raman, Sr. Scientist (Agril Statistics)
Shri Banda Sainath, Scientist (Agricultural Economics)

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Dr Shivani, Principal Scientist (Agronomy)
Dr Anil Kumar Singh, Principal Scientist (Agronomy; on Deputation)
Dr Bikash Sarkar, Principal Scientist (FMP)
Dr Ajay Kumar, Principal Scientist (SWCE)
Dr Manibhushan, Principal Scientist (Computer Application)
Dr Prem Kumar Sundaram, Senior Scientist (Farm Machinery & Power)
Dr Ved Prakash, Scientist (Agrilcultural Meteorology)
Dr Kirti Saurabh, Scientist (Soil Science)
Dr Pawan Jeet, Scientist (L&WME)

Dr Akram Ahmed, Scientist (L&WME)
Dr Arti Kumari, Scientist (L&WME)
Dr Sonaka Ghosh, Scientist (Agronomy)

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Dr SK Naik, Principal Scientist (Soil Science)
Dr Ajit Kumar Jha, Sr Scientist (Plant Pathology)
Dr Santosh Sambhaji Mali, Sr Scientist (SWCE)
Dr (Mrs) Bhavana Patnayakuni, Sr Scientist (Plant Breeding)
Dr Jaipal Singh Chaudhary, Sr Scientist (Entomology)
Dr Reshma Shinde, Scientist (Soil Science)
Dr Mahesh Kumar Dhakar, Scientist (Fruit Science)
Dr Meenu Kumari, Scientist (Hort-Veg Sci)
Dr Prerna Nath, Scientist (Food Technology)
Dr Reena Kumari Kamal, Sr Scientist (LPM)
Mr Victor Thingujam, Scientist (Agroforestry)

KVK Buxar
Dr Deo Karan, Sr Scientist cum Head
Shri Hari Govind, SMS (Agril Botany)
Shri Ramkewal, SMS (Plant Protection)
Shri Arif Parwez, STO (Farm Manager)
Shri Ravi Chatterjee, Personal Assistant
Shri Rakesh Mani, Assistant
Shri Sarfaraj Ahmad Khan, Technical Assistant (Driver)
Shri Rajesh Kumar Rai, Technical Assistant (Driver)

KVK Ramgarh
Dr Sudhanshu Sekhar, Sr Scientist cum Head
Dr Indrajeet, SMS (Agril Extension)
Dr Dharamjeet Kherwar, SMS
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Shri Roshan Kumar, LDC

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Shri PK Singh, ACTO (Field/Farm)
Shri Anil Kumar, ACTO (Computer)
Shri Sarfaraj Ahmad, STO (Computer)
Shri. Sanjay Rajput, TO (Photography)
Shri A.S. Mahapatra, STO (Field /Farm)
Shri Prem Pal Kumar, TO (Field /Farm)
Shri Ramesh Kumar, TO (Driver, Workshop)
Shri Satish Kumar, STA (Library)
Shri Manoj Kumar Sinha, STA (Field /Farm)
Shri Suresh Chandra, STA (Field /Farm)
Shri Akhila Nand Ray, TO (Driver, Workshop)
Shri Amrendra Kumar, TO (Filed/Farm)
Shri Murari Maharaj, STA (Driver, Workshop)
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Shri Subhash Kumar, Technician (Field /Farm)
Shri Manoj Kr Singh, Sr Technician (Field /Farm)
Shri Sunil Kumar, Sr Technician (Field /Farm)
Shri Surendra Kumar Yadav, Sr Technician (Field /Farm)
Shri Anand Ranu, Technician (Field /Farm)
Miss Usha Kiran, Technician (Field /Farm)
Shri Ravi Ranjan Singh, Sr Technician (Field /Farm)
Shri Tarun Kumar Rao, Technical Trainee (Technician)
Shri Vijay Babu Ram, Technical Trainee (Technician)
Shri Rajeev Ranjan Kumar, Technical Trainee (Technician)
Shri Ram Kumar Meena, Technical Trainee (Technician)
Shri Ramesh Meena, Technical Trainee (Technician)
Shri Gautam Ranjan, Technical Trainee (Technician)
Shri Ravi Kumar Meena, Technical Trainee (Technician)

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Shri Vijay Kumar Singh, TO (Lab.)
Shri Shashi Kumar Azad, TO (Field/Farm)

Shri Sagu Kachhap, Sr Technician (Field/Farm)
Shri Nagendra Kumar, Technical Trainee (Technician)
Shri Arun Kumar Yadav, Technical Trainee (Technician)
Shri Rohit Kumar Rajak, Technical Trainee (Technician)
Shri Subham Kumar, Technical Trainee (Technician)
Shri Kamlesh Kumar Meena, Technical Trainee (Technician)

Skilled Supporting Staff (FSRCHPR, Ranchi)
Shri Budhwa Lakra, SSS (Mali)
Shri Balbir Ram, SSS (Mali)
Smt Alice Lakra, SSS (Mali)
Shri Guna Munda, SSS
Smt Kathrina Lakra, SSS
Shri Ram Horo, SSS
Shri Tirathnath Mahto, SSS
Shri Binod Lakra, SSS
Smt. Shanti Munda, SSS
Smt Bahalen Ekka, SSS
Shri Doman Tirkey, SSS
Smt. Munni Kesariar, SSS
Smt Birsi Karkusa, SSS
Shri Rama Kachhap, SSS
Smt Meera Kachhap, SSS
Smt Mangri Ekka, SSS
Smt Subash Devi, SSS
Ms Kiran Lakra, SSS
Shri Umesh Kumar Nayak, MTS/SSS

Administrative staff (ICAR RCER, Patna)
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Shri Vipul Raj, AO
Shri Rajat Kumar Das, F&AO
Shri KK Lal, AF&AO
Smt Prabha Kumari, AAO
Shri Dayanand Prasad, AAO
Shri Md. Sajid Mustaque, AAO
Shri Ravi Shankar, AAO
Shri Akash Patel, Personal Assistan
Shri Madan Paswan, Assistant
Mrs Divyadarshini, Assistant
Shri Nagendra Kumar, Assistant
Shri Markanday Mishra, Assistant
Shri Rashmi Kant, Assistant
Shri Anil Kumar, Assistant
Shri Lakshmi Prasad, Assistant
Shri Arun Kumar Shukla, Assistant
Shri Himanshu Kumar, Assistant
Shri Francis Murmu, UDC
Shri Anikesh Kumar, UDC
Shri Hari Narayan Prasad, LDC
Shri Jyoti Kumar Mani, LDC
Shri Md. Hashim Ansari, LDC

Administrative Staff (FSRCHPR, Ranchi)
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Shri Keshav Kumar, Assistant
Ms Shubhra Ratnam, Assistant
Smt Ritu Rani, UDC
Shri Rajendra Prasad Gupta, UDC

Multitasking Staff
Shri Amitesh Kumar, MTS
Shri Anil Kumar, MTS

New Joining of staff during 2024

Sl.No.	Place of posting (ICAR RCER HQ/FSRCHPR, Ranchi	Name & Designation (if applicable)	Joined as	Discipline	Division/Section of posting	Date of joining
1.	ICAR-RCER, Patna (HQ)	Shri Arun Kumar Shukla	Assistant	Assistant	Administration	17.02.2024
2.	ICAR-RCER, Patna (HQ)	Shri Anikesh Kumar	UDC (on deputation)	UDC (on deputation)	Administration	19.02.2024
3.	ICAR-RCER, Patna (HQ)	Shri Sangeet Kumar	UDC (on deputation)	UDC (on deputation)	Administration	19.02.2024
4.	ICAR-RCER, Patna (HQ)	Shri Amitesh Kumar	MTS	MTS	Farm	19.02.2024
5.	ICAR-RCER, Patna (HQ)	Shri Anil Kumar	MTS	MTS	Farm	01.03.2024
6.	ICAR-RCER, Patna (HQ)	Shri Tarun Kumar Rao	Technical Trainee (Technician)	Technical Trainee (Technician)	DLFM (Dr PC Chandran, PS)	22.04.2024
7.	ICAR-RCER, Patna (HQ)	Shri Rajeev Ranjan Kumar	Technical Trainee (Technician)	Technical Trainee (Technician)	DCR (Dr N Bhakta, PS)	23.04.2024
8.	ICAR-RCER, Patna (HQ)	Shri Ramesh Meena	Technical Trainee (Technician)	Technical Trainee (Technician)	DLWM (Dr Akram Ahmad, Sr Scientist)	25.04.2024
9.	FSRCHPR, Ranchi under ICAR-RCER	Shri Nagendra Kumar	Technical Trainee (Technician)	Technical Trainee (Technician)	Dr SK Nayak, PS	26.04.2024
10.	ICAR-RCER, Patna (HQ)	Shri Vijay Babu Ram	Technical Trainee (Technician)	Technical Trainee (Technician)	DSEE (Dr Banda Sainath, Scientist)	26.04.2024
11.	ICAR-RCER, Patna (HQ)	Shri Ram Kumar Meena	Technical Trainee (Technician)	Technical Trainee (Technician)	DCR (Dr Rakesh Kumar, Sr Scientist)	29.04.2024
12.	FSRCHPR, Ranchi under ICAR-RCER	Shri Arun Kumar Yadav	Technical Trainee (Technician)	Technical Trainee (Technician)	Dr Mahesh Dhakar, Scientist	29.04.2024
13.	FSRCHPR, Ranchi under ICAR-RCER	Shri Rohit Kumar Rajak	Technical Trainee (Technician)	Technical Trainee (Technician)	Dr. Bhavna Patnayakuni, Sr. Scientist	29.04.2024
14.	ICAR-RCER, Patna (HQ)	Shri Gautam Ranjan	Technical Trainee (Technician)	Technical Trainee (Technician)	DSEE (Dr Rohan Kumar Raman, Sr Scientist)	09.05.2024
15.	FSRCHPR, Ranchi under ICAR-RCER	Shri Rajendra Prasad Gupta	UDC (on deputation)	UDC (on deputation)	Administration	10.05.2024
16.	KVK, Ramgarh	Shri Roshan Kumar	LDC	LDC	Administration	13.05.2024
17.	FSRCHPR, Ranchi under ICAR-RCER	Shri Subham Kumar	Technical Trainee (Technician)	Technical Trainee (Technician)	Dr. Reena Kumari Kamal, Sr Scientist)	09.05.2024
18.	ICAR-RCER, Patna (HQ)	Md. Hasim Ansari	LDC	LDC	Administration	16.05.2024

19.	FSRCHPR, Ranchi under ICAR-RCER	Shri Umesh Kumar Nayak	MTS	MTS	FSRCHPR, Ranchi	14.06.2024
20.	ICAR-RCER, Patna (HQ)	Mr Himanshu Kumar	Assistant	Assistant	Purchase & Store	23.09.2024
21.	KVK Ramgarh	Mr Gaurav Kumar	Assistant	Assistant	KVK, Ramgarh	24.09.2024
22.	FSRCHPR, Ranchi under ICAR-RCER	Miss Shubhra Ratnam	Assistant	Assistant	FSRCHPR, Ranchi	25.09.2024

Promotion/MACP during 2024

S.No.	Place (ICAR-RCER Patna - HQ/FSRCHPR, Ranchi, KVKs) and Division/Section	Name & Designation	Scientific/ Technical/ Administrative	From	Promoted to	Promotion date/Joining date of Promotion
1.	ICAR-RCER, Patna (HQ)	Dr Prem Kumar Sundaram, Sr. Scientist (L-12)	Scientific	Sr Scientist (L-12)	Sr Scientist (L-13A)	15.12.2022
2.	ICAR-RCER, Patna (HQ)	Dr Jyoti Kumar, Sr Scientist (L-12)	Scientific	Sr Scientist (L-12)	Sr Scientist (L-13A)	10.02.2022
3.	RC Darbhanga	Dr BR Jana, Sr Scientist (L-12)	Scientific	Sr Scientist (L-12)	Sr Scientist (L-13A)	20.11.2014
4.	ICAR-RCER, Patna (HQ)	Shri Subhash Kumar, Technician	Technical	Technician	Sr Technician	09.03.2021
5.	FSRCHPR, Ranchi under ICAR-RCER	Late Birsa Ekka, Ex-SSS	Administrative	1st MACP	2nd MACP	30.03.2014
6.	FSRCHPR, Ranchi under ICAR-RCER	Shri Bhado Mahli, SSS	Administrative	1st MACP	2nd MACP	30.03.2014
				2nd MACP	3rd MACP	30.03.2024
7.	-do-	Shri Doman Tirkey, SSS	Administrative	1st MACP	2nd MACP	30.03.2014
				2nd MACP	3rd MACP	30.03.2024
8.	-do-	Shri Balbir Ram, SSS	Administrative	1st MACP	2nd MACP	10.05.2013
				2nd MACP	3rd MACP	10.05.2023
9.	-do-	Smt. Alice Lakra, SSS	Administrative	1st MACP	2nd MACP	18.06.2014
				2nd MACP	3rd MACP	18.06.2024
10.	-do-	Shri Narayan Lohar, SSS	Administrative	2nd MACP	3rd MACP	30.03.2024
11.	-do-	Shri Madi Oraon, SSS	Administrative	2nd MACP	3rd MACP	30.03.2024
12.	-do-	Shri Samuel Tirkey,SSS	Administrative	2nd MACP	3rd MACP	30.03.2024

Transfer during 2024

S.No.	Place, whether from ICAR-RCER(HQ.), FSRCHPR, Ranchi/KVKs	Name & Designation	Scientific/ Technical/ Administrative Category	From	Transfer to	Relieving date
1.	ICAR-RCER, Patna (HQ)	Dr Jaspreet Singh, Scientist	Scientific	ICAR-RCER, Patna	NBFGR, Lucknow	28.03.2024
2.	ICAR-RCER, Patna (HQ)	Dr Karnena Koteswara Rao, Scientist	Scientific	ICAR-RCER, Patna	ICAR-NRRI Regional Station, Naira, Srikakulam, AP	23.04.2024
3.	ICAR-RCER, Patna (HQ)	Mr Govind Makrana, Scientist	Scientific	ICAR-RCER, Patna	ICAR-CSWRI, RS, Bikaner, Rajsthan	27.12.2024
4.	ICAR-RCER, Patna (HQ)	Shri Sangeet Kumar, UDC (on deputation)	Administrative	ICAR-RCER, Patna	Ammunition Factory, Khadki, Pune	06.12.2024

Relieved for joining the new assignment during 2024

Sl.No.	Place, whether from ICAR-RCER(HQ.), FSRCHPR, Ranchi/KVKs	Name & Designation	Category (Scientific/ Technical/ Administrative)	Post (new assignment) and Place of joining	Relieving date
1.	ICAR-RCER, Patna (HQ)	Shri Alok Kumar, LDC	Administrative	AFAO at ATARI, Zone-IV, Patna	21.08.2024

Retirement/Death during 2024

S.No.	Place (ICAR-RCER HQ/FSRCHPR, Ranchi/KVKs	Name & Designation	Category (Scientific/ Technical/ Administrative)	Date of Retirement
1.	ICAR-RCER, Patna (HQ)	Dr Naresh Chandra, Pr. Scientist	Scientific	31.07.2024
2.	FSRCHPR, Ranchi	Dr Arun Kumar Singh, Head	Scientific	30.11.2024
3.	FSRCHPR, Ranchi	Shri Dhananjay Kumar, STO (T-6)	Technical	30.06.2024
4.	FSRCHPR, Ranchi	Shri Madi Oraon, SSS	Supporting	31.03.2024
5.	FSRCHPR, Ranchi	Shri Narayan Lohar, SSS	Supporting	21.07.2024 (dead)
6.	FSRCHPR, Ranchi	Shri Bhado Mahli, SSS	Supporting	30.09.2024
7.	FSRCHPR, Ranchi	Shri Samuel Tirkeyi, SSS	Supporting	30.11.2024

28 On-Going Research Projects

Theme wise Ongoing Research Projects 2024

S. No.	Project code	Project title, duration and funding agency	Name of PI & Co-PIs
Theme 1. Farming System Research including Climate Resilient Agriculture Theme Leader: Head, Division of Crop Research			
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. (June 2010- Sep 2025) Funding agency: AICRP on IFS	**Sanjeev Kumar**, A Dey, Ujjwal Kumar, Kamal Sarma, Shivani, Ajay Kumar, RK Raman, Rachana Dubey, AK Dubey, Kirti Saurabh, Kumari Shubha, Saurabh Kumar & Abhishek Kumar
1.2	ICAR-RCER/ RC Ranchi/ 2019/**225**	Evaluation of organic and Natural Farming for Eastern Plateau and Hill Region. (2019 - 2025) Funding agency: ICAR-RCER	**BK Jha**, SK Naik, AK Jha, SS Mali & JS Choudhary
1.3	ICAR-RCER/ DLWM/ 2022/ **272**	Studies on efficacy of natural farming and comparison with existing farming. (2022 - 2028) Funding agency: ICAR-RCER	***Team Leader***-Anup Das ***PI*- Shivani**, Kirti Saurabh, A Upadhyaya, Pawan Jeet, Rachana Dubey, Ved Prakash, Rakesh Kumar, RK Raman, Sonaka Ghosh, Santosh Kumar, AK Dubey & Saurabh Kumar
1.4	--	Optimization of integrated farming system model design. (2023 - 2026) Funding agency: ICAR-RCER	**Manibhushan**, A Upadhyaya, Sanjeev Kumar & Akram Ahmed
1.5	--	Development of sustainable Agroforestry models for Bihar's seasonally water-stressed agro-ecosystem. (2023 - 2027) Funding agency: ICAR-RCER	**Abhishek Kumar**, Rakesh Kumar (Agronomy), Kirti Saurabh, MK Dhakar & Sanjeev Kumar
1.6	--	Standardization of organic farming practices for middle Indo- Gangetic Plains. (2023 - 2026) Funding agency: ICAR-RCER	**Kirti Saurabh**, Kumari Shubha, AK Dubey, Manisha Tamta, Govind Makarana & Abhishek Kumar ACTO -(Farm Section)
1.7	--	Pilot project for crop diversification. (2023-24 to 2027-28) Funding agency: DA&FW, MoA, GoI	**Sanjeev Kumar**, Md Monobrullah, Rakesh Kumar, DK Singh, Kirti Saurabh, Akram Ahmed, AK Dubey, Abhishek Kumar, G Makarana & Arvind K Singh (KVK, Piprakothi)
1.8	--	FLD on Mustard. (Oct. 2023 - 2024) Funding agency: DRMR, Bharatpur	**Sanjeev Kumar**, Rakesh Kumar, Shivani, DK Singh, AK Dubey & Abhishek Kumar
2.0	**Resource Conservation Technology**		
2.1	ICAR-RCER/ DCR/ EF/ 2015 / **40**	Evaluation of Conservation Agricultural (CA) practices under rice-	**Rakesh Kumar**, BK Jha, SK Naik, SS Mali & Rachana Dubey

		fallow system of Eastern Region. (2015 - 2026) Funding agency: CRP on CA (ICAR)	
2.2	ICAR-RCER/ DCR/EF/2016/	Cereal Systems Initiative for South Asia (CSISA) Phase III. (2016 - March 2025) Funding agency: CIMMYT	***Team leader-*** Anup Das ***PI-* Rakesh Kumar**, Rachana Dubey, G Makarana, Saurabh Kumar, JS Choudhary & Kirti Saurabh
2.3	--	Network project on Conservation of lac insect genetic resources (NPCLIGR). (Jan 2019 - 2026) Funding agency: AINP on CLIGR	**Abhishek Kumar** & Md Monobrullah
3.0	**Climate Resilient Agriculture**		
3.1	ICAR-RCER/ DSEE/ EF/ 2019/ **44**	Climate Resilient Agriculture Programme. (Nov 2019 – Mar 2025) Funding agency: Govt. of Bihar	***Project Leader -*** Anup Das ***PI-* Abhay Kumar**, Ujjwal Kumar, Md Monobrullah, PK Sundaram, Rakesh Kumar, DK Singh, Santosh Kumar, Rachana Dubey, RK Raman, A Mukherjee, Manisha Tamta, Saurabh Kumar, Kirti Saurabh, Ramkewal, Banda Sainath & Sarfaraj Ahmad
3.2	--	Development of Weather based Agriculture Advisory System. (2023 - 2026) Funding agency: ICAR-RCER	**Manisha Tamta**, Ved Prakash, Manibhushan, Ajay Kumar, Sanjeev Kumar, Kumari Shubha, AK Dubey, Rakesh Kumar (DLFM), RK Raman, SK Ahirwal, TK Koley & A Mukherjee
3.3	ICAR-RCER/ DCR/2023/ **283**	Rice- Fallow Management (Umbrella Project). (2023 - 2027) Funding agency: ICAR-RCER	***Project Leader-*** Anup Das, ***Nodal Officer-* Sanjeev Kumar**, ***PI-* Rakesh Kumar**, Ajay Kumar, Akram Ahmed, Manibhushan, K Banerjee (ICAR MGIFRI), DK Singh, PK Sundaram, Santosh Kumar, Pawan Jeet, Kirti Saurabh, Kumari Shubha, Rakesh Kumar (DLFM), SK Ahirwal & Ved Prakash, ***FSRCHPR Team-*** BK Jha, SK Naik, SS Mali & JS Choudhary
3.4	ICAR-RCER/ 2021/ PME/ **250**	Weed seed bank dynamics, resource-use efficiency and greenhouse gas foot print under diverse tillage production systems in Eastern Indo-Gangetic Plains. (2021 – Dec 2024) Funding agency: ICAR-RCER	**Sonaka Ghosh**, Rakesh Kumar, Rachana Dubey, RK Raman, Saurabh Kumar, Ved Prakash & Kirti Saurabh
enetic Resource Management and Improved Production Technologies Theme Leader: Head, FSRCHPR, Ranchi			
4.0	**Varietal Development**		
4.1	ICAR-RCER / HARP/ 2001/ **03**	Plant genetic resource and improvement of fruit crops. (2021 – long term) Funding agency: ICAR-RCER	**MK Dhakar**, JS Choudhary, D Kherwar, TK Koley & Victor T
4.2	Umbrella project on plant genetic resource and improvement of vegetable crops		
4.2.1	ICAR-RCER/ RC	Genetic resource management of	**AK Singh**, P Bhavana, RS Pan, VK Yadav,

	Ranchi/ 2017/ **215**	vegetable crops. (Sep 2017 – long term) Funding agency: ICAR-RCER	JS Chaudhary, AK Jha & Meenu Kumari
4.2.2	ICAR-RCER/ RC Ranchi/ 2021/ **278**	Evaluation of vegetable soybean for horticultural and nutritional traits. (Jul 2021 - Jun 2026) Funding agency: ICAR-RCER	**RS Pan**, Meenu Kumari, Reshma Shinde & Sujit Bishi (ICAR-IIAB, Ranchi)
4.2.3	ICARRCER/RC Ranchi/ 2021/ **274**	Improvement of French bean for disease resistance. (Jul 2021 - Jun 2025) Funding agency: ICAR-RCER	**Meenu Kumari**, RS Pan, AK Jha & JS Chaudhary
4.2.4	ICAR-RCER/DCR/2021/**255**	Genetic enhancement of selected vegetable legumes for Eastern India. (2021 - 2025) Funding agency: ICAR-RCER	**Kumari Shubha**, AK Choudhary, AK Dubey, RS Pan & VK Padala
4.3	ICAR-RCER/ RC Ranchi/ 2019/ **226**	Development of multiple disease resistant hybrids in solanaceous vegetables. (2019 – 2024) Funding agency: ICAR-RCER	**P Bhavana**, AK Singh, AK Jha & JS Choudhary
4.4	ICAR-RCER/ RC Ranchi/ 2020/ **244**	Genetic enhancement of pigeon pea for yield and biotic stress resistance. (Jun 2020 - Dec 2025) Funding agency: ICAR-RCER	**P Bhavana**, Kishor Tribhuvan (ICAR-IIAB), JS Choudhary & AK Jha
4.5	--	IRRI NARES Breeding Network (Plant Direct) Project (Erstwhile Accelerated Breeding: Meeting Farmers Needs with Nutritious, Climate-Resilient Crops). (Jul 2022 - Dec 2027) Funding agency: ICAR–IRRI	**Santosh Kumar**, Rakesh Kumar, AK Dubey & Sonaka Ghosh
4.6	--	Evaluation and characterization of rice genotypes for tolerance to drought and submergence. (Jul 2023 - Jun 2026) Funding agency: ICAR-RCER	**Santosh Kumar,** Abhay Kumar, Rakesh Kumar & Rachana Dubey
4.7	--	Studies on genetic variability and molecular marker associated with Maydis leaf blight in maize. (2023 - 2027) Funding agency: ICAR-RCER	**P Bhavana**, AK Jha, Santosh Kumar, AK Dubey, Ganpati Mukri (IARI, New Delhi), Jayant S Bhat (IARI, RRC, Dharwad) & Chikkappa GK, IIMR, Begusarai
4.8	--	Building lentil growing community resilience by the development of climate smart lentil varieties through farmer's participatory interventions. (2023 - 2026) Funding agency: DA &FW	**AK Choudhary** & G Makarana
5.0	**Production Technologies**		
5.1	--	Creation of seed hubs for increasing indigenous production of pulses in India. (2016 - 2025) Funding agency: ICAR-RCER	**AK Choudhary**, G Makarana & Hari Govind (KVK, Buxar)

5.2	ICAR-RCER/ DCR/ 2020/ **236**	Standardization of agro-techniques in nutri-cereals for enhancing the productivity in eastern Indo-Gangetic plains. (Jul 2020 - Dec 2025) Funding agency: ICAR-RCER	**Rakesh Kumar** & N Bhakta
5.3	ICAR-RCER/ DCR/ 2021/ **257**	Sustainable fodder production system under different nitrogen and zinc management practices in eastern India. (2021 - 2025) Funding agency: ICAR-RCER	**G Makarana**, Sanjeev Kumar, A Dey & Saurabh Kumar
5.4	--	Understanding temporal variation in fruit maturity behaviour of litchi growing in Jharkhand and Bihar. (Jul 2022 – Jun 2025) Funding agency: ICAR-RCER	**MK Dhakar**, SS Mali, SK Naik, SD Pandey (ICAR- NRC for Litchi, Muzaffarpur), Dr SK Mehta (ICAR- NRC for Litchi, Muzaffarpur)
5.5	--	Promotion of Commercial Custard Apple Cultivation in Jharkhand. (Apr 2022 – Mar 2025) Funding agency: MIDH	**MK Dhakar** & Meenu Kumari
5.6	ICAR-RCER/ RC Ranchi/ 2022/ **277**	Development of technology for post-harvest management and value addition of jackfruit in Eastern region. (Jan 2022 - 2025) Funding agency: ICAR-RCER	**Prerna Nath**, MK Dhakar, Ajit Kumar Jha, Abhishek Kumar & SJ Kale (ICAR-NISA, Ranchi)
5.7	--	Utilization of major fruit seeds and Underutilized fruits for development of functional food products. (2023 - 2026) Funding agency: ICAR-RCER	**TK Koley**, MK Dhakar, RK Raman, Ujjwal Kumar, Prerna Nath & Kirti Saurabh
6.0	**Protection Technologies**		
6.1	ICAR-RCER/ RC Ranchi/ 2021/ **273**	Insect pest dynamics in litchi and their linking with digital tools for better management. (Jul 2021 - Jun 2026) Funding agency: ICAR-RCER	**JS Choudhary**, SS Mali, MK Dhakar & SK Mehta
6.2	ICAR-RCER/ RC Ranchi/ 2021/ **276**	Morphological and molecular characterization of bottle gourd wilt complex. (Jul 2021 - Jun 2025) Funding agency: ICAR-RCER	**Ajit Kumar Jha**, JS Chaudhary, P Bhavana, Meenu Kumari & AK Singh
6.3	--	Management of false smut through modification in sowing dates and establishing disease relation with weather parameters. (2022 - 2026) Funding agency: ICAR-RCER	**AK Dubey**, Santosh Kumar, Manisha Tamta & G Makarana
Theme- 3. Natural Resource Management for Enhancing Land & Water Productivity **Theme Leader: Head, Division of Land and Water Management**			
7.0 Land & Water Management			
7.1	--	Umbrella project on floodplains of Eastern India	
7.1.1	ICAR-RCER/ DCR/ 2020/ **252**	Collection, evaluation and characterization of popular rice landraces in floodplains of eastern	**N Bhakta** & AK Dubey

		India. (Jul 2020 – Jun 2025) Funding agency: ICAR-RCER	
7.1.2	ICAR-RCER/ DSEE/ 2020/ **242**	Resource inventorization of floodplain wetlands in eastern India. (Jul 2020 - Jun 2025) Funding agency: ICAR-RCER	**RK Raman**, Jyoti Kumar, DK Singh & V Bharti
7.1.3	ICAR-RCER/ DLWM/ 2020/ **251**	Mapping of flood in eastern India and its management strategies. (Jul 2020 - Dec 2024) Funding agency: ICAR-RCER	**Akram Ahmed** & Shivani
7.1.4	ICAR-RCER/ DLWM/ 2021/ **267**	Resource assessment and management framework for sustainable fisheries in selected wetland. (2021 - 2025) Funding agency: ICAR-RCER	**V Bharti**, T Kumar, RK Raman & SK Ahirwal
7.2	ICAR-RCER/ DCR/ 2021/ **266**	Assessment of bacterial diversity and characterization of PGPR in arsenic contaminated soil. (Jan 2021 - Dec 2024) Funding agency: ICAR-RCER	**Saurabh Kumar**, Kirti Saurabh, Rachana Dubey & SK Naik (Associate)
7.3	--	Determining optimum decision variables in furrow irrigated system. (2022 - 2025) Funding agency: ICAR-RCER	**Ajay Kumar**, A Upadhyay, Sanjeev Kumar, Pawan Jeet & Kirti Saurabh
7.4	--	Simulation of soil water dynamics in rice-wheat-moong bean cropping system. (2022 - 2026) Funding agency: ICAR-RCER	**A Upadhyaya**, Pawan Jeet & Kirti Saurabh
7.5	--	Multiple use of water for enhanced agricultural productivity in eastern India. (2023 - 2028) Funding agency: ICAR-RCER	***Project leader-*** Anup Das ***PI* : A. Upadhyaya**, Akram Ahmed, Ajay Kumar, Shivani, Rachana Dubey, Pawan Jeet, TK Koley, Ved Prakash, SK Ahirwal, MK Tripathi, Abhishek Kumar, Arti Kumari (Associate), AS Mahapatra & MK Sinha
7.6	--	Evaluation of the diara ecosystem for sustainable food production. (2023 – 2026) Funding agency: ICAR-RCER	***Project leader-*** Anup Das ***PI* : A Dey**, Abhay Kumar, Sanjeev Kumar, Md. Monobrullah, N Bhakta, Akram Ahmed, TK Koley, Kamal Sarma, RK Raman, PK Sundaram, Saurabh Kumar, Kirti Saurabh, M Debnath & Banda Sainath
7.7	--	Energy flow, C balance, and water footprint of dominant cropping system under different agro- ecological region of eastern India. (2023 - 2026) Funding agency: ICAR-RCER	**Bikash Sarkar**, PK Sundaram, Rakesh Kumar & SS Mali
7.8	--	Performance evaluation of Solar-powered pumping for Low Energy Pressurized Irrigation. (2023 - 2026) Funding agency: ICAR-RCER	**Akram Ahmed**, A Upadhyaya, Ved Prakash, Shivani, M Debnath, Ajay Kumar & Mukesh Kumar CIAE, Bhopal
7.9		**Modified title:**	**SK Naik**, SS Mali, JS Chaudhary, Rakesh

	--	Rice and Millet based cropping system of Eastern Plateau and Hill Region. **Previous Title:** Evaluation of tillage and crop Establishment methods on productivity, resource use efficiency and soil health in rice mustard greengram cropping system of eastern plateau and hill region. (2023 - 2028) Funding agency: ICAR-RCER	Kumar (Agronomy) & BK Jha
7.10	--	Development of solar photovoltaic powered agricultural machineries. (2023 - 2026) Funding agency: ICAR-RCER	**PK Sundaram**, Bikash Sarkar, Pawan jeet, SS Mali, Kamal Sarma, A Dey & Rakesh Kumar (DLFM)
7.11	--	Water budgeting in various rice establishment techniques. (2023 - 2026) Funding agency: ICAR-RCER	**M Debnath**, Ajay Kumar, Arti Kumari & Rakesh Kumar (Associate)
Theme-4. Livestock and Fisheries Management Theme Leader: Head, Division of Livestock and Fisheries Management			
8.0 Livestock and Avian Management			
8.1	ICAR-RCER /DLFM/ EF/ 2011/ **31**	Network project on Buffalo improvement. (Jun 2012 - Mar 2025) Funding agency: ICAR-RCER	**PC Chandran**, Pankaj Kumar, PK Ray, Rakesh Kumar, Rajni Kumari & A Dey (Associate)
8.2	--	AICRP on Goat Improvement. (Jul 2019 - Mar 2025) Funding agency: ICAR	**Shanker Dayal**, PC Chandran, PK Ray, MK Tripathi & Rakesh Kumar
8.3	ICAR-RCER/ DLFM/ 2020/**243**	Assessment of antimicrobial drug resistance in bacteria of animal origin. (Jul 2020 - Jun 2025) Funding agency: ICAR- RCER	**Jyoti Kumar**, Shanker Dayal & PK Ray
8.4	ICAR-RCER/ DLFM/ 2021/ **254**	Reproductive abnormalities and associated common pathogens in special reference to Leptospirosis. (2021 - 2026) Funding agency: ICAR-RCER	**Pankaj Kumar**, MK Tripathi, A Mukherjee & Manish Kumar (IITG)
8.5	ICARRCER/ DLFM/ 2021/ **268**	Exploring genetic basis of Mastitis resistance in livestock. (2021 - 2025) Funding agency: ICAR- RCER	**Shanker Dayal**, Rajni Kumari, Jyoti Kumar, PC Chandran, MK Tripathi & Rakesh Kumar
8.6	ICAR-RCER/ DLFM/ 2022/ **258**	Effect of environmental exposure of arsenic in animals of Bihar. (Jan 2022 - Dec 2026) Funding agency: ICAR-RCER	**MK Tripathi**, Pankaj Kumar, A Dey, Kamal Sarma, V Bharti & Arun Kumar (Mahavir Cancer Institute & Research Centre)
8.7	ICAR-RCER/ RC Ranchi/ 2022/ **275**	Characterization & evaluation of chicken germplasm in eastern region. (2022 - 2026) Funding agency: ICAR-RCER	**Reena K Kamal**, A Dey, PC Chandran & Kanaka KK, (ICAR-IIAB)
8.8	ICAR-RCER/ DLFM/ 2022/ **286**	Identification and characterization of common Zoonotic pathogens in domestic animals. (2022 - 2026)	**PK Ray**, Jyoti Kumar, PC Chandran & Rakesh Kumar

		Funding agency: ICAR- RCER	
8.9	ICAR-RCER/ DLFM/ 2022/ **280**	Study of Genetic polymorphisms of candidate genes associated with production traits in Goats in Eastern Region. (2022 -2026) Funding agency: ICAR- RCER	**Rakesh Kumar**, Shanker Dayal, PK Ray, MK Tripathi, Rajni Kumari & PC Chandran
8.10	--	Assessment of ecosystem services rendered by indigenous livestock, poultry species & breed. (2023 - 2026) Funding agency: ICAR- RCER	**A Dey**, PC Chandran, RK Raman, RK Kamal, Rachana Dubey & Banda Sainath
8.11	ICAR-RCER/ DLFM/ 2023/ **282**	Status of fluorosis in livestock of Bihar and evaluating the ameliorative effect of nutraceuticals on affected cattle population. (2023 - 2026) Funding agency: ICAR- RCER	**Pankaj Kumar**, Manoj K Tripathi, Saurabh Kumar, VS Sinha (KVK Harnaut) & Jaspreet Singh
8.12	ICAR-RCER/ DLFM/ 2023/ **281**	Transcriptome and metagenome approach to characterize the genetic basis of prolificacy in goat. (2023 - 2026) Funding agency: ICAR- RCER	**Rajni Kumari**, A Dey, Shanker Dayal, PC Chandran, PK Ray, Jyoti Kumar, Manoj Tripathi, Rakesh Kumar, Ramesh Tiwary (BVC, Patna), Ramesh Pandit (GBRC, Gandhinagar & CG Joshi (GBRC, Gandhinagar)
9.0 Fisheries Management			
9.1	ICAR-RCER/ DLFM/ 2023/ **285**	Standardization of culture techniques of Pabda fish in eastern region of India. (2023 - 2026) Funding agency: ICAR- RCER	**Tarkeshwar Kumar**, Kamal Sarma, SK Ahirwal, Jaspreet Singh & V Bharti
9.2	--	Geospatial distribution and characteristics of microplastics in the riverine ecosystems of the Eastern Region India. (2023 – 2026) Funding agency: ICAR- RCER	**V Bharti**, Kamal Sarma, Jaspreet Singh, T Kumar & SK Ahirwal
Theme- 5. Socio-Economics, Extension and Policy Research **Theme Leader: Head, Division of Socio-Economics and Extension**			
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. (Jun 2018 - Mar 2025) Funding agency: Farmer FIRST Project	**VK Yadav**, RS Pan, AK Jha, Reena K Kamal, SK Naik, Anirban Mukherjee, PK Sundaram, NK Sinha (ICAR- NISA), Saumen Naskar (ICAR- IIAB) & SK Gupta (ICAR- IIAB)
10.2	ICAR-RCER/ DSEE/ 2019/ **230**	Status of utilization of digital tools in agriculture sector in Eastern India. (Oct 2019 - Sep 2024) Funding agency: ICAR- RCER	**Ujjwal Kumar**, DK Singh, RK Raman, TK Koley, PC, KVK Buxar Indrajeet, SMS, KVK Ramgarh
10.3	--	Agri-Business Incubation Project. (2020 – 2025) Funding agency: NAIF	**AK Singh**, Ujjwal Kumar, P Bhavana & TK Koley
10.4	--	ITMU Project (NAIF Component I). (2011 – long term) Funding agency: NAIF	**P Bhavana**, AK Singh & A Dey

10.5	ICAR-RCER/ DSEE/ 2021/ **246**	Model based inference on agricultural crops for food security in Eastern India. (2021 – 2024) Funding agency: ICAR- RCER	**RK Raman**, Abhay Kumar, Ujjwal Kumar & Akram Ahmed
10.6	ICAR-RCER/ DSEE/ 2021/ **245**	Impact of e-NAM on improving marketing of agricultural produce in eastern India. (2021 – Dec 2024) Funding agency: ICAR- RCER	**Dhiraj Kr Singh**, Abhay Kumar, VK Yadav & A Mukherjee
10.7	--	Sustainability of FPO in eastern India. (2023 – 2026) Funding agency: ICAR-RCER	**VK Yadav**, A Mukherjee, RK Raman, Subhadeep Roy (ICAR-IIVR), Kaushik Pradhan (UBKV), Lipi Das (ICAR-CIWA) & Sujay Kademani (ICAR-IIAB)
10.8	--	Assessing the impact of climate resilient agricultural interventions in enhancing farmers adaptive capacity in Bihar. (2023 – 2026) Funding agency: ICAR- RCER	**A Mukherjee**, DK Singh, RK Raman, Manisha Tamta, Rakesh Kuma (Agronomy), Ujjwal Kumar, Abhay Kumar, Ramkewal (KVK Buxar), Ashok Kumar KVK, Gaya) & Banda Sainath
10.9	--	Participatory Research Application for Yearround income and Agricultural Sustainability (PRAYAS). (2023 – 2026) Funding agency: ICAR- RCER	***Project leader-*** Anup Das, ***Nodal Officer-*** Bikash Sarkar, ***PI-* Anirban Mukherjee** ***CCPI:*** **Assam:** K Sarma, **Bihar:** PK Sundaram, **Chhattisgarh:** BK Jha, **Eastern UP:** DK Singh, **Jharkhand:** SS Mali, **Odisha:** SK Naik, **West Bengal:** Bikash Sarkar
10.10	--	Development of zero hunger and zero technology gap village through innovative interventions. (Oct 2023 – Sep 2026) Funding agency: ATARI, Patna and ICAR- RCER, Patna	***Project leader(s)***-Anup Das & Anjani Kumar, ***PI-* Dhiraj Kr. Singh** ***Team members*:** Ujjwal Kumar, Abhay Kumar, Md Monobrullah, Rakesh Kumar (Agronomy), A Mukherjee, RK Raman, Arti Kumari, Jyoti Kumar, Kumari Shubha, Amarendra Kumar (ATARI, Patna), Pragya Bhaduria (ATARI, Patna), Deokaran (KVK,Buxar) & Ramkeval (KVK, Buxar)
10.11	--	Sustainable improvement in livelihood of SC community in Meskaur and Sirdala block of Nawada district, Bihar. (Jan 2024 – Dec 2026) Funding agency: DST	**DK Singh**, Ujjwal Kumar, A Mukherjee, Shivani, Rakesh Kumar, Kumari Shubha, PC Chandran, RK Raman & Banda Sainath
10.12	--	Building Resilience Model for the Vulnerability Hotspot to Climate change in small holder Dairy Production System of Indo Gangetic plains Region of India Using GIS and Fuzzy Cognitive Mapping Approach. (Sep 2023 – Sep 2026) Funding agency: NASF	**Anirban Mukherjee**, Abhay Kumar, Pankaj Kumar, Kumari Shubha, MK Tripathi, Banda Sainath & Rakesh Kumar (DLFM)

Theme Wise Concluded Research Projects 2023-24

Sl. No.	Project code	Project title, duration and funding agency	Name of PI & Co-PIs
Theme 1. Farming System Research including Climate Resilient Agriculture			
1.0	**Integrated Farming System and Cropping System for Eastern Region**		
1.1	ICAR-RCER/RCRanchi /2020/ **237**	Development of multipurpose trees and medicinal plants-based agroforestry models for Eastern Plateau and Hill Region. (2020 – 2024) Funding agency: ICAR RCER	**Reshma Shinde**, MK Dhakar & Abhishek Kumar
3.0	**Climate Resilient Agriculture**		
3.1	--	Climate change impact studies at selected location in Bihar. (2021 – 2024) Funding agency: ICAR-RCER	**Ved Prakash**, Kirti Saurabh, Sonaka Ghosh, A Upadhyaya & Akram Ahmed
enetic Resource Management and Improvement of Field, Horticultural and Aquatic crops			
4.0	**Varietal Development**		
4.1	ICAR RCER/DLWM /2021/ **271**	Development of high moisture tolerant pigeon pea and its agronomic practices for eastern India. (2021 – 2024) Funding agency: ICAR-RCER	**AK Choudhary**, A Upadhyay, Kirti Saurabh, Md Monobrullah, Pawan Jeet & Yasin JK (NBPGR)
Theme- 3. Improved Production and Protection Technologies for Agri-Horti Crops			
5.0	**Production Technologies**		
5.1	ICAR-RCER/ RCRanchi/ 2020/**238**	Standardization of basin enrichment in bearing orchards of Bael, Mango and Guava under eastern plateau and hill region. (2020 – 2024) Funding agency: ICAR-RCER	**MK Dhakar** & Reshma Shinde
5.2	--	Phosphorous mobilization through organic amendments in acidic soils of Hill and Plateau region. (2021 – 2024) Funding agency: ICAR-RCER	**Reshma Shinde**, SK Naik & AK Jha
5.3	ICAR-RCER/DSEE/2021/**261**	Standardization of hydroponic technology for horticultural crops. (2021 – 2024) Funding agency: ICAR-RCER	**TK Koley**, Kumari Shubha, PK Sundram & A Rahman
5.4	--	Effect of nano-DAP fertilizer on the performance and yield of rice-wheat crop. (2021 – 2024) Funding agency: IFFCO	**Kirti Saurabh**, Santosh Kumar, Ved Prakash, Sonaka Ghosh, AK Dubey & G Makarana
6.0	**Protection Technologies**		
6.1	--	Bio-intensive management of fall armyworm (*Spodoptera frugiperda*) on maize. (2022 – 2026) Funding agency: ICAR-RCER	**Md Monobrullah** & AK Dubey
Theme- 4. Integrated Land & Water Management			
7.0 Land & Water Management			
7.1	ICAR-RCER/DLW/ 2020/ **234**	Land feasibility analysis for rainwater harvesting planning at watershed level in Nalanda, Bihar. (2020 - 2024) Funding agency: ICAR-RCER	**Pawan Jeet** & A Upadhyaya

7.2	ICAR- RCER/DLWM/ 2020/ **239**	Refinement of indigenous plough and weeding rake in Eastern Hill and Plateau region. (2020 - 2023) Funding agency: ICAR-RCER	**Bikash Sarkar**, PK Sundaram & DK Raghav (Associate)
7.3	--	Rhizosphere microbiome of high yielding rice cultivars in arsenic contaminated Indo-Gangetic Plains and their application for arsenic amelioration in rice grains. (2021 – 2024) Funding agency: DST-SERB	**Saurabh Kumar**
7.4	ICAR-RCER/ DLWM/ 2021/**260**	Irrigation and nitrogen management of diversified rice based cropping system in middle Indo-Gangetic Plains. (2021 - 2024) Funding agency: ICAR-RCER	**Shivani**, Kirti Saurabh & Akram Ahmed
7.5	ICAR-RCER/ DLWM/ 2021/**269**	Design and development of motorized cole crop harvester. (2021 - 2024) Funding agency: ICAR-RCER	**PK Sundaram**, Bikash Sarkar & A Rahman
7.6	--	Integrated Modeling approach for developing drought management strategies in the Sakri river basin, Bihar and Jharkhand. (2021 – 2024) Funding agency: ICAR-RCER	**Pawan Jeet,** AK Singh, Ajay Kumar & Arti Kumari
7.7	--	Assessment of Evapotranspiration and Crop Coefficients of fruit crops using Remotely Sensed Data and METRIC approach. (Jul 2022 – Jun 2024) Funding agency: ICAR-RCER	**SS Mali**, SK Naik, MK Dhakar & Akram Ahmed
Theme- 5. Livestock & Fisheries Management			
8.0 Livestock and Avian Management			
8.1	ICAR- RCER/ DLFM/ 2018/**202**	Assessing genetic variability in ducks of eastern states. (2018 - 2024) Funding agency: ICAR-RCER	**Rajni Kumari**, PK Ray, S Dayal & RK Kamal (Associate)
8.2	ICAR-RCER/ DLFM/ 2019/ **231**	Development of meat and egg strains of duck suitable for backyard farming. (2019 - 2024) Funding agency: ICAR-RCER	**PC Chandran**, RK Kamal, A Dey & Rajni Kumari
8.3	--	Evaluation of traditionally used growth promoters on production performances in pig and poultry. (Jul 2020 – 2024) Funding agency: ICAR-RCER	**Reena K Kamal**, A Dey, Sushil Prasad & Singrav S Kullu
8.4	ICAR-RCER/ DLFM/ 2021/EF/**45**	Model project and Demonstration unit for backyard poultry, livestock, vermifarming, and Moringa Integration (DAHD under RKVY). (2021 – 2023) Funding agency: DAHD (under RKVY)	**RK Kamal**, Rakesh Kumar, A Dey, PC Chandran, Jyoti Kumar, PK Ray & V Bharti
9.0 Fisheries Management			
9.1	ICAR-RCER/ DLFM/2020/**241**	Effect of different manures on fish productivity. (Jul 2020 – 2024) Funding agency: ICAR-RCER	**Kamal Sarma**, T Kumar, Jaspreet Singh, Jyoti Kumar, A Dey, SK Ahirwal & S Mondal (Associate)

Theme- 6. Socio-Economics, Extension and Policy Research			
10.0 Socio-economic Research			
10.1	--	Value addition of principal food grains by farmers of Bihar. (2018 – 2023) Funding agency: ICAR-RCER	**N Chandra**, Ujjwal Kumar, DK Singh & PK Sundaram

Theme wise Approved New Research Projects 2024-25

Sl. No.	Project code	Project title, duration and funding agency	Name of PI & Co-PIs
Theme 1. Farming System Research including Climate Resilient Agriculture			
2.0	**Resource Conservation Technology**		
2.1	New	Characterization and appraisal of soil microbiome under conservation agriculture. (Jul 2024 – Jun 2025) Funding agency: ICAR-RCER	**Sonaka Ghosh**
3.0	**Climate Resilient Agriculture**		
3.1	New	Village-level Carbon Budgeting through Climate Resilient Interventions. (Jul 2024 – Jun 2027) Funding agency: ICAR-RCER	**Rachana Dubey**, Banda Sainath, Saurabh Kumar, Abhay Kumar & VS Meena (IARI, RS, Pusa, Samastipur)
enetic Resource Management and Improved Production Technologies			
4.0	**Varietal Development**		
4.1	New	Development of bio-fortified varieties of vegetables. (Aug 2024 - Jul 2029) Funding agency: ICAR-RCER	**Meenu Kumari**, RS Pan, P Bhavna, Reshma Shinde, Prerna Nath & TL Bhutia (ICAR-RC NEH Region)
4.2	New	Evaluation, characterization and identification of high yielding finger millet genotypes for eastern India. (Mar 2024 – Feb 2028) Funding agency: ICAR-RCER	**N Bhakta**, AK Choudhary, Rakesh Kumar, Santosh Kumar, RK Raman & AK Dubey
5.0	**Production Technologies**		
5.1	New	Processing and value addition of soybeans. (Aug 2024 – Jul 2027) Funding agency: ICAR-RCER	**Prerna Nath**, RS Pan & SJ Kale (IINRG)
5.2	New	Nutritional Profiling of Low-BOAA Grass Pea (*Lathyrus sativus* L.) Germplasm for Green Leafy Vegetables in rice –fallow system. (Jul 2024 - Jun 2025) Funding agency: ICAR-RCER	**Kumari Shubha**
5.3	New	Development of spineless cactus and MPTs based Silvi-pastoral system. (Jul 2024 - Jun 2027) Funding agency: ICAR-RCER	**Victor T**, BK Jha, RK Kamal & Reshma Shinde
Theme- 3. Integrated Land & Water Management			
7.0 Land & Water Management			
7.1	New	Design and development of portable soil and water controlling device under field-to-field irrigation practice. (Jul 2024 – Jun 2027) Funding agency: ICAR-RCER	**Pawan Jeet**, Arti Kumari, PK Sundaram, Kirti Saurabh & A Upadhyaya
7.2	New	Sensor-Based Lysimeter: Precise crop evapotranspiration estimation and stage-wise crop coefficient development for selected	**Arti Kumari**, Pawan Jeet, PK Sundaram, Ved Prakash, Kirti Saurabh, Shivani & A Upadhyaya

		Crops. (Jul 2024 – Jun 2028) Funding agency: ICAR-RCER	
Theme- 4. Livestock & Fisheries Management			
8.0 Livestock and Avian Management			
8.1	New	Impact of phytobiotics on Health and Productivity of Swine. (Jul 2024 – Jun 2027) Funding agency: ICAR-RCER	**RK Kamal**, PC Chandran, Victor T, A Dey (Associate), PK Ray (Associate), Ganesh Aderao (IIAB), Nikhil (IIAB) & Sudhanshu Shekhar, KVK, Ramgarh (Associate)
9.0 Fisheries Management			
9.1	New	Assessment of wetland ecosystem services in food production. (Jul 2024 – Jun 2029) Funding agency: ICAR-RCER	**V Bharti**, Tarkeshwar, Kumar, RK Raman, Rachana Dubey, G Makarana *& Associate* Kirti Saurabh
9.2	New	Seed rearing potential of *Pangasianodon hypophthalmus* (Sauvage, 1878) in biofloc system. (Aug 2024 – Jun 2027) Funding agency: ICAR-RCER	**Kamal Sarma**, T Kumar, V Bharti & SK Ahirwal
Theme- 5. Socio-Economics, Extension and Policy Research			
10.0 Socio-economic Research			
10.1	New	Unlocking Green Gains: Assessment of voluntary carbon credit potential in Bihar. (Jul 2024 – Jun 2027) Funding agency: ICAR-RCER	**Banda Sainath**, A Mukherjee, Rachana Dubey, Ujjwal Kumar, Abhay Kumar, DK Singh & RK Raman

New and on-going activities 2024

S. No.	Title of Activities	PI
New Activities		
1.	Effect of water deficit and heat stress on wheat: changes in plant physiological traits & yield	Santosh Kumar and Rachana Dubey
Ongoing Activities		
1.	Breeding for submergence tolerance in rice	N Bhakta
2.	Evaluation and development of drought tolerant rice for Eastern region	Santosh Kumar
3.	Development of nutrient rich lines of pulse legumes for eastern India	AK Choudhary
4.	Maintenance of advance breeding lines of cool season pulses	AK Choudhary
5.	Enhancing nutritional security of rural households through vegetable based nutri-garden in Bihar	Kumari Shubha
6.	Enhancing nutritional security of rural households through fruit-based system.	TK Koley Kumari Shubha
7.	To develop DSS tool for prioritization of rice fallow areas	Manibhusan
8.	Integrated crop and nutrient management for sustainable intensification in Eastern India.	Shivani, Kumari Shubha Kirti Saurabh & Abhishek Kumar (ACTO)
9.	Multi-objective optimization of integrated farming system	Akram Ahmed

Notes

Notes

प्रभावी जल प्रक्षेत्र, सबजपुरा, आईसीएआर आरसीईआर, पटना

Water Smart Farm, Sabajpura, ICAR RCER, Patna

भाकृअनुप
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