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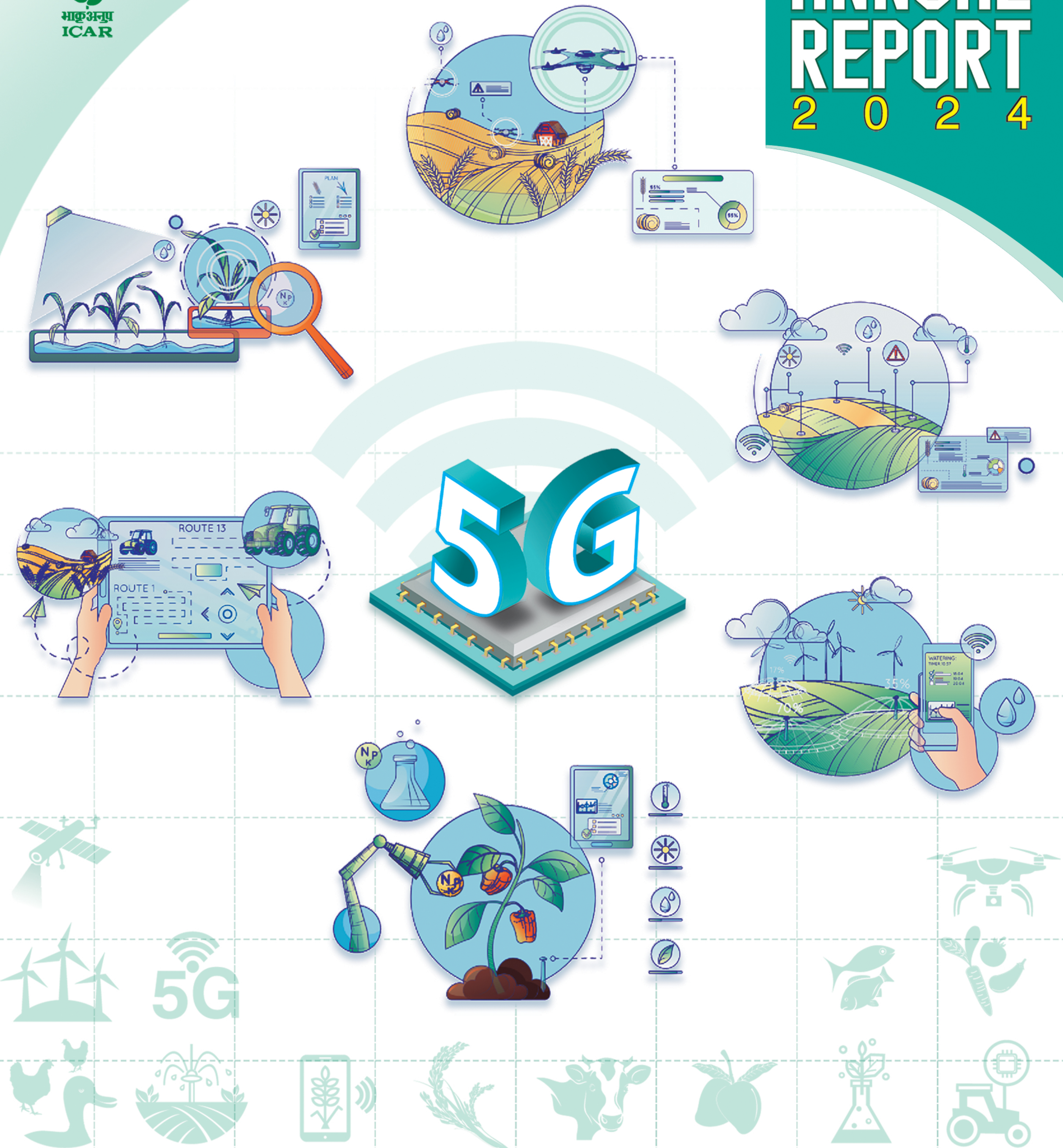
ICAR

वार्षिक प्रतिवेदन
ANNUAL REPORT
2024



CRRI
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भारतीय कृषि अनुसंधान परिषद
ICAR-Central Rice Research Institute
Indian Council of Agricultural Research

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भाकृअनुप - केंद्रीय चावल अनुसंधान संस्थान
कटक (ओडिशा) 753 006, भारत

ICAR - Central Rice Research Institute
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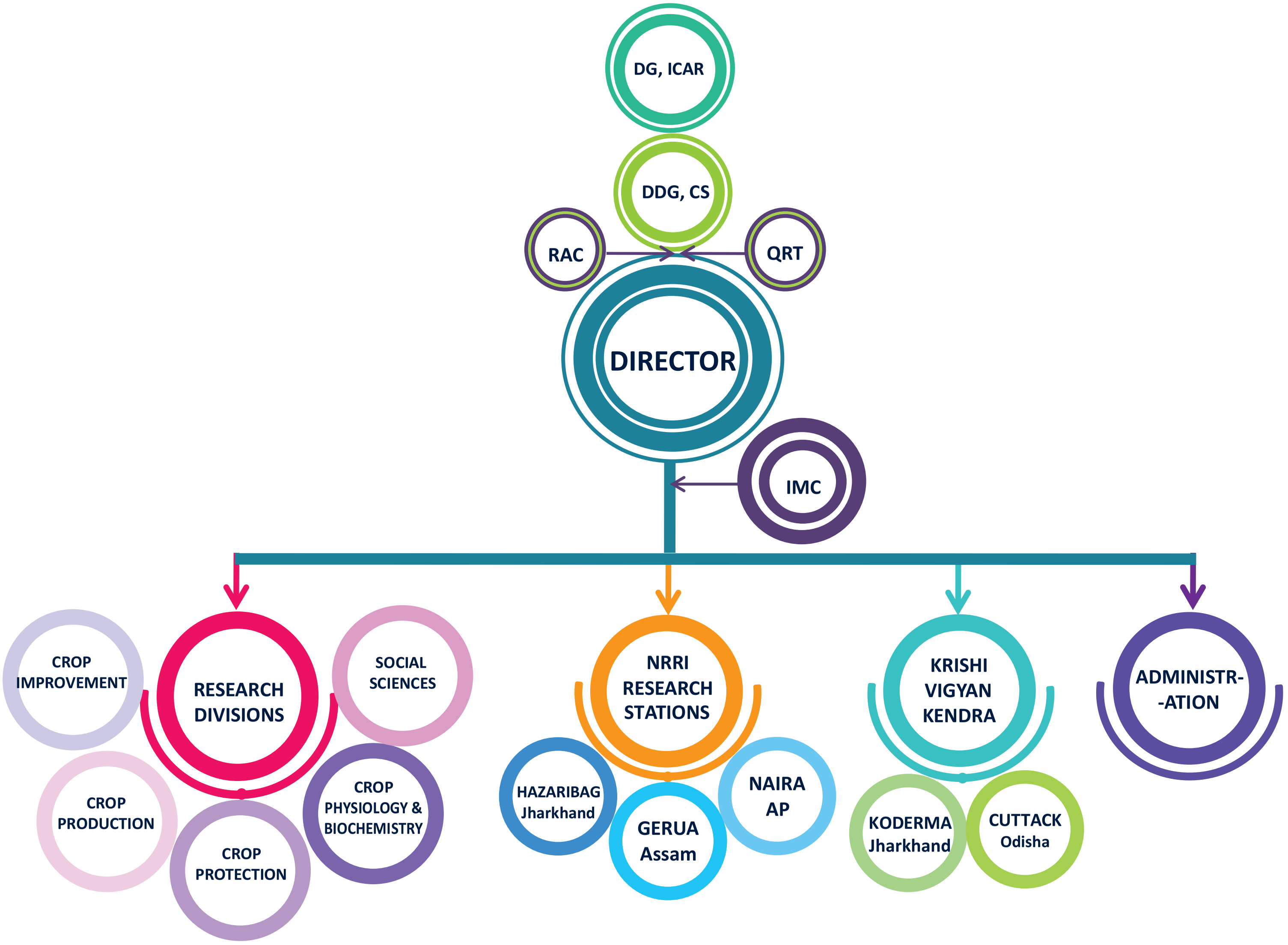

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ADMINISTR-
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Preface

I am pleased to present the Annual Report 2024 of the ICAR-Central Rice Research Institute (ICAR-CRRI), highlighting our key achievements and contributions towards advancing rice research and development. This year has been marked by significant progress in developing climate-resilient rice varieties, innovative agronomic practices, and cutting-edge technological interventions aimed at enhancing productivity, sustainability, and resilience in rice-based agri-food systems.

Recognizing the challenges posed by climate change, biotic and abiotic stresses, and the evolving needs of stakeholders, ICAR-CRRI has continued to focus on developing high-yielding, stress-tolerant, and nutrient-rich rice varieties. Our research efforts have also emphasized sustainable natural resource management, precision agriculture, and digital innovations, including 5G-enabled smart farming solutions. The institute has also made notable strides in promoting mechanization, post-harvest technologies, and value addition to strengthen rice-based agri-businesses.

In alignment with national and global priorities, ICAR-CRRI has actively engaged in multi-institutional collaborations, public-private partnerships, and farmer-centric extension programs. Through our Farmer Producer Organization (FPO) empowerment initiatives, technology dissemination programs, and customized training modules, we have worked towards enhancing the capacity of stakeholders across the rice value chain.

The success of our research and extension programs would not have been possible without the dedication and commitment of our scientists, technical and administrative staff, and the invaluable support from the Indian Council of Agricultural Research (ICAR) and the Ministry of Agriculture and Farmers' Welfare. I extend my sincere gratitude to all our partners, including state agricultural universities, Krishi Vigyan Kendras (KVKs), NGOs, and the farming community, for their unwavering support and collaboration.

In 2024, the CRRI continues to focus on improving rice varieties (17 numbers), improving farming practices (13 numbers of technology/ products/procedures/ concepts) and promoting the development of sustainable agricultural practices. The Institute also organized 170 numbers of training programs for 7398 participants during 2024. In addition, 2 patents were granted to the Institute during the year. Scientists of the institute have also published 147 research articles; 14 popular articles; 30 book chapters; 7 books; 42 research/technology/ extension bulletins. Scientists (6 numbers) visited abroad in countries such as, Philippines, France, Russia and Sri Lanka.

The institute express heartfelt gratitude to Dr. Himanshu Pathak, Director General (DG), ICAR, and Secretary, DARE, for his direction, guidance and encouragement. We sincerely thank Dr. Trilochan Mohapatra, the former secretary of DARE and DG of ICAR, for his unwavering guidance and assistance during the institute's development. We sincerely thank chairman and other distinguished members of the Research Advisory Committee (RAC), Institute Management Committee (IMC) and Institute Research Council (IRC) for their valuable suggestions, encouragement, and support

As we move forward, ICAR-CRRI remains committed to address emerging challenges and exploring new frontiers in rice research. We envision a future where scientific innovations and sustainable practices drive enhanced productivity, improved livelihoods, and food security for millions. I hope this report provides valuable insights into our endeavours and inspires further engagement in our collective mission.

I extend my best wishes to all stakeholders for another year of innovation and progress in rice research and development.

Director
ICAR-Central Rice Research Institute

Executive Summary

The significant outcome during 2024 is releasing of 16 rice varieties with CVRC (CR Dhan 329, CR Dhan 322, CR Dhan 331, CR Dhan 332, CR Dhan 214, CR Dhan 211, CR Dhan 212, CR Dhan 807, CR Dhan 808, CR Dhan 804, CR Dhan 108, CR Dhan 416, CR Dhan 809, CR Dhan 810, CR Dhan 811, and CR Dhan 337), while one variety with SVRC (CR Dhan 6030). In addition, 287 new promising elite entries were nominated in AICRIP testing 2024. Eighty-seven rice landraces comprising 31 winter rice (*sali*), 27 deep-water (*bao*), 22 sticky rice (*bora*), 5 aromatic (*joha*), and two aus/*ahu* accessions from Majuli and adjoining Dhemaji and North Lakhimpur districts of Assam were evaluated for 39 agro-morphological traits along with submergence tolerance. Thirty-five landraces were tolerant to submergence for two weeks at the seedling stage. Twenty-two genotypes were found to possess the Sub1A-1 gene out of the tolerant landraces. In contrast, 20 genotypes were found to have either *the SNORKEL 1* or *SNORKEL* 2 gene. About 23.30 q nucleus seed of 125 varieties and 681.25 q breeder seed of 73 varieties were produced. Through participatory seed production with three farmers' groups, 697.95 quintals of truthfully labeled seeds were produced and subsequently procured back. A total of 135.0 kg of breeder seeds of 13 parental lines and 742.0 kg of truthfully labelled seeds of 32 hybrid combinations were produced and distributed. A rice CSSL (Q12-9) with similar grain type of CR Dhan 307 was developed and this line showed 10-12 days of dormancy over four consecutive crop seasons A breeding line, CR 4107-1-B-4-1-B, with 24 ppm zinc was promoted to AVT-1 in Zone VII, while CR 4375-1-4-1-1-2-2 with medium slender grain type was promoted to AVT-2 in Zone IV, two semi-dwarf Chakhao derivatives, CR4450-48-26-13-14-19 and CR4450-65-36-8-17 were nominated for the IVT-Colored rice trial under AICRP-2024. High protein variety Swarna CR Dhan 411 was registered with PPV&FRA. CR 2667-4-1-2-2-1 (7.49 t ha^{-1}) was promoted to AVT1 in semi-deep ecology. Hybrid CR Dhan 705 (IET28187) possesses long slender (LS) grains with high HRR (67.70%), moderate protein (7.36%), Zn (16.2 ppm), and high Fe (10.0 ppm) is screened for SVRC release in Odisha. Hybrids, CRHR-166 (AVT-1-Late), CRHR 169 (AVT-1-IM), and CRHR 175 were evaluated under the 2nd-year AICRPR and promoted to AVT-2; and CRHR 181 is promoted to AVT1-M. A total of 6 promising DH lines have been screened for SVRC-Odisha, 14 DH lines were nominated in various AICRPR trials. We are using genome editing to develop new varieties. *IPA1* -edited lines are undergoing clearance as per DBT Biotechnology's SOPs for *SDN-1* type genome editing in rice. Additionally, thermo-sensitive genic male sterile (*tms5*) gene-edited plants were developed in the Lalat variety, and one homozygous line was confirmed through sequencing. *TnpB* was used as a plant genome editing tool for developing albino rice plantsby precise gene disruption targeting the green pigment synthesis pathway. Using QTL mapping approach, one main QTL (*qBK5.1*) on chrom#5 explaining PVE of 8.97% associated with bakanae disease resistance was identified and mapped using RIL population (Pooja/Thavalakannan). Through meta-QTL analysis, fifteen highly significant MQTLs were identified, and two of them, MQTL 9.2 and MQTL 11.8, were validated for their significant association with rice blast resistance. Haplotype analysis for leaf rolling (SNP_23715622), relative water content (SNP_55632552), tiller number (SNP_102509308), and leaf number (SNP_263283231) led to the identification of two tolerant *indica* genotypes (TSAO SHENG LI and PODIWEE) for vegetative stage drought stress. Multiple alignment of the candidate genes, disease resistance protein RPM1, leucine-rich repeat family protein, ZOS4-01-C2H2 zinc finger protein in BPH resistance QTL (*qBPH4.3),* and serine/threonine-protein kinase in QTL (*qBph4.4)* regions using whole-genome sequence of Salkathi (R) and TN1 (S) identified the presence of missense mutations between TN1 and Salkathi.

The programme dedicated to improving the efficiency, sustainability, and resilience of rice-based production systems actively conducts diverse research, emphasizing natural resource management and energy-efficient rice farming. Standardized precision nitrogen application using GreenSeeker and the development of an IoT-based real-time irrigation scheduling system. Cost-effective herbicide-tolerant rice management practices have improved weed control, while research on direct-seeded rice (DSR) has linked methane emissions to root characteristics. The synthesis of nano silica (Si NPs) from rice husk has enhanced zinc uptake, boosting productivity. Efforts in climate-smart agriculture have enhanced resilience in stress-prone rice ecosystems, with a strong focus on sustainability and food security. A post-harvest energy footprint analysis has highlighted regional disparities, emphasizing the need for improved efficiency. Paddy straw residue management protocols have been standardized using microbial interventions, leading to better soil quality and manage the methane emission from rice cultivation. Furthermore, the application package for Arbuscular Mycorrhizal has been standardized for wetland rice cultivation. Additionally, nitrogen-fixing biofertilizers and decomposers have been widely promoted among the farming community on a large scale. Technological advancements, including a battery-powered weeder, an IoT-enabled soil moisture monitoring system, and a solar-powered bird-scaring device, enhance agricultural efficiency. Additionally, innovations in rice processing feature fermented rice-based beverages and arsenic reduction techniques. These initiatives collectively promote sustainable rice production, ensuring increased productivity and environmental conservation.

Biotic stress management in rice program addressed various aspects of insect, disease, and nematode pest management. Three genotypes Bhadra, Swetha, and IC 298361 were found to be moderately resistant to Brown Planthopper (BPH). Screening of 152 genotypes and marker-trait analysis identified significant resistance markers (RM1313 and RM7) for BPH. Screening for gall midge resistance identified RM17480 as a key marker. False smut resistance was observed in multiple ARC and NGB germplasm entries, with ARC-5769, 5940, 5982, and 7038 consistently resistant across multiple locations. Four sheath rot-resistant genotypes (AC 9002, AC 9070, AC 9118, AC 9004) exhibited high defense enzyme activity. Rice blast genetic diversity analysis of 108 aromatic landraces highlighted a correlation between genetic clustering and resistance.

The complete genome sequencing of *Rice Tungro Bacilliform Virus* (RTBV) from Cuttack revealed a close genetic relationship with South Asian isolates. Screening for Rice Root

Knot Nematode (RRKN) resistance identified 12 moderately resistant varieties. Analysis of 74 *Ustilaginoidea virens* isolates using ISSR markers showed significant genetic correlation within 10–100 km, with differentiation increasing beyond 100 km. Potassium silicate (1%) spray on TN1 rice reduced Yellow Stem Borer (YSB) settling and egg hatchability. Whole-genome sequencing of *Trichoderma erinaceum* CRRI-T2 revealed diverse CAZymes, secretory proteins, and secondary metabolite gene clusters. Detoxifying gene expression analysis in *Nilaparvata lugens* showed increased resistance-related gene upregulation after repeated insecticide exposure, with triflumezopyrim demonstrating superior control.

Spectral reflectance analysis identified key bands (494, 516, 531, 680 nm) with 79.65% accuracy for rice blast detection. Melatonin seed priming (150 ppm) significantly reduced RRKN infestation while improving plant health. Fungal strains from rice rhizosediments exhibited strong biodegradation potential for tetracycline and streptomycin, indicating a promising remediation approach. *Bacillus thuringiensis* and *Beauveria bassiana* had minimal impact on natural enemies, whereas azadirachtin reduced parasitoid emergence. Sheath blight and bacterial blight infections at the tillering stage caused higher disease severity and greater grain yield losses compared to infections at later growth stages.

The programme photosynthetic enhancement, abiotic stress tolerance and grain nutritional quality in rice, research initiatives focuses on enhancing photosynthesis, improving abiotic stress tolerance, and increasing the nutritional quality of rice through innovative biotechnological and agronomic approaches. The research encompasses genome editing techniques, physiological and biochemical characterizations, and the development of climate-resilient genotypes to support sustainable rice production. The research highlights the use of CRISPR and prime editing techniques to enhance the efficiency of photosynthesis in rice. A major breakthrough in this area involved editing the endogenous Phosphoenolpyruvate Carboxylase (PEPC) gene to transition its function from C3-like to C4-like, improving carbon assimilation efficiency. Prime editing vector modifications significantly increased editing success rates, marking a crucial step towards stress-adaptive rice varieties with improved yield potential under suboptimal environmental conditions. Several rice genotypes were evaluated for their tolerance to extreme water stress conditions, including complete submergence and stagnant flooding. Among the identified stress-tolerant genotypes, Swarna-*Sub1*, Khoda, and AC85 exhibited superior performance in survival and yield. A detailed molecular study of salt tolerance mechanisms in *Oryza nivara* and *Oryza sativa* subspecies revealed crucial gene expressions involved in sodium exclusion and compartmentalization, essential for breeding salt-tolerant rice varieties. Additionally, the introgression of the SUB1 QTL into various rice cultivars significantly enhanced their submergence tolerance, with Swarna-Sub1 and CR Dhan-801 showing the highest resilience. Melatonin application demonstrated a promising role in improving drought tolerance in rice varieties. The study observed a significant reduction in leaf rolling and drying scores under drought conditions, with Swarna and N22 showing enhanced recovery rates post-drought stress. Root and shoot growth parameters were also improved by melatonin application, suggesting its potential as a protective agent against oxidative stress and osmotic imbalance in rice plants. Rice nutritional enhancement remains a pivotal aspect of this research. The study identified low glycemic index (GI) rice varieties and demonstrated how combining rice with tuber crops (e.g., elephant foot yam, yam bean, and taro) effectively lowered GI values, making rice a healthier dietary choice. The inclusion of pulses in rice-based diets was also found to significantly reduce glycemic load (GL), with pigeon pea exhibiting the highest impact. The effect of processing methods such as cooking, parboiling, and fermentation on rice's nutritional and antioxidant properties was investigated. Parboiling retained the highest nutrient levels, while fermentation enhanced bioactive compound content. Milling time variations also influenced iron and zinc retention, with brown rice maintaining the highest levels of these essential micronutrients. Additionally, pigmented rice varieties retained greater antioxidant activity even after cooking, reinforcing their health benefits. Oil content, gamma-oryzanol levels, and antioxidant activity were assessed in 21 rice varieties to determine their oxidative stability and shelf-life. Sahbhagi Dhan and Geetanjali rice varieties demonstrated superior oil stability and high gamma-oryzanol content, making them suitable for extended storage and enhanced nutritional benefits. The research advancements under Programme 4 contribute significantly to the development of climate-resilient and nutritionally superior rice varieties.

The programme focused on socio-economic research to help rice stakeholders enhance farm income through technology dissemination and the development of innovative extension models. These models aim to introduce new technologies to the end users and gather valuable feedback for technologists. In 2024, the programme successfully showcased nine newly released rice varieties in collaboration with KVKs, NGOs, and farmers under the INSPIRE 1.0 and 2.0 models. Based on 305 demonstrations across 23 districts in 8 states, a structural equation model was developed to assess the willingness to adopt improved rice varieties. A scientific assessment of farmers' perceptions, based on qualitative data, provided a deeper understanding of their views on CRRI varieties. The program also explored the effectiveness of YouTube-based agro-advisory, CRRI Barta, and developed the CRRI Training Information & Management System to enhance the institute's outreach and impact. A major achievement was the design of the arORIce rice value chain model, aimed at boosting the production of export-quality non-basmati aromatic rice. Additionally, the programme identified key challenges faced by rice farmers, assessed the economic potential of CRRI varieties, specialty rice, and premium seed varieties. A detailed analysis of consumer preferences and current rice production trends further enrich its outcomes.

The programme development of climate resilient rice technologies for rainfed upland, rainfed lowland and coastal saline ecologies deals with upland, coastal and lowland rice ecology focused on developing stress tolerant varieties, and improved integrated crop production and protection packages for the small and marginal farmers. New rice varieties such as CR Dhan 804, CR Dhan 808, and CR Dhan 214 were released& notified, with additional promising entries identified by CRRI-CRURRS, Hazaribag.

कार्यकारी सारांश

वर्ष 2024 के दौरान केंद्रीय किस्म विमोचन समिति के माध्यम से सीआर धान 329, सीआर धान 322, सीआर धान 331, सीआर धान 332, सीआर धान 214, सीआर धान 211, सीआर धान 212, सीआर धान 807, सीआर धान 808, सीआर धान 804, सीआर धान 108, सीआर धान 416, सीआर धान 809, सीआर धान 810, सीआर धान 811, सीआर धान 337 तथा राज्य किस्म विमोचन समिति के माध्यम से एक किस्म सीआर धान 6030 सहित 16 चावल की किस्मों का विमोचन महत्वपूर्ण घटना थी। इसके अलावा, 2024 के दौरान एआईसीआरआईपी परीक्षण में 287 नई आशाजनक उत्कृष्ट प्रविष्टियों को नामांकित किया गया। असम के माजुली और समीपवर्ती धेमाजी और उत्तरी लखीमपुर जिलों से 31 शीतकालीन चावल (साली), 27 गहरे पानी (बाओ), 22 चिपचिपे चावल (बोरा), 5 सुगंधित (जोहा), और दो एयूएस/आहू सहित 87 चावल भूमि प्रजातियों का जलमग्न सहिष्णुता सहित 39 कृषि-आकृति विज्ञान संबंधी लक्षणों का मूल्यांकन किया गया। चावल की 35 भूमि प्रजातियाँ अंकुरण अवस्था में दो सप्ताह तक जलमग्न सहिष्णु पाई गई। सहिष्णु भूमि प्रजातियों में से 22 जीनप्ररूप में Sub1A1- जीन पाया गया। इसके विपरीत, 20 जीनप्ररूपों में या तो SNORKEL 1 या SNORKEL 2 जीन पाया गया। चावल की 125 किस्मों के लगभग 23.30 क्विंटल न्यूक्लियस बीज तथा 73 किस्मों के 681.25 क्विंटल प्रजनक बीज का उत्पादन किया गया। तीन किसान समूहों के साथ सहभागितापूर्ण बीज उत्पादन के माध्यम से, 697.95 क्विंटल विश्वसनीय लेबल वाले बीज का उत्पादन किया गया तथा बाद में उन्हें वापस खरीद लिया गया। 13 पैतृक वंशों के कुल 135.0 किलोग्राम प्रजनक बीज तथा 32 संकर संयोजनों के 742.0 किलोग्राम विश्वसनीय लेबल वाले बीज उत्पादित तथा वितरित किए गए। सीआर धान 307 के समान दाना प्रकार सहित एक चावल जीनप्ररूप Q12-9 विकसित किया गया तथा इस वंश में लगातार चार फसल मौसमों में 12-10 दिनों की निष्क्रियता देखने को मिला। 24 पीपीएम जिंकयुक्त प्रजनन वंश, सीआर 4107-1-बी-4-1-बी को जोन VII के एवीटी-1 में उन्नत किया गया, जबकि मध्यम पतले दाने वाली किस्म सीआर -4375 2-2-1-1-4-1 को जोन IV के एवीटी2- में उन्नत किया गया। दो अर्ध-बौने चाखाओ व्युत्पन्न, सीआर19-14-13-26-48-4450 और सीआर-4450 17-8-36-65 को एआईसीआरपी2024- के तहत आईवीटी-रंगीन चावल परीक्षण के लिए नामित किया गया।

उच्च प्रोटीनयुक्त किस्म स्वर्णा सीआर धान 411 को पौधा एवं किसान अधिकार संरक्षण प्राधिकरण में पंजीकृत किया गया हैं। सीआर -4-2667 7.49) 1-2-2-1 टन प्रति हेक्टेयर) को अर्ध-गहरी पारिस्थितिकी के लिए एवीटी1 में उन्नत किया गया। संकर सीआर धान 705 (आईईटी28187) दाने लंबे पतले होते हैं, जिसकी उच्च एचआरआर (%67.70), मध्यम प्रोटीन मात्रा (7.36%), जिंक (16.2 पीपीएम) और उच्च लौह (10.0 पीपीएम) है एवं इसे राज्य किस्म विमोचन समिति द्वारा ओडिशा में विमोचन के लिए परीक्षण किया गया है। संकर, सीआरएचआर-166 (एवीटी-1-विलंब), सीआरएचआर 169 (एवीटी-1-आईएम), और सीआरएचआर 175 का मूल्यांकन एआईसीआरपीआर के दूसरे वर्ष के अंतर्गत किया गया और उन्हें एवीटी-2 में उन्नत किया गया तथार सीआरएचआर 181 को एवीटी-1एम में उन्नत किया गया। ओडिशा राज्य किस्म विमोचन समिति के लिए कुल 6 आशाजनक डबल हाप्लाएड वंशों का परीक्षण किया गया है, 14 डबल हाप्लाएड वंशों को विभिन्न एआईसीआरपीआर परीक्षणों में नामित किया गया है। नई किस्मों को विकसित करने के लिए जीनोम एडिटिंग का उपयोग किया जा रहा है। चावल में एसडीएन1- प्रकार के जीनोम एडिटिंग के लिए डीबीटी बायोटेक्नोलॉजी के मानक संचालन प्रक्रिया के अनुसार आईपीए-1 संपादित वंशों को मंजूरी दी जा रही है। इसके अतिरिक्त, ललाट किस्म में थर्मो-सेंसिटिव जीनिक नर स्टेराइल (tms5) जीन-संपादित पौधे विकसित किए गए और अनुक्रमण के माध्यम से एक समयुग्मीय वंश की पुष्टि की गई। TnpB का उपयोग हरे रंगद्रव्य संश्लेषण मार्ग को लक्षित करके सटीक जीन विघटन द्वारा एल्बिनो चावल के पौधों को विकसित करने के लिए एक पौधे जीनोम संपादन उपाय के रूप में किया गया। क्यूटीएल मैपिंग उपाय का उपयोग करते हुए, गुणसूत्र # 5 पर एक मुख्य क्यूटीएल (क्यूबीके 5.1) की पहचान की गई, जो बकाने रोग प्रतिरोधिता से जुड़े %8.97 पीवीई को स्पष्ट करता है और आरआईएल संख्या (पूजा / थवलकन्नन) का उपयोग करके मैप किया गया। मेटा-क्यूटीएल विश्लेषण के माध्यम से, पंद्रह अत्यधिक महत्वपूर्ण एमक्यूटीएल की पहचान की गई और उनमें से दो, एमक्यूटीएल 9.2 और एमक्यूटीएल 11.8, चावल प्रध्वंस प्रतिरोधिता के लिए मान्य किए गए। पत्ती रोलिंग (एसएनपी_23715622), सापेक्ष जल मात्रा (एसएनपी_55632552), दौजी संख्या (एसएनपी_102509308), और पत्ती संख्या (एसएनपी_263283231) के लिए हैप्लोटाइप विश्लेषण से वृद्धि चरण सूखा तनाव के लिए दो सहिष्णु इंडिका जीनप्ररूप (टीएसएओ शेंग ली और पोडीवी) की पहचान की गई। उम्मीदवार जीनों, रोग प्रतिरोधक प्रोटीन RPM1, ल्यूसीन-समृद्ध पुनरावर्तित परिवार प्रोटीन, भूरा पौध माहू प्रतिरोधक क्यूटीएल (qBPH4.3) में ZOS4-01-C2H2 जिंक फिंगर प्रोटीन, और क्यूटीएल (qBph4.4) क्षेत्रों में सेरीन/थ्रेओनीन-प्रोटीन काइनेज के बहु संरेखण ने साल्काथी (R) और TN1 (S) के संपूर्ण जीनोम अनुक्रम का उपयोग करके TN1 और साल्काथी के बीच मिसेंस उत्परिवर्तन की उपस्थिति की पहचान हुई।

चावल आधारित उत्पादन प्रणालियों की दक्षता, स्थिरता और प्रतिरोधिता को बेहतर बनाने के लिए समर्पित कार्यक्रम में विविध अनुसंधान का कार्यान्वयन किया जा रहा है, जिसमें प्राकृतिक संसाधन प्रबंधन और ऊर्जा-कुशल चावल की खेती पर जोर दिया जाता है। ग्रीनसीकर का उपयोग करके मानकीकृत परिशुद्धता नाइट्रोजन प्रयोग और आईओटी-आधारित वास्तविक समय पर सिंचाई समय प्रणाली का विकास किया गया। लागत-प्रभावी शाकनाशी-सहिष्णु चावल प्रबंधन प्रथाओं से खरपतवार नियंत्रण में सुधार हुआ है, जबकि सीधी बुआई बीज चावल के शोध ने मीथेन उत्सर्जन को जड़ की विशेषताओं से जोड़ा है। धान पराली से नैनो सिलिका के संश्लेषण ने जिंक अवशोषण को बढ़ाया है, जिससे उत्पादकता में वृद्धि हुई है। जलवायु-स्मार्ट कृषि के प्रयासों से स्थिरता और खाद्य सुरक्षा पर ध्यान देने के साथ तनाव-ग्रस्त चावल पारितंत्र में प्रतिरोधिता बढ़ा है। फसल कटाई के बाद ऊर्जा पदचिह्न विश्लेषण ने क्षेत्रीय असमानताओं को उजागर किया है, जिससे दक्षता में सुधार की आवश्यकता पर बल दिया गया है। धान पराली के अवशेष प्रबंधन प्रोटोकॉल को माइक्रोबियल हस्तक्षेपों का उपयोग करके मानकीकृत किया गया है, जिससे मिट्टी की गुणवत्ता बेहतर हुई है और चावल की खेती से मीथेन उत्सर्जन का प्रबंधन हुआ है। इसके अलावा, आर्द्रभूमि चावल की खेती के लिए आर्बस्कुलर माइकोराइजल के लिए प्रयोग पैकेज को मानकीकृत किया गया है। इसके अतिरिक्त, नाइट्रोजन-निर्धारण जैव उर्वरक और डीकंपोजर को बड़े पैमाने पर कृषक समुदाय के बीच व्यापक रूप से बढ़ावा दिया गया है। बैटरीचालित वीडर, आईओटी-समर्थित मिट्टी की नमी निगरानी प्रणाली और सौर ऊर्जा से चलने वाले पक्षी-भगाने वाले उपकरण सहित तकनीकी प्रगति ने कृषि दक्षता को बढ़ाया है। इसके अतिरिक्त, चावल प्रसंस्करण में नवाचारों में किण्वित चावल-आधारित पेय पदार्थ और आर्सेनिक कमी तकनीक शामिल हैं। ये पहल सामूहिक रूप से स्थिर चावल उत्पादन को बढ़ावा देती हैं, जिससे उत्पादकता में वृद्धि और पर्यावरण संरक्षण सुनिश्चित होता है।

चावल अनुसंधान कार्यक्रम में जैविक तनाव प्रबंधन ने कीट, रोग और सूत्रकृमि कीट प्रबंधन के विभिन्न पहलुओं का समाधान किया। तीन जीनोप्ररूप भद्र, स्वेता और आईसी 298361 भूरा पौध माहू के लिए मध्यम रूप से प्रतिरोधी पाए गए। 152 जीनप्ररूपों और मार्कर-विशेषता विश्लेषण के परीक्षण ने भूरा पौध माहू के लिए महत्वपूर्ण प्रतिरोध मार्कर (RM1313 और RM7) की पहचान की। गॉल मिज प्रतिरोध की परीक्षण से RM17480 को एक प्रमुख मार्कर के रूप में पहचाना गया। कई एआरसी और एनजीबी जननद्रव्य प्रविष्टियों में आभासी कंड प्रतिरोधिता देखा गया, जिसमें एआरसी-5769, 5940, 5982 और 7038 लगातार कई स्थानों पर प्रतिरोधी पाए गए। चार आच्छद विगलन प्रतिरोधी जीनप्ररूप (एसी 9002,

एसी 9070, एसी 9118, एसी 9004) ने उच्च रक्षा एंजाइम गतिविधि प्रदर्शित की। 108 सुगंधित लैंड्रेस के चावल प्रध्वंस आनुवंशिक विविधता विश्लेषण ने आनुवंशिक क्लस्टरिंग और प्रतिरोधिता के बीच संबंध को उजागर किया। कटक से चावल टुंग्रो बैसिलिफ़ॉर्म वायरस की संपूर्ण जीनोम अनुक्रमण से दक्षिण एशियाई वियुक्तों के साथ घनिष्ठ आनुवंशिक संबंध के बारे में पता चला। चावल जड़गांठ सूत्रकृमि प्रतिरोधिता के लिए परीक्षण से 12 मध्यम प्रतिरोधी किस्मों की पहचान की गई। आईएसएसआर मार्करों का उपयोग करके 74 यूस्टिलागिनोइडिया विरेन्स वियुक्तों के विश्लेषण ने 100-10 किलोमीटर के भीतर महत्वपूर्ण आनुवंशिक सहसंबंध दिखाया, जिसमें 100 किलोमीटर से आगे विभेदन बढ़ गया। TN1 चावल पर पोटेशियम सिलिकेट (%1) का छिड़काव करने से पीला तना छेदक का बसना और अंडे सेने की क्षमता कम हो गई। ट्राइकोडर्मा एरिनेसियम CRRI-T2 के संपूर्ण जीनोम अनुक्रमण से विविध CAZymes, स्रावी प्रोटीन और द्वितीयक मेटाबोलाइट जीन क्लस्टर का पता चला। नीलापर्वता लुगेंस में विषहरण जीन अभिव्यक्ति विश्लेषण ने बार-बार कीटनाशक के संपर्क में आने के बाद प्रतिरोध-संबंधी जीन अपरेगुलेशन में वृद्धि दिखाई, जिसमें ट्राइफ्लुमेज़ोपाइरिम ने बेहतर नियंत्रण प्रदर्शित किया।

स्पेक्ट्रल रिफ्लेक्शन विश्लेषण ने चावल प्रध्वंस का पता लगाने के लिए %79.65 सटीकता के साथ प्रमुख बैंड (680 ,531 ,516 ,494 एनएम) की पहचान की। मेलाटोनिन सीड प्राइमिंग (150 पीपीएम) ने पौधे के स्वास्थ्य में सुधार करते हुए आरआरकेएन संक्रमण को काफी हद तक कम कर दिया। चावल के राइजोसेडिमेंट्स से कवक भेद ने टेट्रासाइक्लिन और स्ट्रेप्टोमाइसिन के लिए मजबूत बायोडिग्रेडेशन क्षमता प्रदर्शित की, जो एक आशाजनक उपचार उपाय का संकेत देता है। बैसिलस थुरिंजिएंसिस और ब्यूवेरिया बेसियाना का प्राकृतिक शत्रुओं पर न्यूनतम प्रभाव पड़ा, जबकि एजाडिरेक्टिन ने परजीवी के उद्भव को कम कर दिया। दौजी चरण में आच्छद अंगमारी और जीवाणुज अंगमारी संक्रमण के कारण बाद के विकास चरणों में संक्रमण की तुलना में रोग की गंभीरता अधिक थी और अनाज की उपज में अधिक नुकसान हुआ।

यह कार्यक्रम प्रकाश संश्लेषण वृद्धि, अजैविक तनाव सहिष्णुता और चावल में अनाज की पोषण गुणवत्ता, अनुसंधान पहल प्रकाश संश्लेषण को बढ़ाने, अजैविक तनाव सहिष्णुता में सुधार, और नया जैव प्रौद्योगिकी एवं कृषि विज्ञान उपाय के माध्यम से चावल की पोषण गुणवत्ता में वृद्धि पर केंद्रित है। इस शोध में जीनोम एडिटिंग तकनीक, शारीरिक और जैव रासायनिक लक्षण वर्णन तथा स्थायी चावल उत्पादन का समर्थन करने के लिए जलवायु-लचीले जीनोटाइप का विकास शामिल है। इस शोध में चावल में प्रकाश संश्लेषण की दक्षता बढ़ाने के लिए CRISPR और प्राइम एडिटिंग तकनीकों के उपयोग पर प्रकाश डाला गया है। इस क्षेत्र में एक बड़ी सफलता अंतर्जात फॉस्फोइनोलपाइरुवेट कार्बोक्सिलेज जीन को संपादित करना था ताकि इसके कार्य को C-3जैसे से C-4जैसे में परिवर्तित किया जा सके, जिससे कार्बन आत्मसात दक्षता में सुधार हुआ। प्राइम एडिटिंग वेक्टर संशोधनों ने एडिटिंग की सफलता दरों में उल्लेखनीय वृद्धि की, जो उप-इष्टतम पर्यावरणीय परिस्थितियों में बेहतर उपज क्षमता के साथ तनाव-अनुकूली चावल किस्मों की दिशा में एक महत्वपूर्ण कदम है। कई चावल जीनप्ररूप का मूल्यांकन अत्यधिक जल तनाव की स्थितियों, जिसमें पूर्ण जलमग्नता और स्थिर बाढ़ शामिल है, के प्रति उनकी सहिष्णुता के लिए किया गया। पहचाने गए तनाव-सहिष्णु जीनप्ररूप में, स्वर्णा-सब1, खोडा और एसी85 ने जीवित रहने और उपज में बेहतर प्रदर्शन किया। ओराइज़ा निवारा और ओराइज़ा सटाइवा उप-प्रजातियों में लवण सहिष्णुता तंत्र के एक विस्तृत आणविक अध्ययन से सोडियम बहिष्करण और विभाजन में शामिल महत्वपूर्ण जीन अभिव्यक्तियों के बारे में पता चला, जो लवण-सहिष्णु चावल किस्मों के प्रजनन के लिए आवश्यक है। इसके अतिरिक्त, विभिन्न चावल की किस्मों में सब1 क्यूटीएल के अंतर्ग्रहण ने उनकी जलमग्न सहिष्णुता को काफी हद तक बढ़ा दिया, जिसमें स्वर्णा-सब1 और सीआर धान801- में सबसे अधिक अनुकूल पाया गया। मेलाटोनिन के प्रयोग ने चावल की किस्मों में सूखा सहिष्णुता को बेहतर बनाने में एक आशाजनक भूमिका निभाई है। अध्ययन में सूखे की स्थिति में पत्ती के मुड़ने और सूखने के स्कोर में उल्लेखनीय कमी देखी गई, जिसमें स्वर्णा और एन22 ने सूखे के बाद तनाव में सुधार दर को दर्शाया। मेलाटोनिन के प्रयोग से जड़ और टहनियों के विकास के मापदंडों में भी सुधार हुआ, जिससे चावल के पौधों में ऑक्सीडेटिव तनाव और आसमाटिक असंतुलन के खिलाफ एक सुरक्षात्मक एजेंट के रूप में इसकी क्षमता का पता चलता है। चावल के पोषण में वृद्धि इस शोध का एक महत्वपूर्ण पहलू है। अध्ययन में कम ग्लाइसेमिक इंडेक्स वाले चावल की किस्मों की पहचान की गई और पाया गया कि कैसे चावल को कंद फसलों (जैसे, जिमीकंद रतालू, रतालू बीन, और तारो) के साथ मिलाने से जीआई मान प्रभावी रूप से कम हो जाता है, जिससे चावल एक स्वस्थ आहार विकल्प बन जाता है। चावल आधारित आहार में दालों को शामिल करने से ग्लाइसेमिक लोड में भी उल्लेखनीय कमी पाई गई, जिसमें अरहर दाल सबसे अधिक प्रभाव दिखाती है। चावल के पोषण और एंटीऑक्सीडेंट गुणों पर खाना पकाने, उबालने और किण्वन जैसी प्रसंस्करण विधियों के प्रभाव की जांच की गई। उबालने से पोषक तत्वों का उच्चतम स्तर बना रहा, जबकि किण्वन से जैवसक्रिय यौगिक सामग्री में वृद्धि हुई। मिलिंग समय में भिन्नता ने लौह और जिंक प्रतिधारण को भी प्रभावित किया, भूरे चावल में इन आवश्यक सूक्ष्म पोषक तत्वों का उच्चतम स्तर बना रहा। इसके अतिरिक्त, रंग-बिरंगे चावल की किस्मों में खाना पकाने के बाद भी अधिक एंटीऑक्सीडेंट गतिविधि बनी रही, जिससे उनके स्वास्थ्य लाभ और भी बढ़ गए। 21 चावल किस्मों में उनकी ऑक्सीडेटिव स्थिरता और भंडारण अवधि निर्धारित करने के लिए तेल की मात्रा, गामा-ओरिज़ैनॉल के स्तर और एंटीऑक्सीडेंट गतिविधि का मूल्यांकन किया गया। सहभागीधान और गीतांजलि चावल की किस्मों ने बेहतर तेल स्थिरता और उच्च गामा-ओरिज़ैनॉल सामग्री का प्रदर्शन किया, जिससे वे लंबे समय तक भंडारण और बेहतर पोषण लाभों के लिए उपयुक्त बन गए। कार्यक्रम 4 के तहत अनुसंधान प्रगति जलवायु-प्रतिरोधी और पोषण संबंधी बेहतर चावल किस्मों के विकास में महत्वपूर्ण योगदान देती है।

इस कार्यक्रम का मुख्य उद्देश्य सामाजिक-आर्थिक अनुसंधान पर ध्यान केंद्रित करना था, ताकि चावल के हितधारकों को प्रौद्योगिकी प्रसार और नवीन विस्तार मॉडल के विकास के माध्यम से कृषि आय बढ़ाने में मदद मिल सके। इन मॉडलों का उद्देश्य अंतिम उपयोगकर्ताओं को नई तकनीकें प्रदान करना और प्रौद्योगिकीविदों के लिए मूल्यवान प्रतिक्रिया एकत्र करना है। वर्ष 2024 में, कार्यक्रम ने INSPIRE 1.0 और 2.0 मॉडल के तहत कृषि विज्ञान केंद्र, गैर-सरकारी संगठन और किसानों के सहयोग से चावल की नौ नई किस्मों को सफलतापूर्वक प्रदर्शित किया। 8 राज्यों के 23 जिलों में 305 प्रदर्शनों के आधार पर, उन्नत चावल किस्मों को अपनाने की इच्छा का आकलन करने के लिए एक संरचनात्मक समीकरण मॉडल विकसित किया गया था। गुणात्मक आंकड़ों के आधार पर किसानों की धारणाओं का वैज्ञानिक मूल्यांकन, एनआरआरआई किस्मों पर उनके विचारों की गहरी समझ प्रदान करता है। कार्यक्रम ने यू ट्यूब-आधारित कृषि-सलाहकार, एनआरआरआई वार्ता की प्रभावशीलता का भी पता लगाया और संस्थान की पहुंच और प्रभाव को बढ़ाने के लिए एनआरआरआई प्रशिक्षण सूचना और प्रबंधन प्रणाली विकसित की। एक बड़ी उपलब्धि एरोराइस चावल मूल्य श्रृंखला मॉडल का डिज़ाइन था, जिसका उद्देश्य निर्यात-गुणवत्ता वाले गैर-बासमती सुगंधित चावल के उत्पादन को बढ़ावा देना था। इसके अतिरिक्त, कार्यक्रम ने चावल किसानों के सामने आने वाली प्रमुख चुनौतियों की पहचान की, एनआरआरआई किस्मों, विशेष चावल और प्रीमियम बीज किस्मों की आर्थिक क्षमता का आकलन किया। उपभोक्ता के पंसद और वर्तमान चावल उत्पादन प्रवृत्तियों का विस्तृत विश्लेषण इसके परिणामों को और समृद्ध करता है।

वर्षाश्रित उच्चभूमि, वर्षाश्रित निम्नभूमि और तटीय लवणीय पारिस्थितिकी के लिए जलवायु अनुकूल चावल प्रौद्योगिकियों के विकास का कार्यक्रम उच्चभूमि, तटीय और निम्नभूमि चावल पारिस्थितिकी से संबंधित है, जो तनाव सहिष्णु वाली किस्मों के विकास और छोटे और सीमांत किसानों के लिए बेहतर एकीकृत फसल उत्पादन और सुरक्षा पैकेज पर केंद्रित है। सीआर धान 804, सीआर धान 808 और सीआर धान 214 जैसी नई चावल किस्मों को विमोचित और अधिसूचित किया गया, साथ ही एनआरआरआई-सीआरयूआरआरएस, हजारीबाग द्वारा पहचानी गई अतिरिक्त आशाजनक प्रविष्टियाँ भी शामिल हैं।

MAJOR RESEARCH AREAS

1

- Germplasm Exploration & Conservation
- Super Rice
- Hybrid Rice
- Bio-fortified Rice
- Climate Smart Varieties

2

- Input Management
- Resource Conservation Technologies
- Farm Mechanization
- Climate Resilience
- Harnessing Microbial Potentials
- Integrated Farming Systems

3

- IPM
- IDM
- Stored Grain Pests
- Pesticide Formulation
- Pesticide Residue Management

4

- Stress Tolerant Rice
- Low Glycemic Rice
- Grain Quality
- C_4 Rice

5

- Development and Testing of New Extension Models
- Socio-economic Studies
- Rice Value Chain
- Technology Dissemination
- Training and Advisory Services

6

Climate Resilient Technologies:

- Rainfed Upland
- Rainfed Lowland
- Coastal Ecology

CRRI AT A GLANCE

1. 17 New Rice Varieties Released
2. 13 Technologies Commercialized and 2 Patent Granted
3. 58 Memorandum of Understanding (MoU) signed
4. 147 Peer Reviewed Research Papers Published
5. 42 Institute Bulletins Released
6. 08 States Covered through Extension Activities
7. 09 New Rice Varieties Demonstrated in Farmers Field
8. 2138 Personnels including Farmers Visited the Institute
9. 169 Trainings Conducted & 7368 Persons Attended
10. 54 Agromet Advisory Bulletins Released
11. 25 Agro Advisory Services & 24 Video Barta Released
12. 569 Field Demonstrations Conducted

Introduction

ICAR-Central Rice Research Institute (ICAR-CRRI), was established by the Government of India in 1946 at Cuttack, as an aftermath of the great Bengal famine in 1943, to initiate a consolidated approach to rice research in India. The administrative control of the Institute was subsequently transferred to the Indian Council of Agricultural Research (ICAR) in 1966. The institute has three research stations, at Hazaribag, in Jharkhand, at Gerua in Assam, and at Naira in Andhra Pradesh. The CRRI regional station, Hazaribag was established to tackle the problems of rainfed uplands, and the CRRI regional substation, Gerua for problems in rainfed lowlands and floodprone ecologies. Two Krishi Vigyan Kendras (KVKs) also function under CRRI, one at Santhpur in Cuttack district of Odisha and the other at Jainagar in Koderma district of Jharkhand. The research policies are guided by the recommendations of the Research Advisory Committee (RAC), Quinquennial Review Team (QRT) and the Institute Research Council (IRC). The CRRI also has an Institute Management Committee (IMC) to support implementation of its plans and programmes.

Vision

To ensure sustainable food and nutritional security and equitable prosperity of our Nation through rice science.

Goal

To ensure food and nutritional security of the present and future generations of the rice producers and consumers.

Mission

To develop and disseminate eco-friendly technologies to enhance productivity, profitability and sustainability of rice cultivation.

Mandate

Conduct basic, applied and adaptive research on crop improvement and resource management for increasing and stabilizing rice productivity in different rice ecosystems with special emphasis on rainfed ecosystems and the related abiotic stresses.

Generation of appropriate technology through applied research for increasing and sustaining productivity and income from rice and rice-based cropping/ farming systems in all the ecosystems in view of decline in per capita availability of land.

Collection, evaluation, conservation and exchange of rice germplasm and distribution of improved plant materials to different national and regional research centres.

Development of technology for integrated pest, disease and nutrient management for various farming situations.

Characterization of rice environment in the country and evaluation of physical, biological, socio-economic and institutional constraints to rice production under different agro-ecological conditions and farmers' situations and develop remedial measures for their amelioration.

Maintain database on rice ecology, ecosystems, farming situations and comprehensive rice statistics for the country as a whole in relation to their potential productivity and profitability.

Impart training to rice research workers, trainers and subject matter/extension specialists on improved rice production and rice-based cropping and farming systems.

Collect and maintain information on all aspects of rice and rice-based cropping and farming systems in the country.

Linkages

The CRRI has linkages with several national and international organizations such as the Council for Scientific and Industrial Research (CSIR), Indian Space Research Organization (ISRO), SAUs, State Departments of Agriculture, NGOs, Banking (NABARD) and the institutes of the Consultative G roup for International Agricultural Research (CGIAR), such as the International Rice Research Institute (IRRI), Philippines and International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India.

Location

The institute is located at Cuttack about 35 km from Bhubaneswar airport and 7 km from the Cuttack railway station on the Cuttack-Paradeep State Highway. The institute lies approximately between 850 55'48" E to 850 56'48" longitudes and 200 26'35" N to 200 27'35" N latitudes with the general elevation of the farm being 24m above the MSL. The annual rainfall at Cuttack is 1200 mm to 1500 mm, received mostly during June to October (*kharif* or *wet* season) from the southwest monsoon. Minimal rainfall is received from November to May (*rabi* or *dry* season).

PROGRAMME

01

Genetic Improvement of Rice

The extensive research and development activities carried out under the Crop Improvement programme of the Institute can be comprehended by significant number of novel varieties and hybrids released, and invented modern tools and technologies in the year 2024 for climate resilience, reduce malnutrition and increase productivity and profitability of rice and rice-based ecosystem. Nineteen scientists with the twenty technical staffs of this division are efficiently managing 11 Institutional research projects and 33 externally funded projects.

Herbicide tolerant variety, CR Dhan 807

DSR variety, CR Dhan 108

Submergence tolerant variety, CR Dhan 810

Salinity tolerant variety, CR Dhan 416

1 NO POVERTY
2 ZERO HUNGER
3 GOOD HEALTH AND WELL-BEING
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION
15 LIFE ON LAND
16 PEACE, JUSTICE AND STRONG INSTITUTIONS
17 PARTNERSHIPS FOR THE GOALS

Managing rice genetic resources for sustainable utilization

Characterisation and documentation of rice germplasm of Rajasthan, Haryana, and U.P. regions

Ninety-five accessions of rice germplasm collected and conserved from Haryana, Rajasthan, and UP regions were characterized for 19 qualitative and 9 quantitative traits as per descriptors. Maximum variability (5) was observed for kernel colour and hull colour. The highest variability (CV) was observed for yield (28.84%), followed by plant height (22.54%). Germplasm of the Haryana region forms a distinct group with a mean early maturity duration (137 days), longest leaf (60.29 cm), wider leaf (1.31 cm), tallest plant (167 cm), longest panicle (29.00 cm), highest hundred-grain weight (2.29 g), and yield per plant (22.56 g). AC33083 was identified having the highest yield (39.58 g/plant). Three landraces, AC 33083, AC 22418, and AC 22426, were identified as superior based on yield (≥ 30 g/plant) (Table 1.1 and Figs 1.1 & 1.2).

Fig. 1.1. Variability in qualitative traits

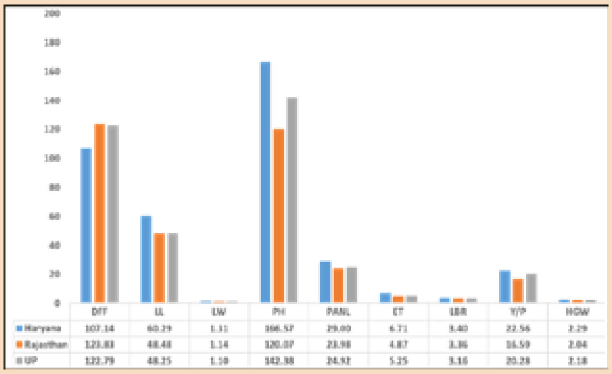


Fig. 1.2. Variability in quantitative traits

Evaluation of rice germplasm

Eighty-seven rice landraces comprising of 31 winter rice (*sali*), 27 deep-water (*bao*), 22 sticky rice (*bora*), 5 aromatic (*joha*), and two aus/*ahu* accessions from Majuli and adjoining Dhemaji and North Lakhimpur districts of Assam were evaluated for 39 agro-morphological traits along with submergence tolerance. The landraces were genotyped using 66 SSRs, *SUB1* and *SNORKEL1 (SK1)* and *SK2* genes. Thirty-five landraces were tolerant to submergence of two weeks at seedling stage. Twenty-two genotypes were found to possess the *Sub1A-1* gene out of the tolerant landraces. In contrast, 20 genotypes were found to have either the *SNORKEL 1* or *SNORKEL 2* gene (Fig. 1.3).

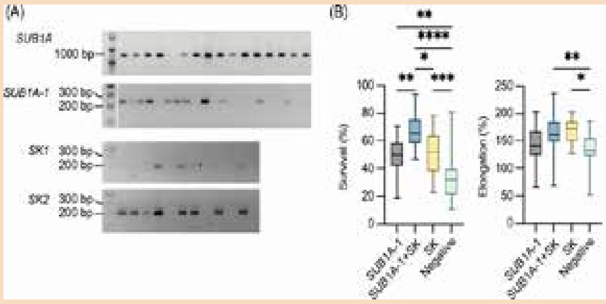


Fig.1.3. Screening of germplasm for submergence tolerance

Germplasm supply A total of 1381 germplasm were supplied to researchers within the institute and other research institutes.

Table 1.1. Variability in quantitative traits

Trait	Mean	Range	CV (%)
Plant height (cm)	128.64	66.0–177.3 (AC 38267–AC 33058)	22.54
Leaf Length (cm)	49.16	26.1-81.6 (AC 38268–AC 38285)	18.17
Leaf width (cm)	1.13	0.60 – 1.17 (AC 38350–AC 38340)	5.16
Panicle length (cm)	24.5	16.2–31.2 (AC 38271–AC 38293)	9.56
No. of Tillers	5.0	2.0-9.0 (AC 38317–AC 22426)	18.90
DFF (days)	122.0	99–129 (AC 33064–AC 33083)	6.67
L/B	3.31	1.79–4.5 (AC 38347 –AC 38270)	8.47
HGW	2.09	1.50-3.10 (AC 22438-AC 33002)	11.25
Yield/plant (g)	17.90	6.65–39.58 (AC 38294–AC 33083)	28.84

Maintenance breeding, quality seed production and seed technology research for enhancing rice yield

Seed production and maintenance

The nucleus seed of 125 varieties released from the institute were multiplied using the standard progeny row approach. Following multiple monitoring field visits by experts, rigorous rouging, and the elimination of potential variants in progeny lines, true-to-type panicles were carefully collected for the next generation of nucleus seed/breeder seed production. A total of 23.30 quintals of nucleus seed was produced for further seed multiplication. To meet the DAC demand for breeder seed and other organizations, a total of 681.25 quintals of breeder seed of 73 varieties were produced at ICAR-CRRI, Cuttack (Fig 1.4). Further, to cater to the demand of farmers, truthfully labelled seeds were also produced. An MoU was signed with the three farmers' groups, i.e., Sahayogi, Saharpur, Kendrapara; Mahatma Gandhi Krushak Club, Bhandilo, Kendrapara, and Nischintakoili Farmer Producer Company Ltd., Cuttack. Through the participatory seed production approach, a total of 697.95 quintals (Fig 1.5) of seed was produced for 16 popular paddy varieties. The seed was subsequently procured back and made available to other farmers for purchase as TL seed from the institute.

Genome-wide association study identifies QTLs governing seed vigor traits

Genotypic differences in seed vigor, evaluated through various physiological growth parameters, represent a vital trait for ensuring successful crop establishment in direct-seeded rice cultivation. This study examined variations in 10 seed vigor-related traits, including the first day of germination (FDG), final germination percentage (FGP), coefficient of velocity of germination (CVG), germination energy on the 3rd day (GE3), germination index (GI), germination rate index (GRI), last day of germination (LDG), mean germination time (MGT), seedling vigor 1 (SV1), seedling vigor 2 (SV2), root length (RL), shoot length (SL), seedling fresh weight (SFW), and seedling dry weight (SDW), using a panel of 170 diverse rice genotypes genotyped with a 44K-Affymetrix SNP chip. By applying the Mixed Linear Model (MLM) method, the study identified 10 QTLs each for CVG, FDG, FGP, GE3, GI, GRI, MGT, SV1, RL, SL, and SFW; 20 QTLs for LDG; 2 QTLs for SV2; and 5 QTLs for SDW. In total, 137 QTLs were associated with 111 distinct SNPs distributed across all 12 rice chromosomes. Of these, 24 QTLs demonstrated pleiotropy, influencing multiple traits. The QTLs identified for all traits explained up to 23.96% of the phenotypic variance (PVE), with the maximum PVE observed for shoot length (SL). The robust and consensus QTLs uncovered in this study underscore the effectiveness of diverse methodologies in deciphering the genetic architecture of seed vigor-related traits.

Multi-trait genomic selection and simulation strategies to optimize grain yield and parental line selection in rice

The inclusion of correlated secondary traits in the prediction of primary traits in multi-trait genomic selection (GS) models can improve the predictive ability. Our objectives in the present investigations were to (i) evaluate the effectiveness of multi-trait and single-trait GS models for the higher predictive ability and (ii) compare the breeding potential of parental lines selected based on phenotype and GS for grain yield in rice. We used phenotype data of five correlated traits as secondary traits evaluated to predict the grain yield, a primary trait. Yield-related functional markers were used for prediction. Breeding populations were simulated using the best parents selected through GS and phenotype-based selection. Results suggest that the multi-trait model resulted in higher predictive abilities (0.82 for grain yield) than single-trait models (0.76 for grain yield), and parents selected through GS have the potential to produce superior progenies. It was concluded that the use of a multi-trait GS approach was advantageous over single-trait models, and the GS also could help select potential parents for developing improved populations. The results of the study have potential scope for improving quantitative traits using GS in rice.

Effect of temperature and humidity regimes on grain discoloration and seed quality in *indica* rice (*Oryza sativa* L.)

Grain discoloration or dirty panicle disease, induced by a number of non-specific fungi, causes substantial loss to seed/grain yield and quality in rice. Fungal sporulation and grain discoloration are greatly influenced by temperature and relative humidity (RH) levels. We studied the effects of three incubation temperatures (25, 27 and 28^{0}C) and two sets of RH levels (Set 1: 85, 90, 95, 98, and 100%, Set-2: 95, 96, 97, 98, 99 and 100%) on sporulation and disease severity in five major fungi (*Curvularia lunata, Fusarium verticilloides, Bipolaris oryzae, Aspergillus niger and Aspergillus flavus*) (Fig. 1.6) and on 10 rice varieties. Results indicated that both fungal sporulation and disease severity increased on most genotypes with increasing incubation temperature from 25- 28^{0}C and RH levels from 95-98%. A linear relationship was observed among RH levels, grain discoloration severity and fungal sporulation. The highest sporulation of all the three fungi occurred at 27^{0}C and 96% RH after 5 days of incubation. Among the three fungi, *C. lunata* grew and sporulated faster than *Fusarium verticilloides* and *Bipolaris oryzae*, in that order. Among the rice genotypes, Naveen supported the least sporulation and had the lowest disease severity, followed by Gayatri and Sarala. Seed quality parameters, such as seed germination, seedling vigor index, field emergence potential, dehydrogenase and þ-amylase activities declined significantly with increasing temperature and RH levels that supported heavy sporulation and grain colonization.

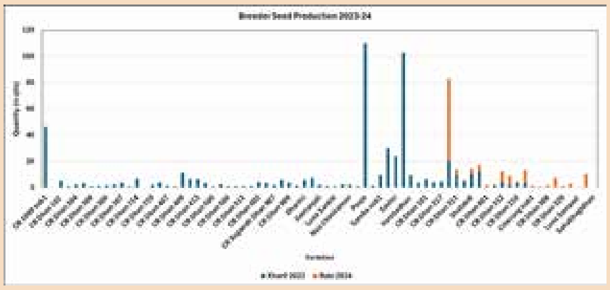


Fig. 1.4. Breeder seed production during 2023-24

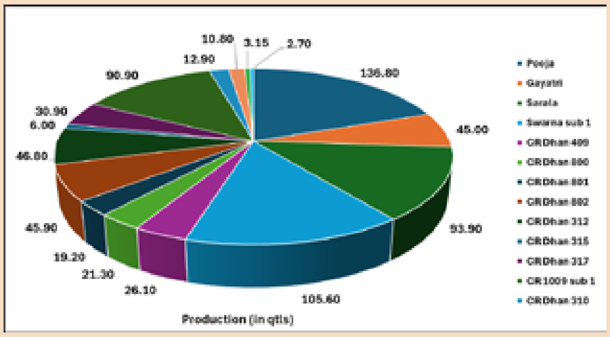


Fig. 1.5. TL Seed production during 2023-24

Fig. 1.6. Common seed borne pathogen of rice under storage condition

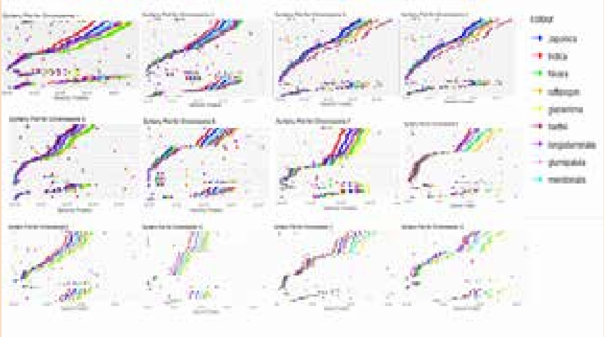


Fig. 1.7. Chromosome-wise synteny plot of the eight Oryza species where y-axis represents markers and X-axis represents the chromosome location in megabase pair (Mb).

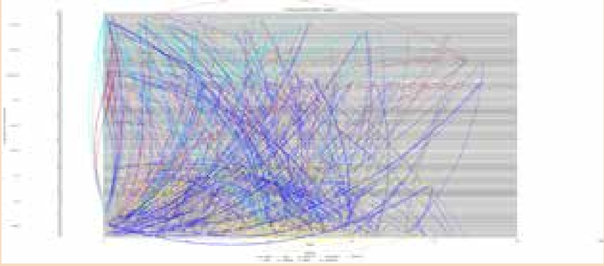


Fig. 1.8. Translocation event in the *O. sativa* complex where X-axis represents chromosome length in Mb and Y-axis represents species with their 12 chromosomes having different colour-coded for the translocation events

Pre-breeding for broadening the genetic base of rice by utilizing wild species of genus-*Oryza*.

Synteny pattern and translocation events among core markers of AA genome

The chromosome-wise synteny of the eight species of the *O. sativa* complex (Fig. 1.7) was studied for the 1K core marker set identified and reported earlier. It revealed a trend line in positional variation where some of the markers were sparsely located, especially in the case of *O. longistaminata* and *O. barthii*. In the translocation plot among these eight *Oryza* species (Fig. 1.8), the majority of translocation occurred in *O. longistaminata* (205), followed by *O. nivara* (119) and *O. meridionalis* (69), and the least number of translocations were observed in *O. rufipogon* (5), followed by *O. glaberrima* (10) and *O. barthii* (11).

Fine mapping of QTLs for submergence tolerance using RILs of *O. nivara* derived introgression line/Swarna

QTL mapping was carried out in the mapping population generated by crossing the submergence-tolerant introgression line of *O. nivara* with Swarna (Table 1.2). Transgressive segregants with up to 50% higher survival compared to Swarna *Sub1* and even at par with FR13A were identified. The major QTL in Chr 9 has the Sub_1A_2 allele of the *Sub 1A* gene. No inhibition of husk colour development by the *IBF-1* gene was observed in the lines, and hence husk colour of Swarna could be recovered, unlike Swarna *Sub1*. Submergence-tolerant semi-dwarf NILs with husk colour like Swarna have been identified and multiplied for nomination in AICRP.

Genetic analysis of seed dormancy in CSSLs of CR Dhan 307/*O. rufipogon* (AC100444)

The *O. rufipogon* accession AC 100444 doesn't germinate for up to one year without dormancy-breaking treatments of its seeds. In the CSSLs developed between CR Dhan 307/*O. rufipogon* AC 100444, it was found that multiple loci control dormancy with cumulative effects in *O. rufipogon*. Most of the loci are associated with wild-type traits. The locus on Chr2 associated with AD14 provides dormancy for at least up to 14 days without wild traits, which might be useful to solve the vivipary problem in CR Dhan 307.

Release and Notification of Brown Planthopper-Resistant NIL 'CR Dhan 809' (IET 30282, CR 4331-74-2-2-1): Naveen is a popular dual-season rice variety in India that is highly susceptible to brown plant hopper (BPH). Two epistatic QTLs (*qBph4.3* and *qBph4.4*) from landrace Salkathi were introgressed in the variety, and the NILs displayed both antixenosis and antibiosis against BPH biotype-4. A NIL with comparable yield and grain quality

Table 1.2. QTLs mapped using RILs of *O. nivara* derived introgression line /Swarna

Trait	Chr.	Pos.	Left Marker	Right Marker	LOD	PVE (%)	ADD
Survival (%) under submergence	9	0	chr09_Sub1A203	chr09_6913547	29.31	30.93	0.18
	9	21	chr09_10119114	chr09_11746684	3.76	3.39	-0.06
	12	1	chr12_23828922	chr12_22600624	3.62	3.21	0.06

like Naveen was notified as a BPH-resistant, essentially derived variety (EDV), CR Dhan 809, for six states (Odisha, Bihar, Jharkhand, West Bengal, Assam, and Tripura) in 2024. The variety with short, bold grains matures within 125-130 days and has an average yield potential of 5.1 t ha^{-1}.

Developing genetic solutions for enhancing input use efficiency

Variety released and notified

CR Dhan 337 has been recommended by CVRC for cultivation in Odisha, Bihar, Jharkhand, and West Bengal (Zone III). This variety features long-slender grains, 113–118 cm height, and has a yield potential of 5.9 t ha^{-1}. It is photo-insensitive and matures in 118–121 days, making it suitable for both *kharif* and *rabi* cropping seasons (Fig. 1.9). The variety exhibits moderate resistance to neck blast, leaf blast, bacterial leaf blight (BLB), sheath rot, rice tungro disease (RTD), and grain discoloration. Additionally, it shows high resistance to leaf folder, stem borer (dead heart), and whorl maggot insect pests.

Breeding for aerobic condition, early maturity and DSR condition

A total of 86 elite rice lines, selected based on yield BLUPs and DSR traits, are set to be utilized in future breeding programs. A new crossing initiative has also been initiated, resulting in 20 F_1 combinations. During Line Stage Testing (LST), 812 lines were evaluated for yield potential under DSR conditions, while 760 lines were evaluated for adaptability to aerobic environments. Furthermore, 450 lines were tested under low nitrogen and phosphorus conditions, with the top-performing lines undergoing further re-evaluation.

Fig. 1.9. CR Dhan 337

Performance of promising nitrogen use efficient genotypes under DSR adaptation

A trial was conducted during *kharif*, 2023 to evaluate 36 promising nitrogen-use-efficient rice genotypes, along with two checks: Swarna (maturity duration: 140–145 days) and CR Dhan 308 (maturity duration: 135 days), under direct-seeded rice (DSR) conditions. The experiment followed a two-replication design, with sowing done on May 24, 2023, by dibbling 3-4 seeds per hill in rows spaced 20 cm apart, with 15 cm intra-row spacing. Light irrigation was applied immediately after sowing to ensure good germination. The pre-emergence herbicide, Pyrazosulfuron ethyl (Saathi), was applied at 30 kg a.i./ha just after sowing, followed by a post-emergence herbicide, Bispyribac Sodium (Nominee Gold), at the same rate five days later. Manual weeding was performed at 40 days after sowing. Fertilizers were applied at a rate of 80:40:40 kg NPK/ha, with full phosphorus and 50% potassium as basal application. Nitrogen was applied in three splits: 50% at seven days after sowing, and the remaining 50% in equal portions at maximum tillering and panicle initiation stages, along with the rest of the potassium. No plant protection chemicals were used, as there were no significant pest or disease outbreaks. Morpho-physiological, agronomic, and post-harvest data were recorded. Grain yield was determined from a 12 m^2 sample area (excluding borders) and extrapolated to calculate per-hectare yield. Lodging was minimal, observed only in two entries. The trial produced an average grain yield of 4854.7 kg ha^{-1} under DSR conditions. Yields ranged from 3023 kg ha^{-1} (CR 4433-4-1-1-2-1) to 7258 kg ha^{-1} (CR Dhan 308). The top-performing entries were CR Dhan 308 (7258 kg ha^{-1}), CR 3549-1-3-1-1-1-1 (6293 kg ha^{-1}), CR 3494-1-2-1-2-1-1 (6055 kg ha^{-1}), and CR 4352-1-1-2-1-1 (6000 kg ha^{-1}). Days to 50% flowering ranged from 93 days (CR 4315-1-1-2-1-1) to 123 days (CR 3562-2-2-1-4-2-1), with a mean of 107 days. Plant height varied between 106.3 cm (CR 3583-3-2-2-1-1-1) and 156.9 cm (CR 4433-4-1-1-2-1), averaging 127.5 cm. Ear-bearing tillers per square meter ranged from 196.0 (CR 4433-4-1-1-2-1) to 388.5 (Swarna), with a mean of 289.1 (Fig. 1.10).

Evaluation of rice genotypes for low phosphorus tolerance

Eighty rice genotypes were screened for low phosphorus tolerance in hydroponics using a modified Hoagland media with two phosphorus treatments (phosphorus deficient and phosphorus sufficient) in a completely

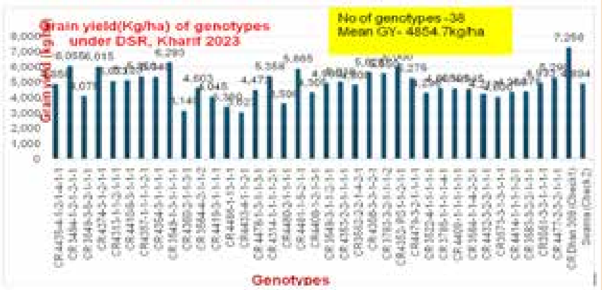


Fig. 1.10. Evaluation of nitrogen use efficient genotypes under DSR adaptation.

randomized design with two replications. The seedlings were grown in the nutrient solution for 21 days and data were collected on shoot length, root length, shoot-to-root ratio, shoot fresh weight, shoot dry weight, root fresh weight, and root dry weight. The genotypes, AC 35000 (shoot length), Dular, Kasalath, AC 35090 (root length), AC 35003 (root-shoot ratio), AC 35173 (shoot fresh weight), AC 35498, Dular (shoot dry weight), Kasalath, AC 35196 (root fresh weight), Kasalath, AC 35066, AC 35137, AC 35178, AC 35090 (root dry weight) recorded highest value for different traits in phosphorus deficient condition (Fig. 1.11). These genotypes can be used as donors for improving low phosphorus tolerance in rice.

Genomic regions associated with yield traits under combination of low P and low N conditions

One hundred and thirty genotypes were subjected to genome-wide association study (GWAS) using seven yield-contributing traits. Fifteen statistically significant marker-trait associations were identified contributing to ~10%-80% phenotypic variation. Further, most of the yield related traits showed reduction in the mean phenotypic values under combined low P and low N conditions. Few candidate genes for nutrient mobilization (NRT2) and hormone related genes could be identified. Furthermore, two superior genotypes ENT-621 and ENT-313 were identified to regulate multiple traits in combined N and P deficient condition. These genotypes can be used in breeding programs.

QTL-meta-analysis and candidate gene(s) for anaerobic germination

A meta-analysis identified 21 Meta-QTLs for anaerobic germination, with 10 having a confidence interval of 1-4 cM and 15 with >4 cM. Gene ontology (GO) analysis identified key processes, including trehalose biosynthesis, protein phosphorylation, cation transport, and ATP binding. The study found 56 differentially expressed genes across these Meta-QTLs, with 13 selected as candidate genes. Key candidates include Os02g0304900, Os01g0568400, and Os01g0566500, which are involved in ABA metabolism and signaling, and an Auxin-responsive SAUR protein regulating coleoptile elongation. Other candidates include genes linked to amylase regulation, proline content, antioxidant activity, and sugar signaling. These genes are valuable for genomic and marker-assisted breeding of direct-seeded rice varieties.

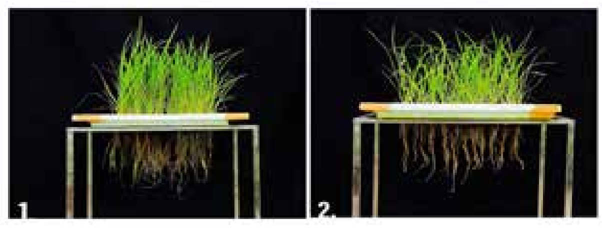


Fig. 1.11. Plants grown in phosphorus deficient medium (left), Plants grown in phosphorus sufficient medium (right).

Breeding for aroma and grain quality in rice

Development of aromatic genotypes with short/medium/long slender grains

Semi-dwarf plants (90 cm plant height) in the Gobindabhog background were identified in BC_3F_2. Intercrossed generation (IC_1F_1) has been developed for semi-dwarf Kalajeera with blast resistance, bacterial blight (BB), brown plant hopper (BPH), and sheath blight utilizing marker-assisted selection (MAS).

Elite lines nominated for AICRP IVT-ASG trial-2024

Two cultures, CR4448-3 and CR4448-5, the pure line selections from the Gobindabhog landrace, have been nominated for the IVT-ASG trial, 2024, under AICRIP for evaluation of performance.

Screening for disease reaction

116 genotypes (aromatic and non-aromatic) were screened for their reaction to leaf blast at UBN, CRURRS, Hazaribag during *kharif*, 2023 (Fig. 1.12).

Breeding for higher zinc, protein, amino acids, and antioxidant traits

Breeding lines with favourable alleles for *NAS3* and *Wx* genes (*Wx-GBSS-ex10*, *Wx-A*_group) CR 4102-1-2-1-3-1 (CR 2829-PLN-32/Mamihanger), CR 4088-2-2-1-B-2-1 (CR 2829-PLN-37-13/PB-140), CR 4199-2-2-1-2

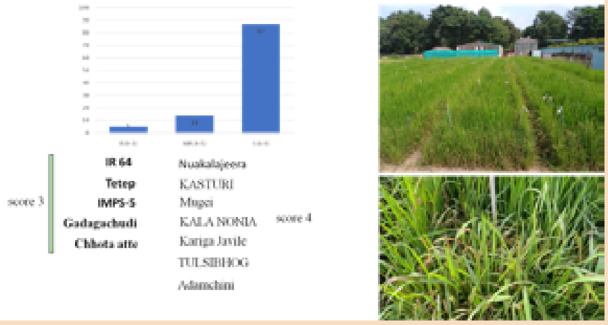


Fig. 1.12. Screening of genotypes for leaf blast at UBN, CRURRS, Hazaribag during kharif -2023.

(Maudamani/CR Dhan 310), CR 4226-2-1-1 (CR Dhan 310/ARB-6027), and CR 4110-2-B-3-1-1 (CR 2830-PLS-17/BPT 5204 Sub-1//Swarna *Sub-1*) were detected through SNP genotyping.

Elite line promoted in AICRP-Biofortification trial

CR 4107-1-B-4-1-B, derived from BPT-5204 Sub-1/CR Dhan 310//Kalinga III with 24 ppm zinc content, was promoted to AVT-1 in Zone VII (yield- 4836 kg ha^{-1} and 98 days to 50% flowering).

PPV&FRA registration

Registration was done for the high-protein Swarna variety CR Dhan 411 (Swarnanjali) with registration no. REG/2014/2032 in 2024.

Breeding for speciality rice, pigmentation, slender grains, and sensory qualities

Pigmented rice

CR-4450-48-2-53-3, a semi-dwarf black rice derivative of Chakhao, was identified with higher antioxidant compounds for two consecutive seasons. IC_2F_1 progeny have been developed for the development of semi-dwarf black rice genotypes resistant to blast, BB, and sheath blight resistance and tolerance to BPH using marker-assisted selection.

Germplasm registered

IC 0646727: AC 43160: Mamihunger, a landrace from Bagabil, Padmabil, West Tripura, with high total anthocyanin, gamma oryzanols, phenolic content, flavonoid content, and ABTS activity, and with low phytic acid content, was registered with NBPGR.

Elite lines nominated for the AICRP IVT-Coloured Rice Trial-2024

Two semi-dwarf derivatives of Chakhao, CR4450-48-26-13-14-19, and CR4450-65-36-8-17, have been nominated for the IVT-Coloured rice trial in 2024.

Elite lines promoted in the medium slender grain category

CR 4375-1-4-1-1-2-2, derived from CR 3522-1-2-1-1-1-1-2 / CR 3497-7-1-3-2-2-1, was promoted to AVT-2 in Zone IV under the MS grain type category. It is non-lodging with a yield of 6166 kg/ha in the zone and 91 days to 50% flowering.

Variety Notified for high HRR%

CR Dhan 331 (IET 28508), with high HRR (>70%), was notified for cultivation in Zones V and VI under irrigated-late ecology.

Breeding for glutinous rice

One hundred and sixty-five landraces from Nagaland and Assam were evaluated for amylose content and other grain quality traits, and *Wx* locus functional polymorphism was surveyed. It was observed that waxy accessions from Assam were mostly *indica* type, whereas those from Nagaland were mostly *japonica* type. Sixty accessions from north eastern India were evaluated for different yield-attributing traits, viz. days to 50% flowering, plant height, number of productive tillers per hill, flag leaf length, flag leaf width, panicle length, and single-plant yield (Fig. 1.13).

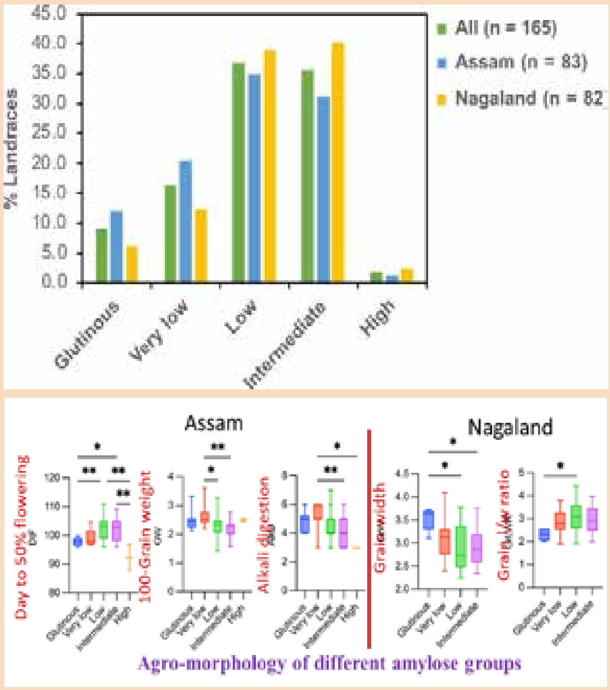


Fig. 1.13. Characterization of Assam and Nagaland rice germplasm for grain quality and morphological traits.

Commercialization/ upscaling/ popularization of released biofortified variety

Eleven MoUs were signed for commercial seed production and marketing of the biofortified varieties, CR Dhan 310, CR Dhan 311 (Mukul), and CR Dhan 411 (Swarnanjali). Around 8 q TL seed was produced for distribution and demonstration of biofortified varieties.

Trainings/demonstrations organized

Seed distribution, training, and planting for seed production of CR Dhan 310 in U.P. in *kharif* 2022 and 2023 were conducted.

Gene mapping and precision breeding for enhancing climate resilience in lowland varieties

Release of rice varieties and development of elite lines suitable for shallow lowland ecology

Two rice varieties, CR Dhan 810 and CR Dhan 811 were identified, while CR Dhan 806 was released for shallow lowland ecology.

CR Dhan 810 (IET 30409) (Gayatri *Sub-1*)

CR Dhan 810 (IET 30409), developed from Gayatri (RP) introgressed with QTLs for submergence tolerance (*Sub-1),* was released for Odisha, W.B., and Assam. It consistently performed at par or better than Gayatri in grain yield and superior seedling survival in submergence stress. The grain quality, phenological traits, and morphological attributes of CR Dhan 810 are also similar to Gayatri. It has a higher resistance to neck blast and stem borer than the Gayatri and is moderately resistant to leaf folder. In the eastern region, the nutrient response (kg grain/kg nutrient) of CR Dhan 810 (4.07 to 37.0%) was higher than Check (4.13 to 14.29%).

CR Dhan 811 (IET 30410) (Sarala *Sub-1*)

CR Dhan 811 (IET 30410) is a MAS-derived NIL introgressed with QTL *Sub-1* for submergence tolerance in Sarala, released for Odisha and W.B. It showed at par or better performance than Sarala consistently in terms of grain yield and seedling survival in submergence stress. The grain quality, phenological traits, and morphological attributes of CR Dhan 811 are also similar to Sarala. It has shown better resistance to sheath blight and stem borer (dead heart) over "Sarala" and is resistant to leaf folder. It had a better nutrient response (kg grain/kg nutrient) than the check (5.8 to 17.8% in CR Dhan 811 and 4.13 to 14.29% in the check) (Fig. 1.14).

CR Dhan 806 (Varshadhan *Sub1*)

It was released by SVRC and notified for lowland areas of Odisha in 2023. It has a maturity duration of 150 days with long, bold grains. The average yield is 3930 kg/ha under submergence stress conditions in Odisha. Both Varshadhan and Varshadhan *Sub1* produce an at-par yield under normal conditions, but Varshadhan *Sub1* produces a higher yield (81.33%) under submergence stress. It is resistant to stem borer (dead heart), BPH, and false smut and moderately resistant to neck blast. It has high hulling, milling, and intermediate amylose content with no grain chalkiness.

Fig. 1.14. Field view of CR Dhan 811 under drought stage c) CR Dhan 806 (Varshadhan *Sub1*)

Variety proposals suitable for shallow lowland ecology: CR Dhan 604, CR Dhan 513 (Mahadev)

Promising elite breeding lines suitable for shallow lowland ecology in AICRIP testing

Several promising cultures were evaluated for unfavourable RSL situations having 40 cm of water for at least 1 month of crop growth. Few genotypes were found promising, *viz.,* CR 3984-1-5-4-2-1 (5.95 t ha^{-1}), CR 4440-16-5-1-1-1-1-1 (5.85 t ha^{-1}), CR 3988-9-1 (5.81 t ha^{-1}), CR 6319-3-2-2 (5.8 t ha^{-1}), SBP-241 (5.74 t ha^{-1}), CR 4439-28-4-1-2-2-2-2 (5.65 t ha^{-1}), and CR 4454-5-3-4-2-1 (5.65 t ha^{-1}). The plant type was found to be suitable for RSL ecology with tolerance to water stagnation. The plants were semi-tall, and the leaves were broad with high biomass. Similarly, SL 46-8-1 (5.87 t ha^{-1}), CR 2688-6-7-3 (5.85 t ha^{-1}), CR 2688-6-7-2 (5.77 t ha^{-1}), and TJ 87-2-4 (5.64 t ha^{-1}) were found promising in semi-deep situations. Besides, CR 2667-4-1-2-2-1 (7.49 t ha^{-1}) was promoted to AVT1 in semi-deep ecology.

Identification of QTLs associated with seed vigour and seed viability under moisture stress conditions.

Fifteen QTLs were identified for the five seed vigour and seed viability under moisture stress conditions using 136 SSR markers in an association mapping panel of 120 rice landraces (**Fig. 1.15**). The QTLs *qGP2*, *qGP2.2*, *qGP8.1,* and *qGP11.2* were validated, while *qGP2.3* and *qGP10.1* were detected to be novel, controlling germination %. QTLs *qSOC9.2* for speed of germination, *qSL2.2* for seedling shoot length, *qDTI2.2, qDTI2.3*, *qDTI8.1,* and *qDTI* for drought tolerance index were validated, while *qSSL4.1* for seedling shoot length and *qSRL11.2* controlling seedling root length were detected as novel QTLs. The co-localized QTLs on chromosome 2 at 82 cM of qGP2 with *qSSL2.2*, *qSRL2.1,* and *qDTI2.1*; *qGP2.3* at 370 cM with *qDTI2.3;* and on chromosome 8 at 177 cM with *qDTI8.1* were detected as genomic hot spots and useful for the improvement programs.

Pyramiding of QTLs/genes for multiple stress tolerance

a) Twenty promising advance lines with 6 or more QTLs/gene combinations for drought (***qDTY1.1, qDTY2.1, and qDTY3.)***, submergence (***Sub1a)***, BLB (***Xa21 + xa13 + xa5),*** and BPH (***qBph4.3)*** were identified in the background of popular variety Swarna.

b) The BC_2F_2 plants in the background of Maudamani were selfed to 31 positive BC_2F_3 plants which were identified and phenotyped in phosphorus-deficient soil for *Pup1* and deeper rooting (***Dro 1***) and phosphorus deficiency tolerance (uptake) (***Pup*1**) (Fig. 1.16**).**

Genetic enhancement for multiple stress tolerance in rice for coastal ecosystem.

Release of rice varieties and development of elite lines suitable for coastal ecology

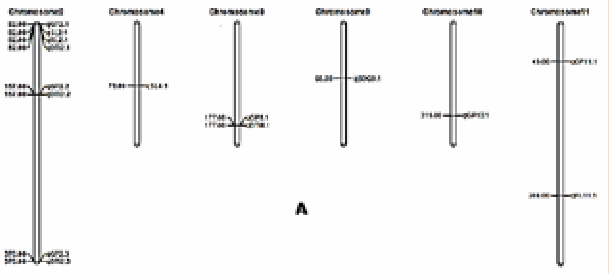


Fig. 1.15. QTL locations on the chromosomes for germination percent, speed of germination, shoot length, root length, and drought tolerance index under moisture stress.

Fig. 1.16. Comparative image of roots of BC2F3 pyramided lines along with donor and recipient parent, Maudamani

Rice variety released: CR Dhan 416 (IET 3020: CR4283-274-6-2-1-3), derived from the CR Dhan 310/Getu cross, has been released and notified for the coastal saline ecology of Gujarat, Maharashtra, and West Bengal. The average yield was recorded at 4.5 t ha^{-1} with a 125-130 days' maturity duration. It showed significant superiority over the best check on an overall basis. It is moderately tolerant to salinity at 6-8 dSm^{-1}. It is moderately resistant to brown spot, neck blast, sheath rot, and rice tungro disease and also resistant to BPH, grass hopper, and stem borer (WE).

Promising elite lines: IET 31876 (CR 4084-1-B-1-B-1) developed from the cross-combination of CR 2838-SR-27/ Binadhan 10 recorded a mean grain yield of 4797 kg ha^{-1}. IET 31074 (CR 3460-E-2-2-B-1) derived from the three-way cross of CR 3299-11-1-1//IR64/FL478 recorded a 4753 kg ha^{-1} mean grain yield. IET 31063 (CR 3439-E-5-2-1-1-B-1) with the cross combination of Naveen/ Chettivirippu (AC 39394) registered a mean grain yield of 4635 kg ha^{-1} and 99 DFF. IET 31065 (CR 4086-5-B-7-B-1) developed from the cross CR 2814-1-S-1-6-3-2B-1/ Binadhan 10 yielded 4564 kg ha^{-1} mean grain yield and 97 DFF. IET 31060 (CR 3478-M-11-B-1) developed from the three-way cross with the pedigree of MTU 1010/Korgut// IR64/FL478///IR 73931-40-1-2-3-2-22-1 with 4281 kg ha^{-1} and 90 DFF exhibited significantly superior to early check-CSR 10. IET 31878 (CR 4290-281-14-3-1-1-1-1) with the pedigree of SR 14-5-1/Luna Sankhi registered a mean grain yield of 4358 kg ha^{-1}. All these lines were found promising in Z-III and were promoted.

Breeding for multiple stress tolerance for coastal saline ecology

Breeding lines evaluated under submergence in kharif, 2023: Thirty elite breeding lines were phenotyped for submergence tolerance. Four lines such as CR 3466-1-2-2-1-Su-1-Su-B, CR 4111-1-1-2-B-1-2-Su-1, CR 4111-1-2-1-B-Su-1-Su-B, and CR 3483-29-M-4-B-1-2-Su-1-Su-B were detected with more than 50% survivability. Around 80 single plants with higher-yielding potential and desirable plant types were harvested.

Submergence-tolerant breeding lines evaluated under salinity stress (EC=12 dSm-1) in Kh, 2023: Forty-eight elite breeding lines with submergence tolerance were phenotyped for salinity tolerance. Four lines such as CR 3477-1-M-1-B-Su-78-S-2-B, CR 3483-29-M-4-B-Su-61-1-S-1-B, CR 3483-1-M-4-B-Su-1-5-S-1-B, and CR 3483-1-M-4-B-Su-60-5-S-2-B were detected with tolerance (SES score- 3). Another 11 lines were detected with moderate tolerance (SES score- 5) to submergence.

'Mutant Shatabdi' with salinity tolerance at seedling and reproductive stages

M_5 lines (derived from gamma radiation) of cv. Shatabdi and moderately susceptible lines of FL 478 were detected at the seedling stage in a salinity micro plot under stress (EC = 12 dSm-1). Tolerant lines (SES score 3 or 5): Shatabdi-300Gy-1, Shatabdi-300Gy-10, Shatabdi-500Gy-1, Shatabdi-400Gy-2, Shatabdi-400Gy-3, Shatabdi-400Gy-6 with desirable grain type and yield (Table 1.3). In Rabi 2024, selected tolerant lines were raised at the salinity micro plot. Salinity stress at the seedling stage was given with EC = 12 dSm-1 and in the reproductive stage with EC = 8 dSm-1. A few lines, such as 1) SHATABDI-300GY-1-5-2, 2) SHATABDI-300GY-1-5-3, 3) SHATABDI-400GY-6-3-5, and 4) SHATABDI-500GY-1-4-1, were found tolerant to salinity at seedling and reproductive stages: The similarity of grain type and yield of those lines with Shatabdi was observed.

Rice Whole Genome Re-Sequencing of Multiple Stress-Tolerant and Susceptible

Re-sequencing of AC39416a and Savitri lines on Illumina Hiseq 2000/2500 was done, and the pre-processed reads were aligned to the rice 93-11 reference genome. Around 12747 homo-polymorphic SNPs were identified. Polymorphic SNPs located on known probable functional genes of multiple abiotic stresses were 130. Selected SNPs located on genes for multiple abiotic stress tolerances (salinity, stagnant flooding, drought, etc.) for marker and functional validation in the RIL population were 29. A total of 27 gene-based SNPs from nine chromosomes showed reproducible polymorphism, which includes genes like cation transporter HKT1, potassium channel KOR2, potassium channel KAT4 homologs, putative ethylene responsive factor, etc., known for their major roles in imparting abiotic stress tolerance.

Table 1.3. Performance of mutant 'Shatabdi' lines under saline conditions at seedling and reproductive stages

Genotype	Kernel length (mm)	Kernel breadth (mm)	L/B ratio	GT	PH (cm)	SES score at seedling stage	Yield (g/plant) (under non stress)
Shatabdi	6.726	1.194	5.6332	LS	72.3	8.167	9.327
SHATABDI-400GY-6-3-5	6.76	1.244	5.4341	LS	71.3	3.833	9.496
SHATABDI-300GY-1-5-3	6.752	1.928	3.5021	LS	72.3	3.833	9.48
SHATABDI-300GY-1-5-2	6.474	1.204	5.3771	LS	71.7	3.833	9.468
SHATABDI-500GY-1-4-1	6.694	1.176	5.6922	LS	71.7	3.833	9.473

Hybrid rice for enhancing yield, quality and sustainability

Maintenance of source nursery

A source nursery with 1253 diverse genotypes was constituted, maintained, and characterized; of these, 28 lines that harboured Rf (*Rf3* and *Rf4*) genes were utilized in the crossing program.

Development of CMS, restorer, and hybrid combinations

A total of 938 test crosses from 12 CMS lines and 162 pollen parents (with >5.0 GEBVs) were evaluated, leading to the identification of 36 heterotic hybrids (7 long, 12 mediums, 9 medium-early, and 8 medium-slender), 27 maintainers, and 63 good restorers. Additionally, 69 heterotic hybrids were re-evaluated in station trials. The medium-duration CRMS60A (WA) (BCN283-38) exhibited 48% outcrossing (Fig. 1.17). Furthermore, 71 sterile backcrosses (BC_2-BC_{12}) with improved seed producibility and sustainability (BLB, BPH, wide compatibility, and outcrossing) were advanced.

Hybrid release/new promising hybrid combinations

CR Dhan 705 (CRHR156; IET 29752), a medium-duration hybrid, possessing long, slender (LS) grains with high HRR (67.70%), moderate protein (7.36%), Zn (16.2 ppm), and high Fe (10.0 ppm) was screened for SVRC release in Odisha (Fig. 1.18). Hybrids, CRHR-166 (AVT-1-Late), CRHR-169 (AVT-1-IM), and CRHR-175, were evaluated in the 2nd year of AICRPR and promoted to AVT-2; and CRHR-181 was promoted to AVT-1-M. In state trials of Bihar, CRHR-150 (IET 28187) and CRHR105 (IET28124) were evaluated for the 3rd year, and CRHR154, CRHR156, and CRHR 173 were in the 2nd year. Under adaptive trials in Odisha, 16 hybrids were evaluated in three districts, Bhadrak, Balasore, and Khordha. Among the 10 hybrids; CRHR 156, CRHR 160, CRHR 166, CRHR 169, CRHR 186, CRHR 176, CRHR 179, CRHR 180, CRHR 181, and CRHR 182 were recorded requisite yield superiority (Fig. 1.19). Under DSR at CRRI, seven hybrids, such as CRHR 102, CRHR 103, CRHR 150, CRHR 175, CRHR 181, CRHR 169, and CRHR 156 recorded requisite yield superiority. The performance of 69 new hybrids identified during 2023-24 was revalidated; amongst them, 18 were sown for yield consistency.

Trait development/genetic diversification of parents and hybrids

Introgression of *BPH31* into Imp-IR42266-29-3R and Imp-CRMS 32A were advanced to BC_2F_6. The introgression of

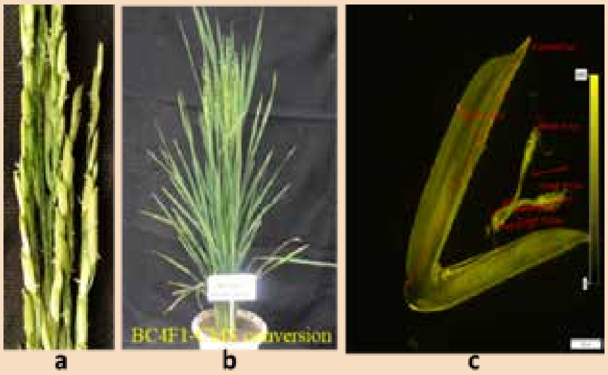


Fig. 1.17. CRMS 60A (BCN283-38) (a) panicle with exserted stigma, (b) single plant view (c) single spikelet view.

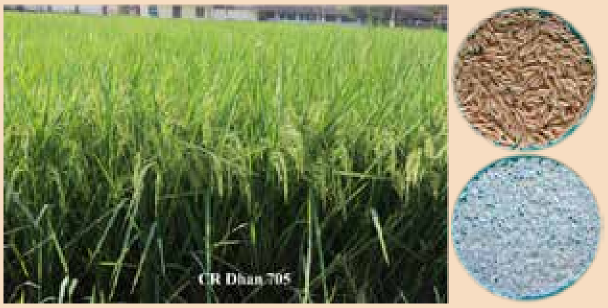


Fig. 1.18. Field view of rice hybrid, CR Dhan 705

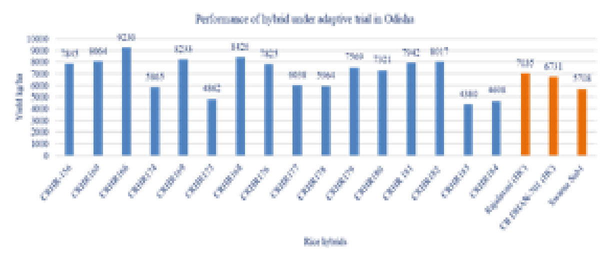


Fig. 1.19. Performance of rice hybrids under adaptive trials in Odisha

WC genes into the partial restorer and good combiner line SR 11-3-1 (Khawo-Hawm-donor) was also advanced to BC_2F_6; in CR 1033 (SR1-5-1, donor) was advanced the BC_2F_3. IR42266-29-3R, restorer of Ajay and Rajalaxmi, was pyramided with 4BB resistance, *Sub1*, and *Saltol* genes/QTLs. Additionally, improved CRMS31B and CRMS32B, carrying 4BB resistance, *Sub1*, and *Saltol* genes/QTLs, are under CMS conversion. Two candidate genes associated with stigma exsertion have been mapped on chromosomes 1 and 7 (Fig. 1.20). Introgression of the long stigma trait into CRMS31B and CRMS32B from the donor *O. longistaminata* was advanced to the BC_3F_8. Twelve genetically fixed lines with long stigma are under CMS conversion; the population is advanced to BC_5F_1.

Development of heterotic pool

A total of 288 genetically diverse lines (87 maintainers and 201 restorers) were phenotyped and genotyped using 342 hypervariable SSR markers. The data will be utilized for the development of heterotic groups.

Restorer and maintainer breeding

A total of 3,723 single-plant progenies (F_3 to F_{13}) from 134 crosses (AxR, RxR, and BxB) were evaluated, with 36 selected for use in HR breeding. Six random mating populations (RMPs), consisting of four maintainers and two restorers, were advanced to the 11th RMP generation. Besides, two inter-subspecific MAGIC populations (B and R, each comprising 10 parental genotypes) were advanced to the IC_3F_5.

Genomic selection and speed breeding

A total of 108 breeding populations (F_3 to F_6) were advanced under field RGA. In the Parental Selection Trial-4, 120 entries including 40 ABLs from CRRI (F7-8 generation, 15 families), were phenotyped across four locations; among them, 25 ABLs with yields over 6.0 t $ha^{-1}$and high BLUP were selected for hybrid development. In the station trial for Kh-2023, 911 ABLs of R and B derivatives were evaluated along with checks under DSR, of those 179 lines yielded more than 6.0 t ha^{-1}.

Seed production of parents/hybrids

A total of 742.0 kg of TL seeds from 32 hybrids were produced, along with 135.0 kg of breeder seeds from 13 CMS lines and nucleus seeds from 6 hybrids. Agro-practices for seed production of 12 new hybrids were refined. Additionally, 25 paired crosses for each CMS line-CRMS 31A, CRMS 32A, PMS17A, IR 42266-29-3R, CRL 22R, CRL123R, and CR 546 with CMS were generated and evaluated for the constitution of nucleus seeds of the respective parental lines.

DNA fingerprinting of parent/hybrid

Fingerprints of the hybrids CR Dhan 705 and CRMS 59A were generated using 36 hypervariable SSR markers. Through GWAS analysis of 182 lines, a QTL hotspot (09_4136552) was identified, influencing the number of secondary branches (NSB), grain filling (NFG), and yield (GYP).

Evaluation of AICRIP trials

Altogether, 05 hybrid rice AICRPR trials, IHRT-E (25 entries), IHRT-ME (31 entries), IHRT-M (26 entries), IHRT-MS (16 entries), and MLT (32 entries) were evaluated, and data is submitted to the coordinator.

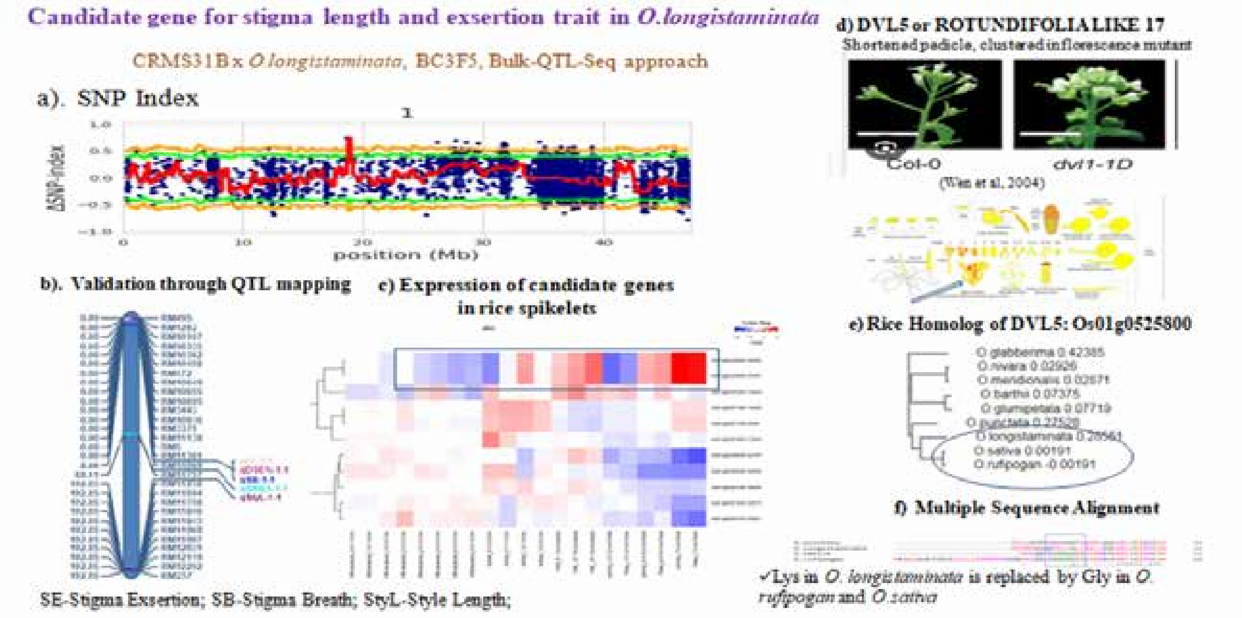


Fig. 1.20. Candidate gene for stigma exsertion.

MoUs/Consultancy services

A total of 12 licenses, three for each hybrid (CR Dhan 702, CR Dhan 703, and CR Dhan 704), were granted to M/s Niali Farmer Producer Company Limited, M/s Mahanga Farmer Producer Company Limited, M/s Baramba Farmer Producer Company Limited, and M/s Tangi Farmer Producer Company Limited for commercial seed production. Additionally, consultancy services for hybrid rice seed production were provided to four of our licensees: M/s Sansar Agropol, M/s Delta Seeds, and M/s Nath Biogene.

Development of New Generation Rice for enhancing yield potential in favourable ecology

Identification and Release of Variety CR Dhan 603

CR Dhan 603 was released for Odisha with a grain yield of 5881 kg ha^{-1} with excellent grain quality (Fig. 1.21). It possesses long, slender grains with high amylose content combined with low GC, which gives soft-cooked rice. Odisha has a great demand for high-yielding LS grain-type varieties in the *rabi* (*dalua)* season. It is resistant to leaf folder, stem borer (dead heart & white ear head), gall midge, and false smut while moderately tolerant to BPH, blast, sheath rot, and brown spot.

Identification and Release of Variety CR Dhan 108

Another early DSR variety, CR Dhan 108 (IET 29052), has been released and notified for cultivation in Odisha and Bihar. This variety was moderately tolerant to drought, and the average yield was 3.2 t ha^{-1} with (83-87) days to 50% flowering. The variety is having medium slender grain type.

Identification and Release of Variety CR Dhan 332

CR Dhan 332 (IET 28506) was released for Odisha and W.B. with an average productivity of 5758 kg ha^{-1}. The maturity duration of the variety is 125-130 days with semi-dwarf plant type. It possesses long, bold grain with moderate test weight (23.5 g). It is moderately resistant to brown spot and sheath rot, leaf folder, whorl maggot, and thrips attack.

Release and notification of Variety CR Dhan 322

One new NGR variety, CR Dhan 322 (IET 28544), was released and notified for cultivation in Chhattisgarh and Maharashtra. It is a high yielder with an average yield of 5.45 t ha^{-1}. It matures in 145 days with ideal plant architecture along with excellent grain quality traits. It performed superior w. r. t. check Swarna (highly popular and mega variety) during the four years of testing. The variety possesses long, slender grain, with a high head rice recovery (HRR: 67%) (Fig. 1.22). Because of the superiority of HRR and grain type, the stakeholders will get more profit.

Fig. 1.21. Field view of CR Dhan 603 (IET 26434) in dough stage, paddy and rice grains

Another variety CR Dhan 328 which was released in 2023, is now notified for cultivation in Odisha.

Evaluation and nomination of promising NGR

Two promising entries (CR 4425-1-1-3-1-1 and CR 4338-2-1-1) were promoted to AVT 2, and five (CR 4460-8-1-1-1-1, CR 4379-4-1-1-1, CR 4379-4-3-1-1-5-1, CR 3856-44-22-2-1-11-4-5-5, CR 3856-44-22-2-1-11-4-2-4-1) were promoted to AVT 1. The other two lines, CR 3969 24-1-2-1-1 and CR 3856-44-22-2-1-11-4-1-1 were repeated in different stages of testing. Several other NGR entries, viz., CR 4425-1-1-3-1-1 (8.2 t ha^{-1}), CR3967-51-2-1-1-1-1-1-1-1-1-1-1-1 (7.6 t ha^{-1}), CR 6317-5/3-2-1 (7.6 t ha^{-1}), and CR 3856-44-22-2-1-11-2-4-1 (7.09 t ha^{-1}), were found promising with yield advantages over the very high-yielding variety check in late duration. Six promising entries (CR4633-12-1-1-1-1 (8.7 t ha^{-1}), CR 6312-4-1-1-1 (8.4 t ha^{-1}), CR 4630-9-1-4 (8. t ha^{-1}), CR4379-12-1-1-1-1

Fig. 1.22. Field view of CR DHAN 322 (IET 28544) in dough stage, panicle and grains

(7.9 t ha^{-1}), CR 6313-1-1-1-2-1 (7.7 t ha^{-1}), and CR4379-1-1-1-1-3 (7.3 t ha^{-1})) were selected for medium duration with yield superiority over CR Dhan 314 (6.9 t ha^{-1}).

Introgression of BB, sheath blight, and BPH in CR Dhan 316

CR Dhan 316 is a very high-yielding NGR, susceptible to BB, BPH, and Sh. Blight. Efforts for introgression of genes for resistance to these traits were made, and generation advancement was done to BC_3F_1 using markers for sheath blight (*qSHB1.1*), BB (*xa5, xa13, Xa21*), and BPH (*BPH31*). The background was studied by using SNP to find out the % of genome recovery (average of 72.14%) (17) and was backcrossed with RP to obtain BC_3F_1 seeds.

Molecular dissection of NGR traits

An NGR-based panel of 200 was selected from 630 genotypes, based on grain yield. Three major clusters were identified from the genetic diversity analysis of the association panel (Fig. 1.23 a, b). Analysis showed the presence of 10 subpopulations in the association panel (k=10). In each subpopulation, the genotypes with a probability ≥ 0.8 were considered pure. The result revealed most of the genotypes were admixture and highly diverse, hence subjected to Genome-Wide Association Studies (GWAS). Marker-trait association analysis identified four major QTLs (two for TN, one for FLW, and one for TGW). One common SNP, chr01_932866, in the QTL, *qTGW1.*1, for 1000-grain weight was detected in both the years (Fig. 24). Three candidate genes have been identified: SPL33, SUI1, and LOC_Os01g02880 in the vicinity of this SNP chr01_932866 of TGW.

Contribution of physiological traits for higher grain yield in NGR

A total of 211 rice genotypes, including 47 new-generation rice (NGRs) and 164 non-NGRs, were evaluated for 25 morphological, physiological, and yield-attributing traits. Few genotypes were found to be highly efficient in multiple traits and were of the NGR category. A highly significant and positive association (0.45) was found between photosynthetic rate and grain yield in the NGR category, while it was non-significant in the non-NGR category. Out of 211 genotypes, 8 genotypes (2 NGRs, 2 high-yielding non-NGRs, and 4 low-yielding non-NGRs) were selected based on grain yield, photosynthetic rate, and flag leaf area. These were evaluated for (1) source strength: photosynthetic rate, (2) SPS, AGPase, and SS enzyme activity in leaf and stem, and (3) NSC content in leaf and stem. (2) Transport ability: No. and area of vascular bundle in stem (3) (Sink strength: (i) sink size-total grain no./panicle (ii) sink activity- SuS, AGPase, SS enzyme activity in grain (iii) NSC content in grain). The study suggests that in NGRs, higher grain yield is supported by the high correlation between photosynthetic rate and grain yield, which in turn is attributed to the higher source strength in terms of higher SPS enzyme activity in the leaf and stem. It caused faster sucrose remobilization to grain, which was supported by a higher number of vascular bundles along with moderate vascular bundle area. Sink strength was also higher in NGRs due to a higher number of total grains/panicle and higher SuS, AGPase, and SS enzyme activity in grains. In the case of high-yielding non-NGRs, a perfect balance between source strength (in terms of carbohydrate

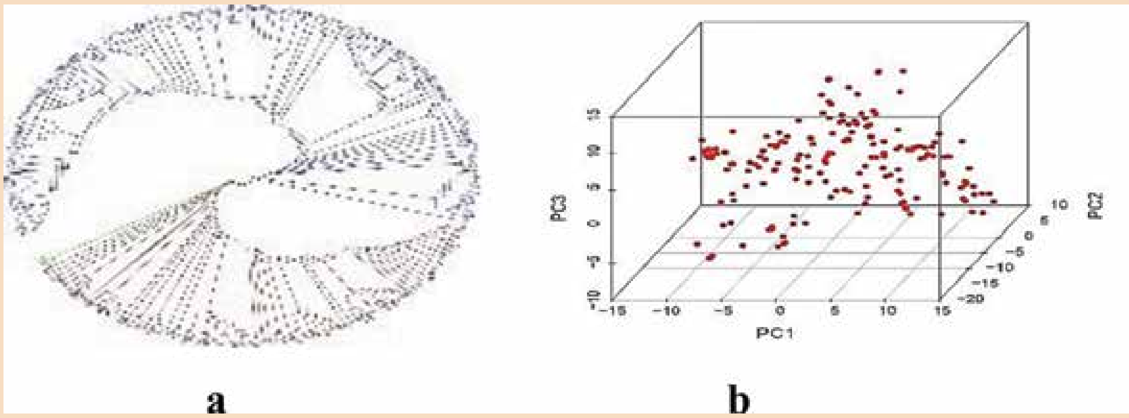


Fig. 1.23. a) Cluster (a), and Principal component (b) analysis of NRR genotypes

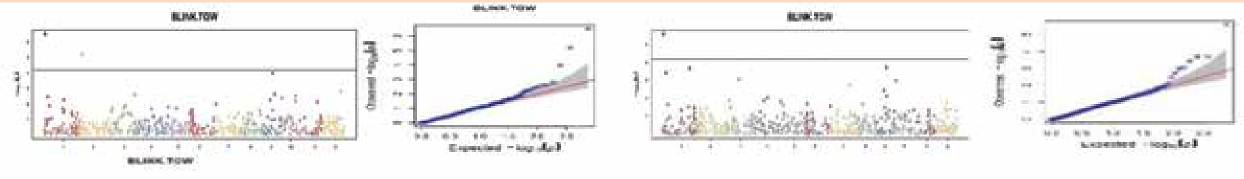


Fig. 1.24. Manhattan plots and Q-Q plots for markers associated with TGW in 1st yr (1st& 2nd) and 2nd yr (3rd& 4th)

remobilization), transport ability, and sink strength caused higher grain yield even with a low photosynthetic rate. In the case of low-yielding non-NGR genotypes, lower source strength, transport ability, and sink strength caused lower grain yield even with a high photosynthetic rate. Thus, a higher source strength, flow efficiency, and sink strength can lead to higher grain yield in rice, irrespective of their single-leaf photosynthetic potential.

Utilization of genome editing, *in vitro* mutagenesis, transgenics and doubled haploid technologies for rice improvement

New promising DH lines

Six promising DH lines have been nominated and screened for release by SVRC, Odisha They are CR 3918-109-5-6-4-1, IET 29446 (early); CRAC-3998-104, IET 29240 (medium-early); CRAC-3994-9-1, IET 28846 (medium); CRAC-3998-325-2, IET 30754 (medium late); CRAC-3998-41-2, IET28743 (medium) and CRAC-3995-48, IET 26446 (medium). Among these, the most notables are CR 3918-109-5-6-4-1, suitable for aerobic condition possessing anaerobic germination trait and also exhibiting tolerance to germination stage salinity stress; CRAC-3998-41-2, with a low GI (55.0) and high iron content (20.1 ppm) (Fig. 1.25); and CRAC-3995-48, with premium quality LS aromatic grains.

Field evaluation of promising DH lines (*Kharif,* 2023)

A total of 14 DH lines were nominated for various trials under the AICRP *Kharif,* 2024 (Table 1.4). These trials span a diverse range of categories, including IVT-MS, IVT-IM, IVT-Biofort, IVT-Aerobic, IVT-CSTVT, IVT-ETP, IVT-AGT, and IVT-DS-MID, showcasing the versatility of the DH lines for different agro-climatic zones and traits. Notably, CRAC-3998-325-3 and CRAC-3998-128-2, derived from parentage 27P63, have advanced from IVT-MS to AVT1-MS in Zone V. Similarly, CRR DH64, developed from the cross Savitri × Pokkali, has been promoted from IVT-ETP to AVT1-ETP in Zone IV. Additionally, CRAC-3994-2-2, DH derivative of CR Dhan 701, has been shifted from IVT-IM to IVT-IRME in Zone II.

Refinement of androgenic protocol for generation of DHs from B x R and F_1s of inter-varietal cross

The refined androgenic method without any anti mitotic agent was used to study anther culture response of **F_1s** of inter-varietal cross, QCR 48-1-41 (Ratna x Chakhao) and B x R line (PMS17B x CRL22R) which showed callus induction efficiency of 33.8% and 34.4% and green shoot regeneration frequency of 64.7% and 70.2% with no albinos. A total of 66 and 75 DHs, respectively were generated from inter-varietal and B x R crosses.

Comparison of the androgenic response between AxR and BxR of hybrid CRHR 150

A study was carried out for a comparative androgenic response between A x R and B x R cross of a hybrid rice line CRHR 150 (CR Dhan 704). Interestingly, a high regeneration frequency of 80.34% was observed in the A × R cross, highlighting its robust response of to the regeneration media (MS + PGRs). However, the B × R cross exhibited a significantly lower regeneration frequency of 35.5% with the same regeneration media. To address this issue, proline was supplemented at a concentration of 5 mg/L, which remarkably improved the regeneration frequency of B x R cross to 70.0%. This finding underscores the critical role of media optimization in enhancing regeneration efficiency (Fig. 1.26)**.**

Parental line improvement through DH Approach

A total of 113 DHs were successfully developed from the BC_1F_1 generation of a cross between IR 42266-29-3R, which harbors the *Xa5*, *xa13*, and *Xa21* genes, and N22, known for carrying *qHTSF4.1* and *qDTY1.1* QTLs. Among these, five DH lines were identified as particularly promising, as they combined multiple desirable traits, including resistance to bacterial blight (BB), high-temperature tolerance, and drought resilience. These DH lines hold significant potential for enhancing the restorer lines of popular hybrid rice varieties such as Ajay and Rajalaxmi. Interestingly, three of these DH lines exhibited

Fig. 1.25. Field view of low GI DH CRAC 3998-41-2

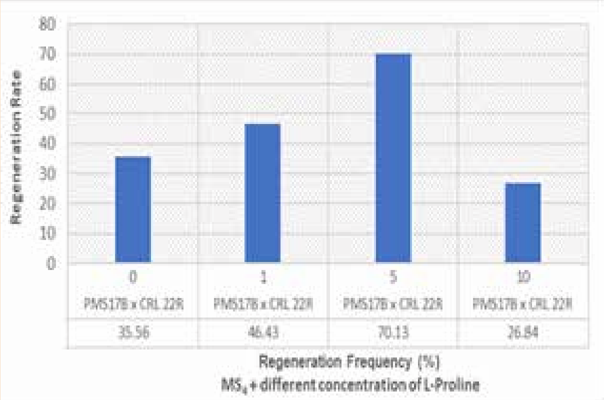


Fig. 1.26. Effect of Proline in regeneration of BxR

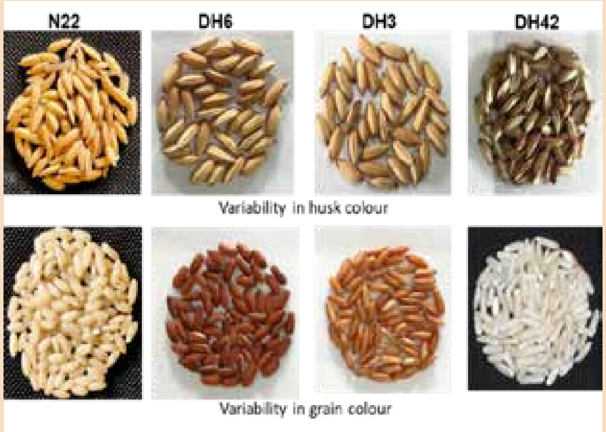


Fig. 1.27. Variability in husk and kernel colour among the developed DHs

red-pigmented seeds, a surprising discovery since neither parent in the cross possesses this trait. This unexpected observation warrants further investigation to understand its genetic basis and potential implications (Fig. 1.27). surprisingly, no segregation was observed in indvidual mutants.

In vitro mutagenesis

Generation of mutants through *in vitro* mutation approach

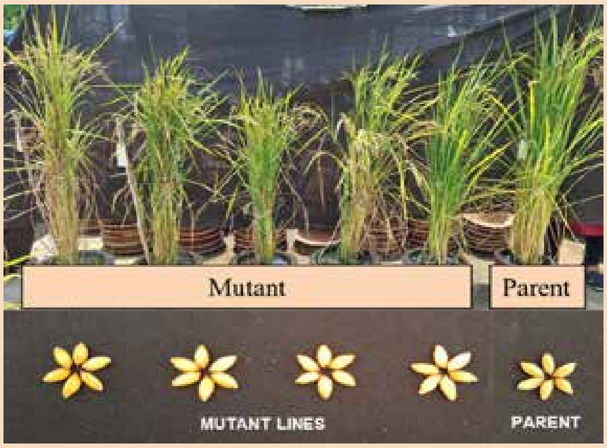


Fig. 1.28. Significant height reduction in mutant line of Acharmati plant with no significant variability in seeds

A total of 86 mutants of Acharmati at M0 generation and 22 mutants of Kalajeera at M1 generation developed through EMS mutagenesis showed 19.76-39.14% and 12.18-26.08% reduced height, respectively, without compromising the grain quality (Fig. 1.28).

Genome Editing

The *IPA1* gene was edited in the popular rice variety Swarna (T2-4-7-1), which showed ~23% yield enhancement over

Table 1.4. Field evaluation of promising DH lines (*kharif*, 2023)

Sl No	DHs	Parentage Hybrids/ Inter-varietal crosses	Duration (days)	Yield ($t\ ha^{-1}$)
1	CRAC-3998-324-3*	27P63	112	5.22
2	CRAC-3998-101-2*	27P63	135	5.26
3	CRAC-3998-247-3*	27P63	130	5.21
4	CRAC-3994-7-4*	CR Dhan 701	112	5.26
5	CRAC- 4424-101-2*	Arize 8433DT	122	6.54
6	CRAC- 4424-118-2*	Arize 8433DT	118	6.84
7	CRAC- 4424-122*	Arize 8433DT	128	4.20
8	CRAC-3995-68-1*	BS 6444G	120	5.58
9	CRAC-3995-48-4*	BS 6444G	128	5.34
10	CRAC-4423-17*	F1s (Savitri x Pokkali)	130	5.18
11	CRAC-4423-114*	F1s (Savitri x Pokkali)	130	6.58
12	CRAC-4423-111*	F1s (Savitri x Pokkali)	132	5.22
13	CRAC-4423-49*	F1s (Savitri x Pokkali)	120	5.20
14	CRAC-6323-52*	F1s (Gitanjali x Bindli)	127	5.36
15	CRAC -3998-325-3#	27P63	135	5.10
16	CRAC -3998-128-2#	27P63	130	5.34
17	CRR - DH64[1]	F1s (Savitri x Pokkali)	125	5.20
18	CRAC 3994-2-2[2]	CR Dhan 701	130	5.30

*Nominated in AICRIP *Kharif,* 2024 (IVT-MS, IVT-IM, IVT-Biofort, IVT-Aerobic, IVT-CSTVT, IVT-ETP, IVT-AGT, IVT-DS-MID, #Promoted to AVT1-MS, 1-Promoted to AVT1-ETP, 2-Shifted IVT-IM to IVT-IRME the commercialized Swarna variety. The miR396 binding site was edited using the CRISPR-Cas9 approach. miR396-resistant allele of *GRF4* (Growth Regulating Factor 4) increases yield and NUE and is resistant to grain shattering during harvest. Two thermo-sensitive genic male sterile edited plants of the *tms5* gene in Lalat were developed, out of which one showed homozygous, which was validated through sequencing. The *IPA1* genome-edited lines have been screened as per the SoPs of DBT for the clearance of the SDN-1 type genome editing lines in rice.

Novel miniature genome editing tools developed using TnpB

We demonstrated high-efficiency genome editing in both monocots and dicots, with average editing rates ranging from 0.63% to 33.58% and reaching up to 69%, using a 408-amino acid-long transposon-associated TnpB. Furthermore, we repurpose a catalytically dead TnpB system for transcriptional activation and base editing. This miniature TnpB, approximately one-third the size of canonical Cas9/Cas12a, emerges as a highly valuable tool for diverse applications in plant genome engineering and gene regulation. A patent has been filed for this invention (Fig. 1.29).

Fig. 1.29. Albino plants resulted from TnpB-mediated disruption of *hmbpp* gene.

Development of Novel Genomic Resources for Rice Improvement

Diversity analysis for straw quality traits for industrial traits and digestibility traits

This study evaluated the fodder quality traits of 449 rice varieties developed between 1921 and 2020, focusing on protein, fibre, lignin, silica, digestibility, and straw yield. The findings revealed that lower lignin content enhances digestibility, and varieties developed after the Green Revolution maintained higher grain yields while upholding fodder quality (Table 1.5). Maturity duration and environmental adaptation also influenced the composition of straw, particularly protein and lignin levels. The study identified varieties with higher protein content (>7%) and improved fibre digestibility, which is valuable for livestock nutrition. The findings suggest that optimizing both fodder and grain traits can lead to enhanced economic benefits, particularly in rice straw trading.

Identification and mapping of QTLs/genes associated with resistance to bakanae and blast diseases

One main QTL (*qBK5.1*) on chrom#5 associated with bakanae disease resistance was identified in the resistant rice genotype, Thavalakannan, using 150 RILs developed from the cross between Pooja (S) and Thavalakannan (R). It explained a PVE of 8.97% (Table 1.6). The significant MQTLs associated with rice blast resistance were identified and validated using *in silico* (and PCR-based) approaches (**Fig. 1.30**).

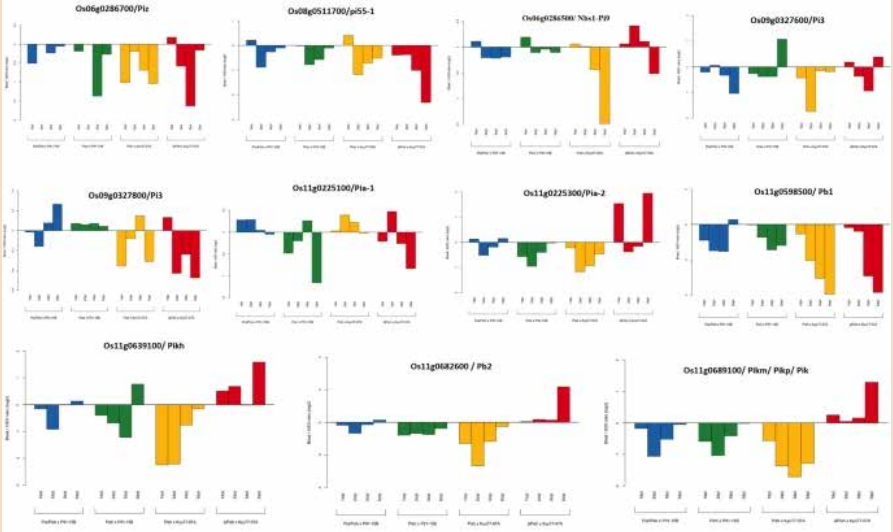


Fig. 1.30. Graphical representation of the fold change in the expression of characterized blast resistance genes within significant MQTLs at 1, 2, 3- and 5-days post inoculation (dpi) of leaves with two *M. oryzae* strains from RiceXPro. *Pia/Pish* × P91-15B and PISH × Kyu77-07A indicate incompatible (resistant) reactions, and *Pish* × P91-15B and ΔPISH × Kyu77-07A indicate compatible (susceptible) reactions. P91-15B and Kyu77-07A are *M. oryzae* strains, while Pia, Pish and ΔPISH represent Nipponbare (NB) genotypes harboring the corresponding genes (*Pia* and *Pish*).

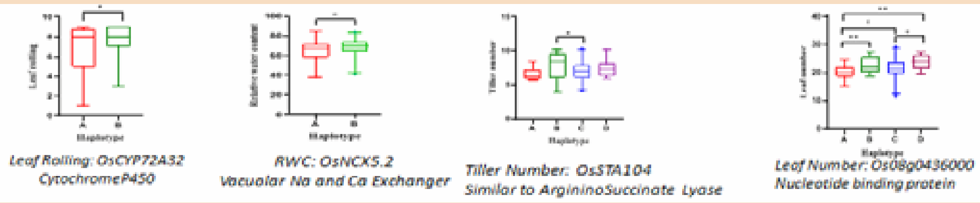


Fig. 1.31. Haplotype analysis for leaf rolling, relative water content (RWC), tiller number, and leaf number in association mapping panel of 223 rice genotypes from 3K RGP under vegetative stage drought stress conditions.

Gene prospecting and epigenetics for tolerance to abiotic stresses

Twelve significant SNPs (QTLs) were identified for six traits (LR, RWC, LR, PH, LA, and TN) under vegetative stage drought stress conditions in an association panel of 223 genotypes of 3K RGP (Table 1.7). Haplotype analysis for leaf rolling (SNP_23715622), relative water content (SNP_55632552), tiller number (SNP_102509308), and leaf number (SNP_263283231) led to the identification of two tolerant *indica* genotypes (TSAO SHENG LI and PODIWEE) for vegetative stage drought stress **(Fig. 1.31).**

Functional validation of putative candidate genes for resistance to biotic stresses

415 IC_1F_6 lines derived from the cross between Naveen and CR3006-8-2 were phenotyped for BPH reaction and genotyped with 14 polymorphic markers in QTL regions. Linkage analysis led to the confirmation of QTL regions (*qBph4.3* and *qBph4.4*). Multiple sequence alignment and annotation of the putative candidate genes, disease resistance protein RPM1, leucine-rich repeat family protein, ZOS4-01-C2H2 zinc finger protein in BPH resistance QTL (*qBPH4.3),* and serine/threonine-protein kinase in QTL (*qBph4.4)* regions using the whole-genome sequence of Salkathi (R) and TN1 (S) identified the presence of missense mutations between TN1 and Salkathi. Functional markers will be developed for these candidate genes using the whole-genome sequences of TN1 and Salkathi for use in the MAS breeding programs.

Table 1.5. Phenotypic diversity for industrial straw traits

Descriptive statistics of fodder quality traits

Traits	Mean	Standard Deviation	Range		Standard Error
			Min	Max	
Protein (%)	6.00	1.05	4.00	9.62	0.05
Fiber (%)	50.83	1.87	43.98	60.55	0.09
Lignin (%)	4.07	0.79	2.43	7.24	0.04
Silica (%)	14.40	1.63	10.62	20.97	0.08
Digestibility (%)	43.10	2.21	38.15	49.16	0.10
Straw yield (t ha^{-1})	7.58	2.46	2.38	18.15	0.12

Table 1.6. Position and effect of main effect QTL conferring Bakanae disease resistance in RIL population of Pooja (S), and Thavalakannan (R).

Sl. No.	Trait/QTL	Chrom#	Position (cM)	Left marker	Right marker	LOD	PVE%	Additive effect
1	Bakanae PDI (*qBK5.1*)	5	63.29	RM249	RM289	3.14	8.97%	6.94

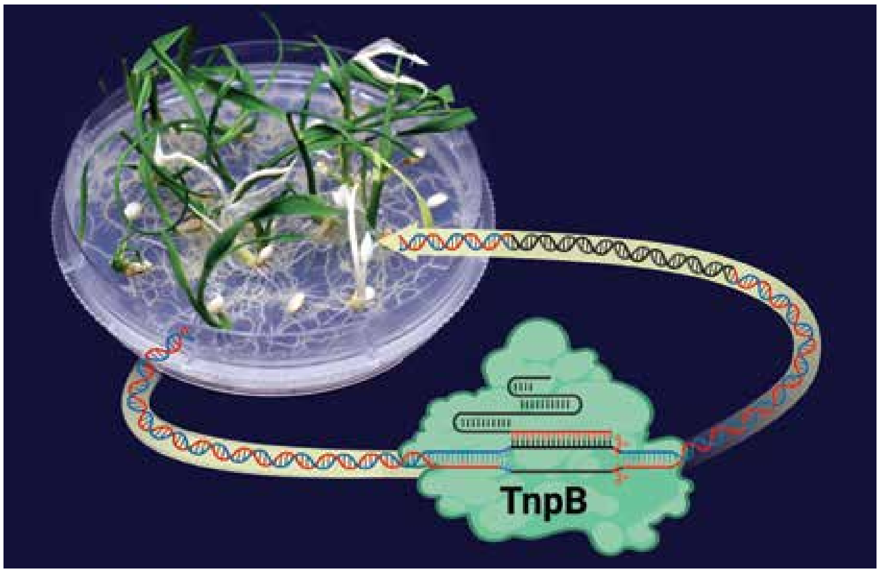
Table 1.7. Significant marker-trait associations (MTAs) identified by association mapping under vegetative stage drought stress among rice genotypes.

Trait	SNP	Chrom#	Position	P-value	MAF	Effect	PVE (%)
LR_L1	262173966	8	20144438	1.44E-09	0.143	1.07	34.49
LR_L2	23715622	1	23715622	3.10E-07	0.081	1.44	47.89
RWC_L1	55632102	2	12361179	2.70E-07	0.085	15.65	79.13

RWC_Mean	55632552	2	12361629	9.10E-10, 6.02E-08, 1.96E-07, 1.96E-07	0.072	10.06	72.64
PH_L1	77845247	2	34574324	8.13E-10, 9.16E-08, 9.16E-08	0.067	-8.32, -9.55, -9.55	29.19, 40.78, 40.78
PH_L1	220016447	7	7684540	2.79E-10, 2.32E -07, 2.32E-07	0.112	-5.40, -5.74, -5.74	12.29, 14.59, 14.59
PH_L2	40082952	1	40082952	1.11E-08, 1.10E-07, 1.10E-07	0.135	-2.43, -3.48, -3.48	22.63, 54.34, 54.34
PH_L2	174060	1	174060	3.45E-08	0.260	1.63	10.55
PH_Mean	48944363	2	5673440	3.94E-09	0.067	-8.67	80.05
LA_L2	143029234	4	27407242	2.45E-09	0.273	-0.92	23.92
TN_Mean	102509308	3	23301135	1.99E-07	0.054	1.41	71.53
LN_Mean	263283231	8	21253703	8.96E-10, 1.71E-07, 9.37E-08, 9.37E-08	0.090	-2.03	46.56

Conclusion

Presently, the agriculture sector faces many challenges, including changing climatic scenarios, reduction in land for agriculture, malnutrition, demographic changes affecting the food habit, and diminishing workforce in agricultural. At CRRI, Crop Improvement Division (CID) has undertaken research and varietal development programs using both traditional breeding and modern molecular and biotechnological techniques to achieve sustainable developmental goals. This division is also playing a pioneering role in releasing rice varieties developed through doubled haploids approach and also using marker-assisted selection techniques, with an objective to shorten the breeding cycle and consequently reduce the product development timeline. Our multipronged strategies offer dual advantages: the creation of hybrids and new-generation rice varieties with high yielding potential will enhance productivity, while the development of varieties resilient to various biotic and abiotic stresses will ensure sustainable production amid changing climatic scenarios. Additionally, we are focused on achieving nutritional security by breeding genotypes with diverse nutritional traits, which can significantly improve the nutritional status of rice consumers. To tackle the labor shortage in agriculture, we are focusing on developing herbicide resistant rice genotypes and also actively involved in breeding varieties suitable for aerobic and direct seeded rice ecosystems addressing cultivation costs and promoting the economical and environmentally sustainable use of available resources. Active involvement in modern tools, such as genomics and genome editing could find a place in rice varietal developmental program and some of the novel products developed are undergoing various stages of evaluation. Overall, CID is at forefront to address present and future challenges and the outcomes will certainly enhance the socio-economic condition of our stakeholders, both directly or indirectly. Our research and development contribution also facilitate to shaping or revising new policies in agricultural planning and development.



Gene edited albino rice plants using *TnpB* as a plant genome editing tool

PROGRAMME

02

Enhancing Productivity, Sustainability and Resilience of Rice Based Production System

Sustainable rice production hinges on enhancing productivity, profitability, resource efficiency, and resilience to climate change. To address these priorities, a comprehensive program has been developed to create, test, and promote innovative technologies aimed at advancing rice-based systems. Its objectives include leveraging digital sensors and nanotechnology for precision nutrient and water management, designing site-specific cropping and weed management systems to optimize productivity, promoting eco-friendly rice residue utilization through conservation technologies and microbial interventions, refining small-scale farm machinery to meet diverse needs, formulating microbial solutions for efficient nutrient, pest, and residue management, assessing the effects of land use changes on ecosystem services, and prioritizing climate-smart technologies to strengthen resilience in stress-prone regions. This holistic approach aims to tackle current challenges while ensuring the long-term sustainability of rice agriculture.

Enhancing nutrient use efficiency in rice through advance agronomy using smart sensors, models and nano fertilizers

Calibration and validation of Greenseeker for in-season N application in rice

The GreenSeeker is an optical crop sensor that measures reflected light to calculate NDVI, which correlates with leaf chlorophyll and informs nitrogen topdressing rates. Accurate recommendations require region-specific calibration for cultivar groups. An earlier algorithm for second topdressing in rice was validated based on the relationship between INSEY (dependent on NDVI) and yield. To improve precision, new algorithms considering greenness and crop duration were developed. Tests were conducted on six (Pooja, Swarna, CR Dhan 409, CR Dhan 410, and CR Dhan 413) rice varieties (145-160 days duration) with six nitrogen levels (0, 40, 60, 80, 100, 120 N ha^{-1}). NDVI readings at 22 DAT showed yield-INSEY relationships best fit a polynomial equation ($y = -53430x^2 + 1797.4x - 9.821$ with a r^2 value of 0.75). First topdressing recommendations varied from 31-35 kg ha^{-1} for plots with 20 kg N ha^{-1} basal and 16-20 kg ha^{-1} for plots with 26.6 kg N ha^{-1}.

Estimation of N footprint of rice production in India using partial LCA (gate to gate) approach

Life Cycle Impact Assessment (LCIA) links emissions to environmental impacts like global warming potential (GWP), eutrophication potential (EP), acidification potential (AP), photochemical ozone creation potential (POCP), and ozone depletion potential (ODP). A gate-to-gate partial Life Cycle Assessment was used to estimate India's nitrogen (N) footprint in rice production, focusing on raw material transformation and reactive N emissions (N_2O, NH_3, NO_3). State-wise inventories included rice area, production, fertilizer use, and emission factors, with eutrophication potential calculated as per ISO 14044 guidelines. Eco-costs of AP, GWP, and EP were derived using the Eco-costs 2023 system and Environmental Footprint standards. NH_3 emissions ranged from 1.8–25.1 kg ha^{-1} or 0.7–8.8 kg t^{-1}, with corresponding AP of 3.3–47.2 g ha^{-1} or 1.3–16.5 kg t^{-1}. N_2O emissions varied from 0.3–0.36 kg ha^{-1} or 0.01–0.13 kg t^{-1}, contributing to GWP of 7.8–111.1 kg ha^{-1} or 3.1–38.9 kg t^{-1}. The average ecological cost of nitrogen fertilizer in India is Rs 18,735 per hectare of rice area and Rs 7,807 per ton of rice yield, with the highest costs observed in Telangana, followed by Haryana.

Synthesis of nano silica from rice husk and its effect on zinc uptake and productivity of rice

Nano silica (Si NPs) synthesized from rice husk was studied for its effects on zinc (Zn) uptake and rice productivity in two rice varieties. Treatments included five silica levels: control, 25%, 50%, 75%, 100% recommended dose of Si NPs, and 100% recommended dose as SiO_2. Zinc was applied as Zn NPs (5 and 10 kg ha^{-1}) and $ZnSO_4{\cdot}7H_2O$ (25 kg ha^{-1}). Applying 100% Si NPs significantly increased rice yields, and combining 100% Si NPs with Zn NPs boosted Zn accumulation in grains by 22.06% to 30.1%, demonstrating the benefits of optimized silica dosing for yield and micronutrient enrichment.

Assessment of methane metabolism in 52 years old long-term fertility paddy soil

Methanogenesis and methane oxidation pathways were studied in 52-year-old long-term fertility paddy soils. The methylotrophic pathway (marked by mttB/COG1795 for trimethylamine transferase) dominated over acetoclastic and hydrogenotrophic pathways across treatments. The mttB/COG1795 gene was most abundant in FYM+N treatment, less so in FYM alone, and negligible in the control (no NPK or FYM). Methane oxidation, identified by particulate methane monooxygenase (PMO) biomarkers, showed pmoA abundance in FYM treatment and pmoC abundance in FYM+N, while both were negligible in other treatments.

National level zonation of rice ecologies, site specific planning and development of cropping and farming system models

Zonation and mapping of different rice ecologies

Study was done for identification of the proneness of ponded water for demarcating the different rice ecologies using Geospatial tools. Multi-criteria analysis (MCDA) was used for mapping proneness to ponding water in Odisha state. MCDA along with the application of analytical hierarchy process (AHP) method were used to identify the optimal selection of weights for the factors that contribute to the ponding water. Odisha state covers a geographical area of 15.571 million hectares (Mha) where rice is the predominant cereal crop and covers nearly 4 million hectares of land. Eastern and Western parts of Odisha show more agricultural land whereas the central part of Odisha shows more permanent vegetation. Coastal districts are more prone to flooding compared to North and western part of the state.

Studies on the micro-climate interactions among the enterprise components under integrated system

Experiment was conducted during *kharif* 2024 to study the growth and yield of Rice + Fish under four treatments T_1- Control; T_2- 100 % Organic; T_3- 50 % Organic + 50 % RFD; T_4- 100 % Inorganic (RFD @ 60: 30: 30 kg NPK ha^{-1}). Long duration rice variety CR Dhan 508 (160 days) was taken integrated with different kinds of fish in the ratio of 30: 30: 20:20 weighing 40-60 gms, (*Labeo rohita, Catla catla, Oreochromis niloticus* and *Hypophthalmichthys molitrix).* Results revealed that the maximum average Chlorophyll-a, Zooplankton no/l and Zoo benthos (g m^{-2}) was observed in the organic fertilizer treatment (T_2) with 64.6± 5.32 mg/m^3, whereas highest average phytoplankton (g m^{-2}) was observed under the treatment T_3 *i.e.*, 50 % Organic +50 % RFD. Maximum harvest size with Rohu, Catla and Tilapia was observed under the treatment T_3 *i.e.* 50 % Organic + 50% RFD, whereas maximum harvest size of silver carp was observed under the treatment T_2 *i.e.* 100 % organic. All the fish species exhibited lowest harvest size in treatment T_1 *i.e.*, Control. Highest SGR in all the fish species was observed under the treatment T_2 *i.e.* 100 % Organic.

Sustainability and profitability of different production systems under various rice-based cropping systems

The experiment was conducted to study the sustainability and profitability of organic and natural farming systems in various rice-based cropping systems: Rice-Rice, Rice-Green gram, and Rice-Groundnut. Under organic farming system, varying doses of FYM were applied as per the requirement of different crops and seeds were treated with bio-fertilizers and *Trichoderma sp*. In natural farming, seeds were treated with beejamrita, and jeevamrita was applied as foliar spray to the crop @500 liters ha^{-1} at 15-days interval. Straw mulching (Achhadana) between crop rows was practiced to conserve soil moisture and to control weeds. Neemastra, Bramhastra, and Agniastra were applied for the management of pests and diseases. Biodiversity in the field was promoted by growing plantation crops like coconut, arecanut, and pulse crops on bunds (Arhar) and erecting straw bundles in the experimental plots to improve the spider population. During the *kharif* 2023-24, no significant difference was observed between organic and natural farming systems (5.82 and 5.40 t ha^{-1}, respectively) with respect to rice yield. Significant difference was observed in rice yield between Rice-Rice (5.83 t ha^{-1}) and Rice-Green gram (5.59 t ha^{-1})/ Rice-Groundnut (5.41 t ha^{-1}) cropping systems. Rice yield was on par in Rice-Green gram and Rice-Groundnut cropping systems (Table 2.1).

Developing Agronomy for New Generation Rice and Rice-based Cropping Systems

An experiment was conducted to evaluate the effect of crop establishment methods, rice varieties, and agro-ecological intensification on rice-based cropping system productivity (Fig 2.1). A split-plot design included two production systems (conventional and conservation agriculture), two rice varieties (CR Dhan 314 and CR Dhan 312), and three intensification strategies (Maize, Maize + Cowpea, Maize + Groundnut). Sub-sub plot treatments were imposed during the rabi season after kharif rice cultivation. Plant height was significantly influenced by variety, with CR Dhan 314 (105.9 cm) taller than CR Dhan 312 (87.2 cm). Conventional agriculture (98.9 cm) showed slightly higher plant height than conservation agriculture (94.2 cm), though not statistically significant. Leaf Area Index (LAI) was highest in Maize + Groundnut plots (3.28), followed by Maize + Cowpea (3.07), and lowest in Sole Maize (2.75). CR Dhan 312 (15.7) produced more tillers per hill than CR Dhan 314 (10.7). SPAD readings were highest in Maize + Groundnut (41.8) and Maize + Cowpea (41.2) plots, significantly higher than Sole Maize (39.7). Panicle length was influenced by variety and cropping system, with CR Dhan 314 (27.6 cm) having longer panicles than CR Dhan 312 (25.9 cm). Panicles were longest in Maize + Groundnut (27.3 cm) and Maize + Cowpea (26.8 cm) plots compared to sole Maize (26.2 cm).

Fig 2.1. General view of the experimental plot at grain filling stage

Table 2.1. Rice yield (t ha^{-1}) in different production systems under various rice-based cropping systems

Treatment	Rice-Groundnut	Rice-Green gram	Rice-Rice	Mean (PS)
Organic Farming	5.55	5.84	6.08	**5.82**
Natural Farming	5.27	5.35	5.57	**5.40**
Mean (CS)	**5.41**	**5.59**	**5.83**	
	Production system (PS)	Cropping system (CS)	CS at PS	PS at CS
CD	NS	0.22	NS	NS
SE(d)	0.175	0.098	0.139	0.208
SE(m)	0.123	0.069	0.214	0.147

Enhancing water use efficiency in rice-based cropping system

Evaluation of varietal performance under Direct Seeded Rice

Direct Seeded Rice (DSR) is a viable alternative to conventional puddled transplanted rice. DSR reduces methane emission not only by reducing flooding duration but also by reducing the crop cultivation duration compared to conventional methods due to reduced stress on the seedlings. The experiment was conducted in *kharif*, 2024 under irrigated conditions. The seeds of 16 rice varieties were sown manually under direct seeded condition. Pre and post emergence weed control measures were followed to keep the field weed free. Standard agronomic practices were followed for optimum crop growth. The rice varieties selected for this study were categorized into three maturity duration groups: short duration (< 120 days) (CR Dhan 807, Naveen, CR Dhan 321, CR Dhan 212, CR Dhan 805), medium duration (121-135 days) (CR Dhan 308, CR Dhan 314, CR Dhan 328, CR Dhan 312, CR Dhan 704), and long duration (136-150 days) (CR Dhan 307, CR Dhan 802, CR Dhan 317, Pooja, CR Dhan-414, CR Dhan 702). The experiment was conducted to assess crop performance and methane emissions of rice varieties of different durations under DSR conditions. The experimental results suggest that there was a varietal difference in methane emissions. The seasonal methane emission was correlated with the duration of the variety. The cumulative methane emission was highest for long duration varieties (> 135 days) followed by medium duration varieties (120-135 days) and lowest for short duration varieties (<120 days). The emissions of methane were highly linked to the root architecture like root length, root density, root diameter, root oxidation activity, root density and root aerenchyma.

Estimation of Potential Recharge Flux from Paddy fields under varying Ponding depth

In order to measure the *in-situ* recharge rate/percolation flux from the paddy field, a field experiment was conducted following the drum culture technique. Drums of 60 cm diameter and height of 80 cm were inserted in the experimental paddy field of CRRI up to 40 cm depth. One drum was having open bottom (Drum-1) with rice plants grown inside and another closed bottom (Drum-2) with rice plants grown inside. Daily ET value (Drum 1) and the ET+R values were measured in the field and the recharge rate/percolation rate was calculated as the difference between water depth at Drum-1 and the Drum-2 on daily basis. From daily water balance study, it was observed that out of the total water losses through ET and percolation, from the paddy field ET contributed 60% whereas Recharge Flux contributed to 40%. Monthly average ET was observed as 0.6 cm/day, 1.2 cm/day and 1.5 cm/day and the monthly average Recharge Flux was observed as 0.1 cm/day, 0.8 cm/day and 0.7 cm/day for the months of March, April, and May. The irrigation return flow from the experimental field was observed as 40% (Fig 2.2 and Fig 2.3)

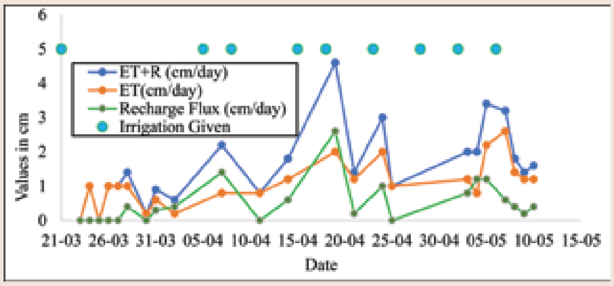


Fig 2.2. Measured daily ET, and Recharge Flux from Bunded Paddy Field from CRRI, Farm (Plot B4B)

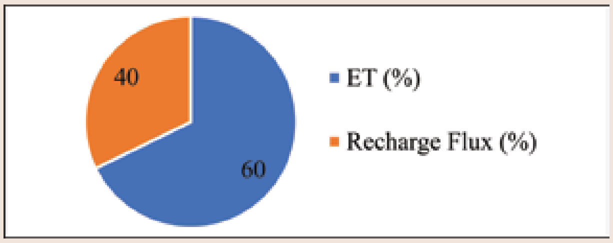


Fig 2.3. Percentage contribution of ET and Recharge Flux to the total water loss

Vulnerability analysis and assessment of climate smart agricultural technologies for enhancing resilience in stress prone rice ecologies

Block wise drought vulnerability index for West Central Table Land Agro climatic Zone of Odisha

Droughts, intensified by climate change, severely affect agriculture and livelihoods in Odisha's West Central Table Land Zone (WCTL). This agro climatic zone spans 17.19 lakh hectares across seven districts, with 56.95% cultivated land and a cropping intensity of 136%, dominated by rice (55.6%). Limited irrigation (30%) heightens vulnerability. A Block-Wise Drought Vulnerability Index (DVI) assesses vulnerability using climatic, agricultural, hydrological, and socio-economic data, normalized and weighted via Principal Component Analysis (PCA). Among 46 blocks, 10 show low vulnerability, 20 medium, 11 high, and 5 very high. Blocks like Jharsuguda, Binika, Birmaharajpur, Kolabira, Agalpur, Rairakhol, Kirmira, Maneswar, Reamal, and Jharbandh are less vulnerable, while Bangomunda, Belpada, Lakhanpur, Titilagarh, and Tureikela face significant drought risks (Fig 2.4).

Dynamics of gene expression associated with arsenic uptake and transport in Rice var. Shatabdi and Rajalaxmi during the whole growth period

Rice, a staple crop in South and Southeast Asia, is a primary conduit for arsenic (As) entry into the food chain. This study examines arsenite (As III) and arsenate (As V) transporters (OsLSi1, OsLSi2, OsLSi6, OsPT1, OsPT2) and

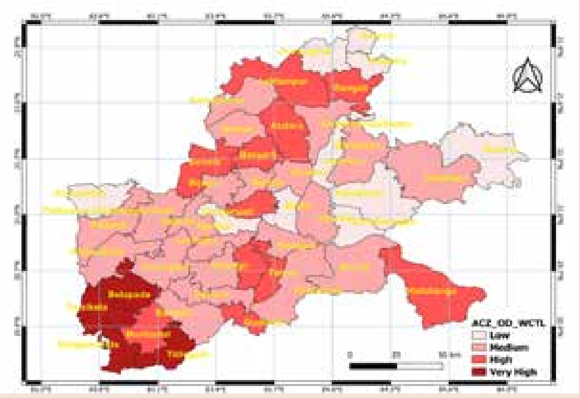


Fig 2.4. Block wise map of drought vulnerability index (VI) of the West Central Table Land Agro climatic Zone in Odisha

detoxification pathways (OsABCC1) in two rice varieties, Shatabdi and Rajalaxmi, across six growth stages. OsLsi1 and OsPT1 expression peaked at the jointing stage in Shatabdi and the dough stage in Rajalaxmi, leading to maximum root As concentrations (18.5 mg kg^{-1} and 23.5 mg kg^{-1}, respectively). Shatabdi showed sharp transporter expression increase at the jointing stage, while Rajalaxmi exhibited gradual increases, resulting in higher grain As levels (0.93 mg kg^{-1}). Strong OsABCC1 expression in Shatabdi reduced grain As translocation, as evidenced by a lower translocation factor (0.09 vs. 0.18). Arsenic speciation revealed As V as the dominant form in grains (42%). Critical uptake stages were the jointing stage for Shatabdi and the dough stage for Rajalaxmi.

Development and evaluation of biochar based composites for removal of meta(loids) from rice ecosystem (Biochar-$FeSO_4.7H_2O$ composite)

Fe-modified biochar was developed using $FeSO_4$ and rice husk in ratios of 1:2, 1:3, and 1:5. The mixtures were stirred for 6 hours, dried at 70°C for 48 hours, and pyrolyzed at 450°C. The biochar was then ground, sieved, washed, and re-dried before pH adjustment with $Ca(OH)_2$. Characterization and adsorption studies were conducted, optimizing parameters like pH (2–11), contact time (10–360 min), adsorbent dose (10–100 mg), and contaminant concentrations (0.1–20 mg L^{-1}) at room temperature. Arsenic (As) removal increased significantly between pH 2–6, plateauing at 6–7, and decreased beyond pH 8.5. Cadmium (Cd) removal peaked between pH 7–9. Adsorption equilibrium for both occurred at 120 minutes. As(V) adsorption followed both Langmuir and Freundlich models, while Cd(II) was better described by the Langmuir model. RSM optimization achieved 77.96% Cd removal at pH 6.3, 127 minutes, 30 mg L^{-1} adsorbate concentration, and 30 mg adsorbent dose.

Extraction, Projection and Bias Correction of Future Rainfall data for 2050 under RCP 4.5: Analysis Across 22 Blocks in Balangir and Dhenkanal Districts, Odisha

Climate change is projected to intensify regional vulnerability in Odisha's Balangir and Dhenkanal districts by 2050 under RCP 4.5. Using bias-corrected future climate data from the IITM-RCM model for 22 blocks, the Distribution Mapping Technique revealed significant rainfall declines across all blocks, with Dhenkanal experiencing a steeper reduction than Balangir. This trend poses serious challenges for water resources and agriculture. Illustrates the block-wise percentage change in rainfall compared to the 1976–2005 baseline, emphasizing the need for adaptive strategies to mitigate climate change impacts (Fig 2.5).

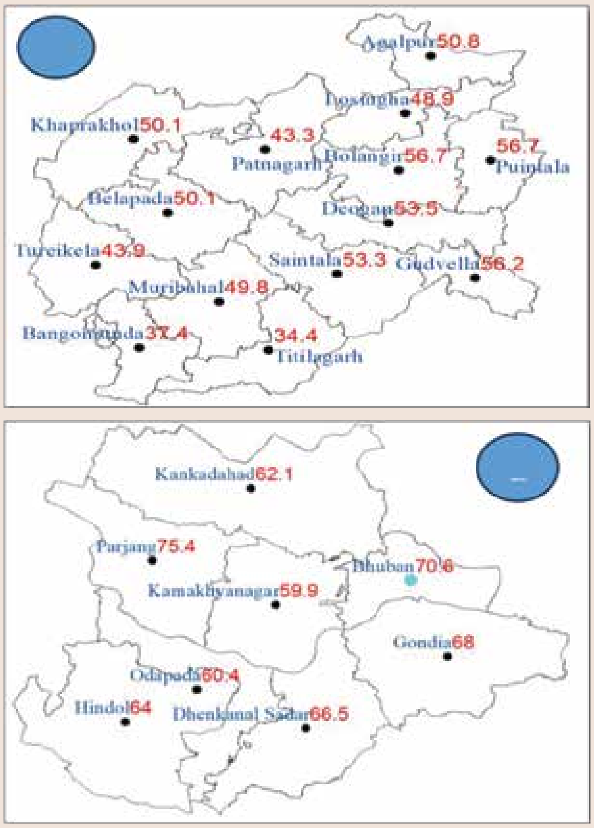


Fig 2.5. Reduction of RF in 2050 in Blocks of Balangir District (A) and Dhenkanal District (B) as compared to the base year (1976-2005)

Ecosystem services quantification and analysing the nexus of climate change-land use change-food security in rice production systems

Quantification of the ES from rice and rice-based production systems

This study examines ecosystem services (ES) in India's rice production systems, focusing on climate and land use changes. A web tool was developed to assess ES categories, including provisioning, regulating, and supporting services. Data was analyzed by dividing India into five regions: North, South, East, West, and North East, each representing varying characteristics like temperature, soil, and rainfall. State-wise data on rice cultivation methods was collected and analyzed using a framework by Sandhu *et al*. (2008) to estimate total ES values. The analysis revealed significant regional variations in ecosystem service values across India. The factors used for calculating ecosystem services are mentioned in Table 2.2.

The southern region showed the highest nitrogen fixation and carbon accumulation rates, while the eastern region excelled in soil fertility. Western India recorded the highest non-marketable ecosystem service values ($1,463 to $2,221 per hectare), while northern India had the lowest in some metrics (Fig 2.6). Regional soil fertility and land management practices played key roles, with the southern and eastern regions contributing most to soil fertility and services like soil erosion control. Economic valuation further underscored the importance of these ecosystem services. Soil fertility values ranged from $100 to $896 per hectare annually, with notable contributions from the eastern and southern regions. These findings highlight the importance of region-specific agricultural practices for enhancing sustainability and addressing climate and food security challenges.

Analysing Post-Production Energy Footprints of Rice across different states of India

This study aims to quantify the energy footprint of rice from post-production to cooking across different Indian states and identify factors contributing to variations in energy footprints. State-wise rice production data for 2022-23 was used. Energy cost estimates for milling one tonne of rice were calculated by summing the energy costs for milling, transportation, machine use, building, and labor, along with cooking costs (assuming a 55-60% head rice recovery). Transportation energy was estimated using a road transport coefficient (0.12 kcal/kg) for a 10-12 km distance. Various formulas were used for calculations, considering machine working hours, lifespan, energy coefficients (e.g., rice sheller: 0.0072 Mcal/kg, diesel: 0.47 Mcal/L), and rice quantity.

The resulting energy cost data was grouped into five zones: North, East, West, South, and North Eastern India. The highest energy cost in post-production was due to fuel consumption (85.67%), followed by labor

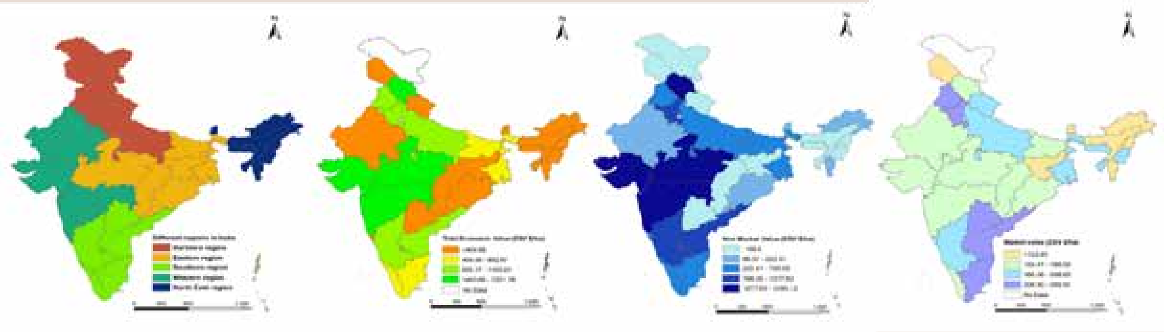


Fig 2.6. Different regions of India for analysis in this study and marketable, non-marketable and total ecosystem service values for different regions

Table 2.2. Conversion factors for calculating ecosystem services

Services	Conversion factor	Economic value
Food	Grain yield in quintals	MSP of crops
By-products	1.5 times of grain	US$ = 0.0155 kg^{-1}
Bio control of pest	Market cost of recommended dose of pesticide at ETL level	1 Spider = US$0.038, 1 Mirid bug = US$0.008,
Soil formation	1 tonne of earthworms forms 1 tonne of soil ha^{-1}yr^{-1}	Top-soil value is US$ 2093 ha^{-1}
Mineralization of plant nutrients	Total N = 77.78% of NH_4	Equivalent price of N = US$ 0.082kg^{-1}
Hydrological flow	About 45% of total rainfall and irrigation as recharge to groundwater	US$ 1.5 per 1000 m^3
Carbon flow	Carbon accumulation is 40% of total biomass incorporated in field, Percentage left over C of the applied amount from organic amendments & crop residues is 28.8% in rice field	CER (Carbon Emission Reduction) is about US$ 21.71
Nitrogen fixation	Rice =19 kg N ha^{-1} crop^{-1}	Equivalent price of N = US$ 0.082 kg^{-1}
Soil fertility	NUE=34%; PUE=25%; KUE=60% for rice	Market price of fertilizers
Erosion	Sediment delivery ratio (SDR) = 0.3	Top soil value as US$ 2093 ha^{-1}

(7.26%) and transportation (6.4%). The eastern zone had the highest energy cost at 894.33 Mcal/MT, followed by Northern (780.31 Mcal/MT), Southern (659.61 Mcal/MT), North Eastern (130.54 Mcal/MT), and Western zones (116.60 Mcal/MT). Among states, West Bengal had the highest energy cost at 313.14 Mcal/T, followed by Uttar Pradesh (285.86 Mcal/T) and Punjab (241.21 Mcal/MT), primarily due to higher paddy production in these states. Analyzing rice post-production energy footprints across India revealed regional variations, highlighting factors influencing energy use. Understanding these differences is key to developing strategies for reducing consumption and promoting sustainable practices.

Environment friendly management of rice straw and value addition for income generation to rice-farmers

In-situ rice straw decomposition

India produces around 126.6 million tonnes of rice straw, and burning it is increasing in states like West Bengal, Odisha, Bihar and Jharkhand. This practice worsens air pollution and increases carbon emissions. Eco-friendly solutions for straw management are essential. A field experiment was conducted to explore *in-situ* management options with different treatments (i) immediate incorporation of straw (IIRS), (ii) zero tillage with glyphosate (ZT), (iii) straw spreading (SRS), and (iv) zero tillage with straw retention without glyphosate spray (ZT+SR). GHG emissions (methane and nitrous oxide) were measured during both the in-situ straw decomposition and subsequent rice crop growth periods. Methane emissions were highest in IIRS, followed by SRS, ZT, and ZT+SR. Emissions increased from 3 to 18 days after treatment and then decreased by day 38. Zero tillage (ZT) showed relatively lower emissions. Higher GHGs (Fig 2.7) were recorded during crop growth stages compared to the decomposition period. IIRS produced the highest crop yield (5.64 kg ha^{-1}), followed by SRS (5.19 kg ha^{-1}).

Modify the pre-treatment techniques of rice straw for bioethanol production through microbial intervention.

Rice straw, a plentiful agricultural residue, is a valuable feedstock for bioethanol production, providing sustainable energy and reducing waste and pollution. Its lignocellulosic composition of cellulose, hemicellulose, and lignin makes it ideal for bioethanol, a renewable alternative to fossil fuels. Converting rice straw into bioethanol aids in waste management, energy security, and climate change mitigation. Pre-treating rice straw with a microbial consortium (*Bacillus cereus* ((MN784664) and *Penicillium* sp (MK855473)) for 14 days yielded a bioethanol recovery of 11.4-12.3%.

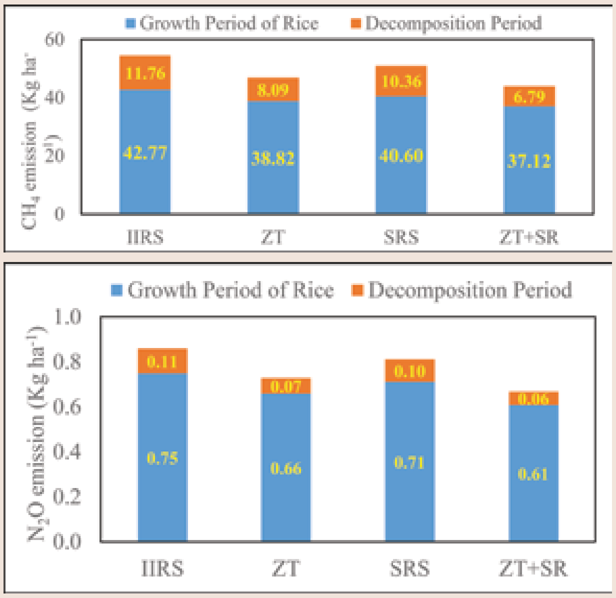


Fig. 2.7. Seasonal CH_4 and N_2O emission (both decomposition and crop growth period)

Harnessing Microbiome for enhancing rice productivity and improving soil health

Cross inoculation of cyanobacteria in two contrasting *Azolla* species

The study examined the cross-inoculation of cyanobacteria in two Azolla species (*A. microphylla* and *A. pinnata*). Results showed higher cyanobacteria density in natural *A. microphylla* (AM) and *A. pinnata* (AP), while none were observed in cyanobacteria-free *A. microphylla* (CFAM) and A. pinnata (CFAP). Cyanobacteria density was low in cross-inoculated treatments. Both relative frond number (RFN) and heterocyst frequency (HF) were higher in AM and AP, while CFAM and CFAP showed lower RFN. Cross-inoculated cyanobacteria from AP in CFAM and from AM in CFAP showed higher RFN than other treatments, though HF was absent in CFAM and CFAP, but it was present in Cross-inoculated cyanobacteria (Fig. 2.8).

Occurrence of Dissimilatory Nitrate Reduction to Ammonia (DNRA) bacteria population in rice agro-ecosystem

Sixty-nine Dissimilatory Nitrate Reduction to Ammonia (DNRA) bacteria were isolated using minimal salts medium (MSM) from paddy soils across six diverse rice agro-ecosystems (irrigated, shallow-lowland, intermediate-lowland, semi-deep lowland, upland, and aerobic conditions) of CRRI field in Cuttack. Among these, 39 isolates tested positive in the nitrate disc test. Of the

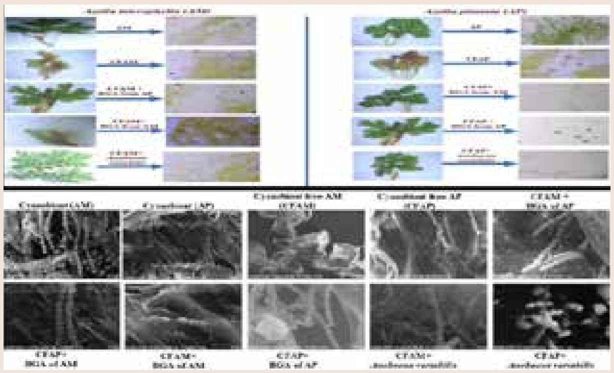


Fig. 2.8. Cross inoculation of cyanobacteria in *Azolla microphylla* and *Azolla pinnata.* AM: *Azolla microphylla;* AP: *Azolla pinnata;* CFAM: Cyanobacteria-free *Azolla microphylla;* CFAP: Cyanobacteria-free *Azolla pinnata; BGA:* Blue green algae (Cyanobacteria)

39, 17 isolates showed positive amplification for the *nrfA* gene and were identified as follows: *Escherichia coli* (1IL), *Actinobacillus succinogenes* (2IL), *Ferrimonas balearica* (3SD), *Shewanella baltica* (4AR), *Citrobacter* sp. (5IR), *Citrobacter koseri* (6IR), *Shewanella oneidensis* (7AR), *Pseudomonas aeruginosa* (8DR), *Anaeromyxobacter* sp. (9AR), *Actinomyces* sp. (10SL), *Geobacter sulfurreducens* (11IL), *Meiothermus* sp. (12SD), *Desulfovibrio* sp. (13SD), *Sorangium* sp. (14IR), *Deinococcus* sp. (15SD), *Bacillus* sp. (16SD), and *Paenibacillus* sp. (17SD).

Evaluation of Arbuscular Mycorrhizal fungal (AMF) incoulum for rice production

The AMF inoculum, made from mixed fungal strains of *Glomus* sp. (CRRI-CPD-AMF3), *Funneliformis* sp. (CRRI-CPD-AMF1), *Rhizophagus* sp. (CRRI-CPD-AMF6), and *Acaulospora* sp. (CRRI-CPD-AMF7), contained 1.56–1.68 x 10^3 infective propagules. Applying 2.0 kg of AMF inoculum per 1000 m^2 in rice nursery beds significantly increased mycorrhizal colonization (59.0-71.0%) in rice seedlings compared to the un-inoculated control (26-35%). Field evaluation of AMF inoculated (AMF^+) and un-inoculated (AMF^-) Swarna rice seedlings showed that transplanting of AMF^+ with 100% NK+75% P significantly increased yield and mycorrhizal root colonization (56.8 %) compared to AMF^- with 100% NK+75% P.

Evaluation of strigolactones (SLs) application in rice production

The study aimed to enhance native soil Arbuscular mycorrhizal fungi (AMF) colonization in rice crops through synthetic strigolactones (SLs-GR 24). Seed priming with SLs-GR 24 (5µM of 100 ml per kg of seeds) significantly improved mycorrhizal colonization and plant growth at the nursery stage. Seed priming (SLs-GR 24) with AMF application (2.0 kg per 1000m^2) increased mycorrhizal colonization by 53 % compared to un-inoculated control. In another experiment, SLs-GR 24 seed priming influenced OsSPL14 gene expression in different rice varieties under varying soil phosphorus levels. OsSPL14 expression was highest in CR Dhan 201 under low-P conditions but was downregulated under high-P conditions. Field trials with Naveen rice revealed that 100% NK + 75% P with SLs-GR 24 and AMF significantly increased yield compared to 100% NK + 75% P.

Popularization and demonstration of Microbial inoculants technology

A model liquid biofertilizer production plant has been established at ICAR-CRRI, Cuttack, to facilitate the large-scale production and commercialization of liquid bioinoculants. The facility has produced various microbial inoculants, including 5000 liters of CRRI-EndoN, 100 liters of CRRI-EndoNPK, 2.0 tonnes of Tech CRRI Decomposer, and 10 tonnes of Azolla. Orders amounting to 15,000 liters of CRRI-EndoN and 3.0 tonnes of Tech CRRI Decomposer have been received through various schemes such as SCSP, TSP, NEH, and E-CHASI. Efforts to promote and demonstrate the use of CRRI bio inoculants, such as CRRI-EndoN and the decomposer for *in situ* and *ex situ* residue management, have been conducted in six districts of Odisha (Cuttack, Dhenkanal, Puri, Bhadrak, Ganjam, and Jagatsinghpur), covering over 1,000 acres of rice fields and receiving coverage in local print media.

Development of weed management strategies assessing the risk of herbicide resistance in rice weeds

Standardization of management practices for herbicide tolerance rice in double zero tillage rice

Weed control is a major challenge in direct-seeded rice (DSR) and zero tillage (ZT), particularly when combined. Herbicide-tolerant rice (HTR) may address this issue, so an experiment was conducted to optimize the application of Imazethapyr herbicide and compare its effectiveness with hand weeding and Pendimethalin. Ten treatments, including combinations of Pendimethalin and Imazethapyr at various timings, hand weeding, and control plots, were tested using the Sahabhagi Dhan-HTR variety under zero and conventional tillage. The study aimed to evaluate weed suppression and yield under different herbicide schedules.

The results of the experiments (Table 2.3) indicated that, the timing of Imazethapyr application significantly affected plant dry matter and density. In conventional tillage, late application (28 DAE) increased weed density by 132% and 141% with and without Pendimethalin, respectively. In zero tillage, weed density rose by 282% and 235% under the same conditions. Similar trends were observed for weed dry matter, as delayed suppression of ratoon hindered seedling emergence and boosted weed growth. Ratoon height at 15 DAE (i.e. 21 days after harvest of previous rice crop) ranged from 25.9 cm to 30.4 cm, while at 28 DAE in untreated plots, it ranged from 33.9 cm to 39.5 cm. Imazethapyr application at 15 DAE caused necrosis, leading to a 61-74% reduction in ratoon height. At 21 DAE, the reduction reached up to 122%. Complete degradation of ratoon was observed in treated plots at 15 DAHA of Imazethapyr application.

The yield data showed that Imazethapyr, applied with or without Pendimethalin, significantly impacted yield and attributes compared to Pendimethalin alone. Imazethapyr at 15 DAE resulted in the highest plant height, panicle count, grains per panicle, test weight, and both grain and straw yields in both zero and conventional tillage. The highest yield occurred with Imazethapyr at 15 DAE in zero tillage, followed by Pendimethalin + Imazethapyr. Yield decreased with delayed Imazethapyr application, with a 65% reduction in zero tillage and 33% in conventional tillage after a two-week delay. The ratoon effect influenced grain yield, with early suppression improving crop growth. Nitrogen content in grain and straw, as well as nitrogen

Table 2.3. Effect of herbicide application treatments on rice growth and yield at harvest

	Plant height (cm)		No. of panicles/m^2		No. of grains/ panicle		Test weight (g)		Grain yield (t/ha)	
	ZT	**CT**	**ZT**	**CT**	**ZT**	**CT**	**ZT**	**CT**	**ZT**	**CT**
T1	86.66	97.10	233	278	103.4	112.2	21.9	21.6	3.54	4.10
T2	99.86	112.06	350	360	160.2	165.4	22.2	21.9	6.19	6.23
T3	98.52	110.7	345	345	161.8	156.6	21.8	21.7	5.1	6.08
T4	90.52	102	297	290	110.0	123.8	21.6	21.6	3.82	4.60
T5	97.54	112.26	346	360	168.7	162.8	22.3	21.3	6.3	6.18
T6	94.28	109.14	335	350	162.1	165.8	21.3	21.6	5.06	6.17
T7	89.14	99.08	295	280	93.8	114.8	21.4	21.4	3.72	4.62
T8	94.88	106.66	318	300	150.2	145.6	21.7	22.0	5.77	5.85
T9	96.78	107.48	329	320	153.0	150.8	21.8	21.4	6.03	5.94
T10	81.92	90.3	217	200	86.6	106.6	21.2	21.6	1.72	2.49
Mean	93.01	104.678	306.5	308.3	133.98	140.44	21.72	21.61	4.725	5.216

Pendimethalin @ 1000g a.i./ha (**T1**), Pendimethalin @ 1000g a.i./ha + Imazethapyr @ 100g a.i./ha at 15 DAE (**T2**), Pendimethalin @ 1000g a.i./ha + Imazethapyr @ 100g a.i/ha at 21 DAE (**T3**), Pendimethalin @ 1000g a.i/ha + Imazethapyr @ 100g a.i/ha at 28 DAE (**T4**), Imazethapyr @ 100g a.i/ha at 15 DAE (**T5**), Imazethapyr @100g a.i/ha at 21 DAE (**T6**), Imazethapyr @ 100g a.i/ha at 28 DAE (**T7**), Hand weeding at 15 and 30 DAE (**T8**), Weed free (**T9**), Weedy (**T10**). Conventional tillage (**CT**), Zero tillage (**ZT**).

uptake and protein content, were significantly affected by the treatments.

Development and Refinement of Farm implements, Post-harvest and value-addition technologies for Small Farm Mechanization

Development and refinement of battery powered weeder for rice crop

The developed battery-power weeder was evaluated at the CRRI field at a row spacing of 25 cm and weeding done after 25 and 40 days of transplanting. The two sets of batteries (each set consists of two 12V batteries) were used to operate weeder (Fig 2.9). The average current required for weeding operation was 6-8 amperes in field. The performance of cutting blade on the periphery of cage wheel was the best among other cutting unit and also the clogging of weed in the cutting blade was minimum. The cost of weeder was Rs. 15000/- and cost of operation was around Rs. 1200/- per hectare.

Development of Non-destructive Solar Powered Bird Scarring System for protecting crop yield.

The unique bird scarring system is designed to protect crops from yield loss by effectively scarring away birds. With a range of 500 meters in diameter, the system operates with two 10 W solar panels and a 7Ah, 12V battery, ensuring efficient performance. The scarring efficiency is an impressive 98%, making it highly effective in safeguarding crop fields. The system is being developed and will undergo testing during this season. The tentative cost of the system is Rs. 8000 per ha.

Conceptual CAD model

Cutting blades on the periphery of cage wheel

Developed Battery powered weeder

Fig 2.9. Battery operated power weeder

Development and performance evaluation of IoT based smart real-time pipe irrigation Scheduling System for Rice

An IoT-enabled real-time soil moisture monitoring system has been developed, utilizing the market-available Granular Matrix Sensor (Chlapeca *et al*., 2021) to accurately measure soil moisture levels. The system integrates IoT-enabled circuitry, allowing for continuous monitoring of soil moisture in the field and providing real-time data that is accessible online. The system has been field-tested and has proven efficient in providing accurate moisture readings, helping farmers optimize irrigation practices. Additionally, the system includes a rain sensor, which detects rainfall during irrigation, automatically stopping the pump to prevent over-irrigation.

Preparation of packaged flavored rice water

The rice drink prepared contained healthy bacteria and bioactive compounds. Fermentation activity enhanced nutritional value and anti-oxidant properties as total phenolics, flavonoid and sugar content of rice water increased. The *Penicillium* sp. and *Aspergillus* sp. were present in fermented product. The rice drink has a shelf life of 7- days stored in plastic cups at 10°C and 3-4 days in paper cups with respect to the acceptability.

Development of innovative processing technologies for fermented rice beverage

The process technology developed for retaining micronutrients in rice water focuses on using single-parboiled, unpolished rice, which retains significantly higher levels of iron (25–54.6 mg kg^{-1}) and zinc (16–45 mg kg^{-1}) compared to polished rice, which retains only 35-47 mg kg^{-1} of iron and 8-15 mg kg^{-1} of zinc, respectively. It was found that a shorter fermentation time of 12–16 hours at 35–37°C resulted in maximum retention of essential nutrients, including zinc (51–55 mg kg^{-1}) and folate (32–45 mg kg^{-1}). Also, the sensory qualities of the rice water, such as flavor, aroma, and mouthfeel, were either maintained or enhanced, making it an appealing option for traditional consumption. Longer fermentation periods led to a decrease in these nutrients. The final product, a fermented rice water, was found to be shelf-stable for up to two weeks when stored under refrigerated conditions, with no significant degradation in nutrient content, ensuring both nutritional and sensory quality.

Optimization of rice processing for arsenic reduction and nutrient enhancement

Optimizing rice processing to reduce arsenic content while enhancing its nutritional profile involves analyzing multiple factors. Parboiling methods, such as hot soaking (HS), cold soaking (CS), and pressure parboiling (PP), can influence arsenic mobility and nutrient retention, compared to non-parboiled (NP) rice. Milling levels and Cooking methods, such as traditional (CT) and pressure cooking (PC), modify arsenic levels and nutrient availability. Combining these factors in an optimized process could yield safer and more nutritious rice. Non-parboiled rice (NP) exhibited the lowest arsenic (As) levels in polished rice, with hot soaking (HS), cold soaking (CS), and pressure parboiling (PP) leading to 25.3%, 17.4%, and 32.7% higher arsenic entry, respectively. Full milling (100%) effectively reduced arsenic by 52.4% in polished rice compared to brown rice. Traditional cooking, involving excess water removal, further decreased arsenic by 22.3–35.8%, while pressure cooking resulted in minimal change (+2 to -5.2%). Overall, paddy processing could lower arsenic in cooked rice by 70.2–90.1%, with the maximum reduction (90.1%) achieved through non-parboiled rice, full milling, and traditional cooking (NP + M100 + CT)

Development, validation and commercialization of rice by-product based fish feed

Rice by-products, such as husk and bran, sourced from CRRI varieties, were selected alongside suitable fish species for formulation. The optimization of ingredients, including rice by-products, legume proteins, and binders, was carried out to meet the specific nutritional requirements of the selected fish species. The protein content of the formulations (ranging from 29.85% to 37.43%) indicates that these vegetarian-based feeds can provide equivalent nutrition to traditional non-vegetarian diets, which include fish meal, chicken liver, and poultry by-products. Additionally, the pellet durability values (ranging from 84.31% to 98.49%) demonstrate that the formulations remain stable in water, and stay intact until consumed by the fish. These formulations, primarily based on affordable and easily accessible rice by-products, provide a sustainable and cost-effective alternative to conventional fish feeds, benefiting farmers at the household level while supporting the growth and nutrition of selected fish species.

Conclusion

The Crop Production Division has undertaken various research initiatives, leading to significant advancements in agricultural practices. Key achievements include standardizing precision nitrogen application using GreenSeeker, an advanced optical crop sensor, and developing an IoT-based real-time irrigation scheduling system tailored for rice cultivation. Cost-effective herbicide-tolerant rice management practices have also been established. Assessment of crop performance and methane emissions of rice varieties under DSR conditions indicated that the emissions of methane were highly linked to the root architecture like root length, root density, root diameter, root oxidation activity, root density and root aerenchyma. Research on nano silica (Si NPs) synthesized from rice husk demonstrated its ability to enhance zinc uptake and improve rice productivity. Climate-smart agricultural technologies were assessed to boost resilience in stress-prone rice ecosystems within the West Central Table Land Agro climatic Zone of Odisha. Studies on ecosystem services from rice-based systems highlighted the importance of region-specific practices for sustainability and addressing challenges related to climate change and food security. Post-production energy footprint analysis for rice across India revealed regional disparities and identified factors affecting energy use, underscoring the need for strategies to reduce energy consumption and enhance sustainability. For paddy straw management, standardized packages were developed to improve yields and mitigating greenhouse gas emissions. Microbial interventions demonstrated the potential to significantly reduce the use of chemical fertilizers in rice cultivation, also standardized mycorrhizal application for rice cultivation. Innovations introduced include a battery-powered weeder, an IoT-enabled real-time soil moisture monitoring system, and a solar-powered, non-destructive bird-scaring system designed for rice farming. Additionally, advanced processing technologies were developed, including methods for creating fermented rice beverages, enhancing nutrients, and reducing arsenic content.

PROGRAMME
03

Biotic Stress Management in Rice

The Crop Protection Division focuses on advancing sustainable and effective pest management strategies for rice cultivation. The Division emphasizes key areas such as identifying donors for enhanced pest resistance, insect pests, pathogen and nematode population dynamics in response to climate change, and exploring the chemical mechanisms that govern interactions between rice plant, pests, and natural enemies. In addition, the Division is enhancing its research on innovative pest monitoring and forecasting tools, while also seeking to develop new management solutions that integrate both existing pesticides and natural resources. The Division continues to implement Integrated Rice Health Management (IRHM) strategies across diverse rice-growing ecologies.

1 NO POVERTY
2 ZERO HUNGER
3 GOOD HEALTH AND WELL-BEING
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION
15 LIFE ON LAND
16 PEACE, JUSTICE AND STRONG INSTITUTIONS
17 PARTNERSHIPS FOR THE GOALS

Identification and characterization of donors against biotic stresses

Unveiling new genetic resources for resistance to Insect pests and diseases

Brown Planthopper and White Backed Planthopper

Out of 103 genotypes evaluated, three genotypes Bhadra, Swetha, and IC 298361 were found to be moderately resistant to Brown Planthopper (score 3). Another screening revealed that among the 17 gene differentials evaluated, only two differentials PTB 33 (bph2 + Bph3 + unknown factors) and RP 2068-18-3-5 (Bph33(t) gene) showed promising resistance, with a score of 1, against the Cuttack *N. lugens* populations. Screening of 152 rice genotypes against *N. lugens* and genotyping with 82 SSR markers linked to 29 resistance genes revealed 33 resistant genotypes (score 1). Marker-trait analysis revealed significant markers RM1313 (Bph9) and RM7 (Qbph3), with RM7 confirmed through GLM and MLM. Phenotypic analysis showed high resistance (score 1) in Salkathi, Dhobanumberi, and PTB33, and resistance (score 3) in eight genotypes. Marker-trait association analysis identified five markers (RM261, RM1305, RM6843, RM6869, and RM16853) as significantly associated with phenotypic traits related to *N. lugens* resistance, with RM261 (*Bph15*) showing the highest significance. These findings provide valuable resources for breeding *N. lugens*-resistant rice varieties.

Additionally, IC 316446 and CO-52 recorded moderate resistance (score 3) against WBPH.

Rice Leaf folder

Morphology of rice trichomes in 15 Assam Rice Collection (ARC) germplasm along with resistant and susceptible checks was studied through Scanning Electron Microscopy (SEM). The resistant genotypes, ARC-11249, ARC-11891, ARC-11308, ARC-11324, and ARC-11855 exhibited consistently higher trichome densities and lengths than the moderately resistant and susceptible ones. Among these, ARC-11324 demonstrated the highest abundance of glandular and papillae trichomes, but notably lacked macro-trichomes. The study also established a negative correlation between trichome metrics (density and length) and leaf folder (*Cnaphalocrocis medinalis*) infestation. Particularly, glandular trichomes might play a dual role by providing physical and possibly chemical deterrents to the leaf folder (Fig. 3.1).

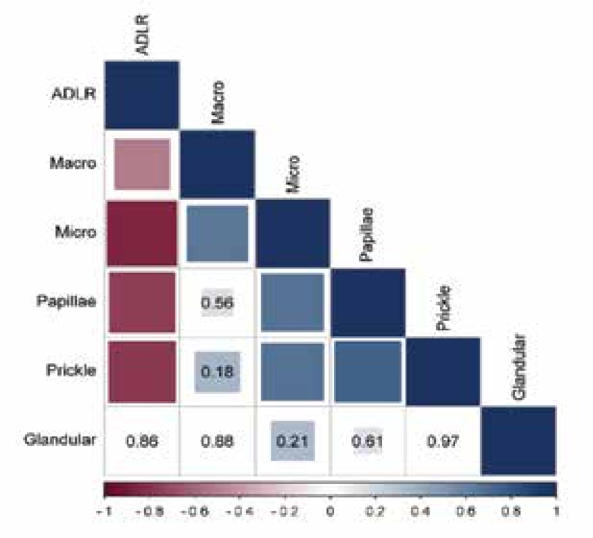


Fig. 3.1. Correlation of trichome metrics with the Adjusted Damaged Leaves Rating (ADLR) ($p<0.05$)

Rice Gall midge

Out of 198 aus rice germplasm screened, none of the accessions exhibited incidence of gall midge under Direct Seeded Rice (DSR) conditions. A total of 202 rice genotypes were phenotyped and analyzed using genomic markers linked to gall midge resistance. Among the markers, gm3del3 accounted for the highest genetic variation, followed by RM28574, while RM22709 contributed minimally. A single-marker linear regression approach was employed to identify genomic regions or genes associated with gall midge resistance. Marker RM17480, located on chromosome 4 and linked to the gm3 gene, showed a significant association with gall midge resistance, with allelic effects negatively correlated to resistance reactions.

Rice Sheath blight

Out of 27 CRRI newly released varieties, 115 Assam Rice Collections (ARC), 42 New Generation Rice (NGR) lines, and 80 breeding lines (provided by CRRI rice breeders) screened for resistance against sheath blight disease under artificial inoculation, 3, 8, 4, and 6 entries, respectively, were found moderately resistant. The promising entries identified are CR Dhan 324, CR Dhan 409, and CR Dhan 801; ARC 5791, 6001, 6033, 6180, 5783, 5913, 6097, and 11211; and C 1418-1-1-1-1-3, C 1781-4-1-1, C 3021-1-1-2-1-1, and TRB-7-1-1-1-1-2.

False smut

A total of 879 entries, comprising of Assam Rice Collections (ARC), selected entries from the National Gene Bank (NGB), CRRI varieties, and various AICRIP materials, were screened against the false smut pathogen. ARC collections like ARC-6005, 6006, 5842, 5769, 7048, 7038, 5776, 5982, 6609, 5940, 7085, 5975, 7008, 6606, and germplasm from NGB, namely IC 466660, IC 114371, IC 435159, IC 324679, IC 379843, and IC 595241, were found resistant to false smut disease in rice. Additionally, 10 promising ARC collections were evaluated for resistance to false smut disease during *kharif* 2024 at RRS Nawagam, CRURRS Hazaribagh, and CRRI Cuttack. Among these, ARC-5769, 5940, 5982, and 7038 were consistently resistant across all three locations, whereas the local susceptible checks GAR

13 at Nawagam, PHB-71 at Hazaribagh, and Moudamani at Cuttack were found to be susceptible.

Rice Sheath rot

Four resistant genotypes (AC 9002, AC 9070, AC 9118, AC 9004) and two susceptible genotypes (AC 9362, AC 9417) were selected from the core population based on phenotypic data for studying resistance mechanisms against sheath rot disease. The defense enzymes activity analysis revealed the highest levels of PO, PPO, PAL, CAT, SOD and TP activity at 72 hours' post-inoculation, with a decrease observed by 96 hours. Additionally, the observed increase in the activity of defense enzymes such as PO, PPO, PAL, SOD, CAT, and total phenols suggests that the resistant landraces put forth a strong defense mechanism against sheath rot disease (Fig. 3.2).

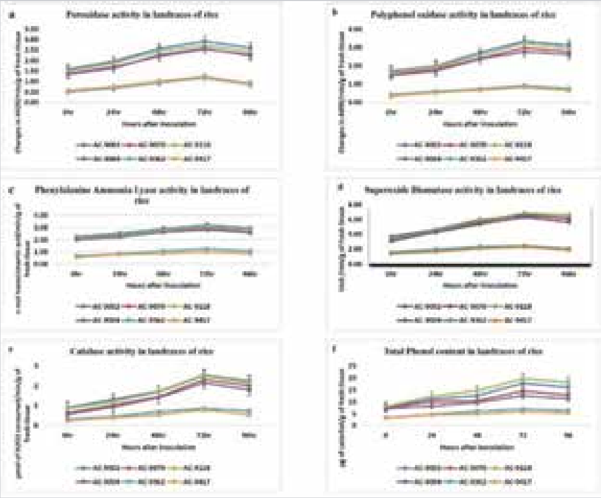


Fig. 3.2. Changes in defence enzyme activities in resistant and susceptible genotypes against sheath rot disease in rice landraces (a) PO (b) PPO (c) PAL (d) SOD (d) CA (e) total phenol

Rice Blast

The genetic diversity of 108 aromatic landraces was analyzed using 27 marker loci linked to 20 blast resistance (R) genes. Major allele frequency ranged from 0.52 to 1.0, with an average of 0.85, while the number of alleles per locus varied from 1 to 4, averaging 1.85. Gene diversity values ranged between 0 and 0.499 (mean: 0.207), with the highest observed for marker YL155/YL87. Cluster analysis classified the landraces into three major clusters (I, II, III) based on their genetic similarity and disease reactions from the uniform blast nursery, with resistant (R), moderately resistant (MR), and susceptible (S) genotypes. Cluster I contained 25 landraces with a higher proportion of resistant genotypes, Cluster II was the smallest with two genotypes, and Cluster III, the largest, included 80 landraces, primarily composed of susceptible genotypes. These findings indicate a correlation between genetic similarity and blast disease resistance among the landraces (Fig. 3.3).

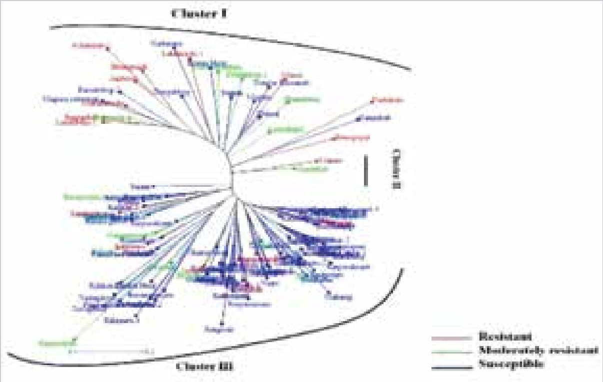


Fig. 3.3. Dendrogram showing genetic diversity of aromatic rice landraces

Bacterial Blight

A total of 88 landraces were evaluated, of which 43 showed the presence of the *Xa4* gene, 44 lines had the xa5 gene, 17 lines contained the *Xa7* gene, 18 lines had the *xa13* gene, and only 4 lines possessed the *Xa21* gene. The combination of *Xa4+xa5* was observed in 13 lines, *Xa4+Xa5+Xa7* was present in 9 lines, and only 5 lines carried four genes, namely *Xa4+xa5+Xa7+xa13*.

Complete genome characterization of *Rice tungro bacilliform virus* (RTBV) isolate from Cuttack, Odisha

The complete genome of RTBV isolate collected from the experimental farm of ICAR-CRRI, Cuttack (RTBV-Cuttack) was sequenced (NCBI # PQ361286). The full length of the RTBV-Cuttack isolate is 7935 nucleotide (nt) long. The circular genomic map of RTBV-Cuttack is represented accordingly locating the tRNA^{met} – binding site at nt 1-18 (Fig. 3.4a). The newly sequenced isolate encodes four open reading frames (ORFs). The first three ORFs (ORF I, II, III) are overlapping and have the interface ATGA, the ATG being the start codon of the downstream ORF and TGA being the stop codon of upstream ORF. The ORF IV is separated from ORF III by a small intergenic region and there was a large intergenic region between ORF IV and ORF I. The nucleotide sequence of complete genome of RTBV-Cuttack showed 95.20-96.87% identity with south Asian (SA) isolates, while only 81.13-81.83% identity with south-east Asian (SEA) isolates**.** The phylogenetic analyses also revealed the grouping of present isolate (RTBV-Cuttack) within SA cluster having previously reported Indian isolates (Fig. 3.4b). To the best of our knowledge, this is the first complete genome of RTBV from Cuttack, Odisha.

Rice Root Knot Nematode

During 2023-24, two trials were conducted to identify resistant sources against the rice root-knot nematode *Meloidogyne graminicola*. A total of 102 rice germplasm, including 88 varieties released by CRRI and 14 previously reported moderately resistant varieties from the CRRI

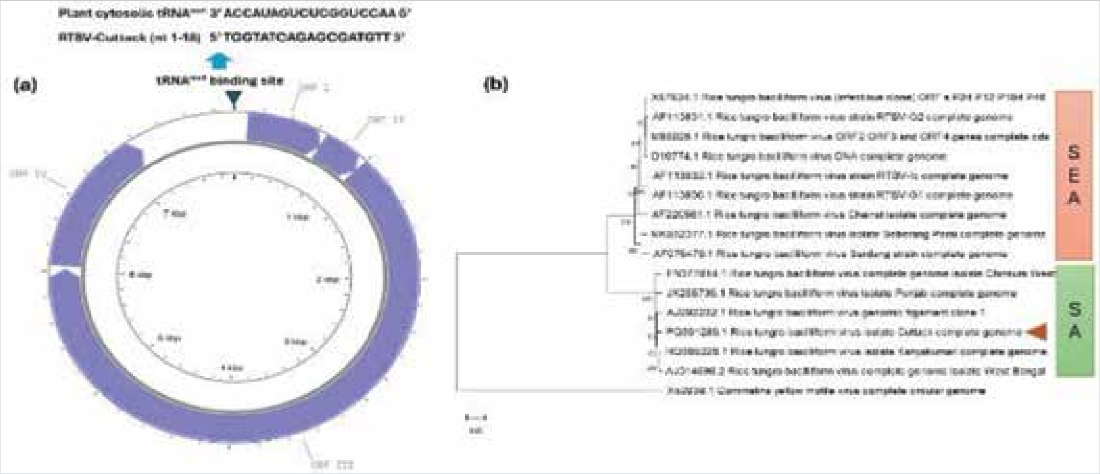


Fig. 3.4. Genome organization (a) and phylogenetic analysis (b) of complete genome of RTBV-Cuttack isolate

database, were selected for screening. All accessions were screened twice during *rabi* 2023 and *kharif* 2024 at a nematode inoculum density of 1 J2/g soil. Based on the results, 48 accessions were categorized as highly susceptible, 42 as susceptible, and 12 as moderately resistant to *M. graminicola* infection (Fig. 3.5a and 3.5b). The following varieties exhibited a moderately resistant reaction to the rice root-knot nematode: CR Dhan 602, CR Dhan 328, Ramakrishna, Abhishek, Sarala, Panidhan, Nua Kalajeera, CR Dhan 403, CR Dhan 306, IR-38, IR-72, and Fukunishiki.

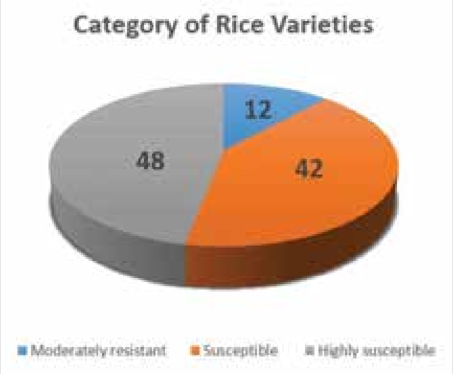


Fig. 3.5a. Documentation of rice genotypes screened against rice root knot nematode in 2023-24.

Fig. 3.5b. Juveniles of *M. graminicola* penetrating rice roots

Ecology, diversity and interaction of plant, pests and natural enemies in rice

Community structure of parasitoids under upland and lowland ecosystem

Parasitoids were collected from the upland ecosystem at KVK, Santhapur, and the lowland ecosystem at ICAR-CRRI. Data from both rice ecosystems were used to estimate three indices: Shannon-Wiener Diversity Index, Simpson's Index of Diversity (1-D), and Margalef Richness Index. BPH parasitoids (*Mymar* sp., *Gonatocerus* sp., *Pseudogonatopus* sp., and *Haplogonatopus* sp.) and spider abundance were higher in the lowland ecosystem. Simpson's Index and Shannon-Wiener Diversity Index were consistently higher for parasitoids in the lowland ecosystem, while predator diversity was greater in the upland ecosystem.

Spatial genetic structure and isolation by distance (IBD) analysis of Indian population of the rice false smut

Fifteen polymorphic ISSR markers were used to analyse 74 *U. virens* isolates collected from Assam, Bihar, Himachal Pradesh, Madhya Pradesh, Meghalaya, Odisha, Uttar Pradesh, and West Bengal. The analysis revealed that the spatial genetic correlation coefficient (r) was significantly positive within the distance classes of 10–100 km, whereas it was negative for the distance class of 110–200 km. This indicates that populations located within 10–100 km are more genetically similar to each other than expected under an isolation-by-distance (IBD) pattern. Genetic differentiation among populations located at distances greater than 100 km was higher than expected under a random spatial distribution. (Fig. 3.6a).

The Mantel test revealed a linear correlation between the genetic and geographical distances of the samples collected from different locations. The correlation coefficient (r = 0.120) and p-value (p = 0.001) indicated a significant relationship within the population. This suggests that

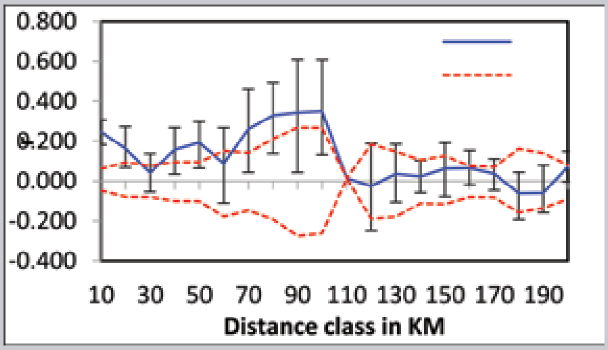


Fig. 3.6a. Spatial distance autocorrelation at different classes by distances

genetic diversity increases with geographical distance among populations (Fig. 3.6b).

UPGMA clustering of *U. virens* isolates using Darwin software grouped all isolates into three major clusters. Cluster I consisted of 32 isolates from northern Indian states (U.P., M.P., U.K. and H.P.) and eastern and northeastern states (Meghalaya, Odisha, Assam and W.B.). Cluster II included 22 isolates, primarily from northern states. The remaining 18 isolates formed Cluster III, which exhibited an admixture pattern similar to Cluster I (Fig. 3.6c).

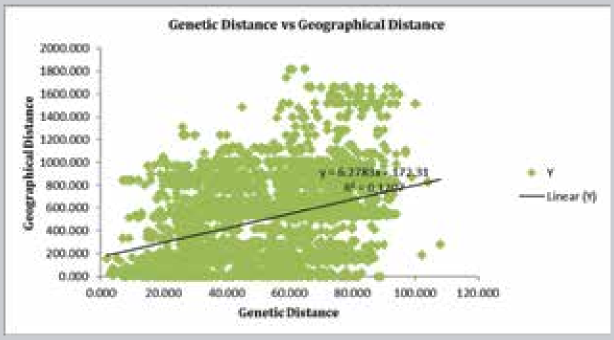


Fig. 3.6b. The relation between the genetic distances with geographical distance by mantel test

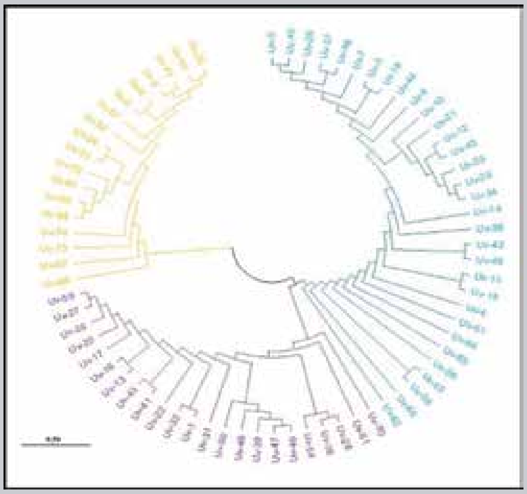


Fig. 3.6c. UPGMA clustering of *U. virens* isolates using Darwin software

Identification of the volatile compounds responsible for the tritrophic interaction among rice, *Cnaphalocrocis medinalis* and parasitoids

The dynamic headspace sampling technique was used to collect plant volatiles, employing a pull-and-push system with charcoal-filtered air to maintain a clean environment. Volatiles released by the plants were trapped on a 100 mg Porapak adsorbent over four hours and eluted using 3 mL of hexane. Crude volatiles were collected at 25 DAT from resistant (Asphol, Karpurkali, TKM 6) and susceptible (Kalabhat, Kouka-Kh-1, TN 1) rice accessions. The samples were stored at -20^0C for subsequent GC-MS analysis for chemical profiling and behavioural studies. Antennal responses were recorded using GC-EAD software, and GC-FID peaks corresponding to antennal EAD peaks were identified.

Deciphering the genetic diversity of rice yellow stem borer populations

Hypervariable SSR markers were designed across 22 chromosomes based on the whole genome sequence of YSB (Sequence ID: ASM3641904v1) using Krait software, resulting in 169,538 perfect SSRs. Based on annealing temperature, GC content, and hairpin sites, 44 SSR markers with a PIC value of 0.3–0.7 (average 0.4) were selected and validated using YSB samples from ICAR-CRRI, Cuttack. Mitochondrial COX1 gene analysis revealed two major clades: Clade 1 (populations from China, Thailand, Malaysia, and Australia) and Clade 2 (populations from Indonesia, Canada, and India). Clade 2 further divides into a unique sub-clade with Indonesian populations and a heterogeneous sub-clade with populations from Canada and India. A total of 38 haplotypes were identified, with a haplotype diversity of 0.964.

Potassium silicate elicitor and settling/oviposition behaviour of YSB on host plants

Spray of potassium silicate @ 1% on TN1 (susceptible variety) disturbs the settling behaviour of YSB moths under cage experiment. Observed lesser number of YSB adult moths settling on sprayed plants than the unsprayed plants. It was also observed that the number of neonate larvae emerges from the egg mass laid by moth on the sprayed plants is significantly less than the egg mass laid on the unsprayed plants. The GC-MS analysis shown increased amounts of repellents and reduced amount of oviposition attractants in the crude extract of potassium silicate sprayed rice plants.

Use of precision tools and techniques in rice insect pests and diseases management

Identifying sensitive spectral bands for detection of rice blast, *Magnaporthe oryzae*

Rice blast is one of the most destructive diseases affecting rice (*Oryza sativa* L.). This disease poses a significant threat to global rice production, causing yield losses of up to 30–50% under severe outbreaks. Rice blast affects various stages of the crop, from seedlings to mature plants, and can manifest in different plant parts, including leaves, nodes, necks, and panicles. Advances in remote sensing have paved the way for innovative approaches to monitor, predict, and control this devastating disease, ensuring sustainable rice production worldwide. In current research work, the purpose is to characterize the rice blast's spectral reflectance in order to identify its sensitive spectral bands. The damage was classified based on the Disease Severity (DS) percent of blast samples (50 and 100%). Result shows that the healthy sample has higher reflectance value than the rice blast diseased samples in all the spectral regions. Change in the reflectance for the infected rice blast sample as compared to the healthy plant was more pronounced in the 500-550, 680-780, and 800-840 nm [common spectral region identified after performing spectral derivative analysis (SDA)]. The combination of identified sensitive bands from all the methods (SDA, CR and SA) were done and it was found that the combination of bands 494, 516, 531 and 680 nm gave maximum accuracy of 79.65 per cent. Hence, those bands can be used for predicting indices and can also be used with satellite imagery to predict the presence of blast (Fig. 3.7).

Search for novel mediators in plant defense response to pathogenic infections in rice through molecular techniques

Genome sequencing of *Trichoderma erinaceum* CRRI-T2

The efficacy of *erinaceum* CRRI T2 as a biocontrol agent and biostimulant was demonstrated through confrontation assays, germination and early vigor tests, growth promotion studies, induction of stress-related enzymes, enhanced nutrient uptake, and improved disease resistance in field trials. Building on these findings, whole-genome sequencing of *T. erinaceum* CRRI T2 was performed. The availability of its genome information enables the exploration of its full genetic potential and provides valuable insights into the applications of this novel strain. The estimated genome size was approximately 35.53 Mb, comprising 11 contigs with a GC content of ~48.8%. Tandem repeat sequences accounted for 1.53% of the genome, and the number of unique predicted genes was 18,815. Analysis revealed a scarcity of transposable elements (TEs), which made up only 0.24% of the total genome. Mining for simple sequence repeats (SSRs) identified 8,408 SSRs. Since fungi are well-known for their protein secretion capabilities, 387 secretory proteins and their targets were identified using SignalP. Further analysis showed that the *T. erinaceum* CRRI T2 genome contains 4,961 genes associated with pathogenicity. CAZyme analysis identified 413 enzyme families, with a notable abundance of glycoside hydrolases (Fig. 3.8). Additionally, the genome revealed a diverse array of secondary metabolite gene clusters, highlighting its potential for producing bioactive compounds.

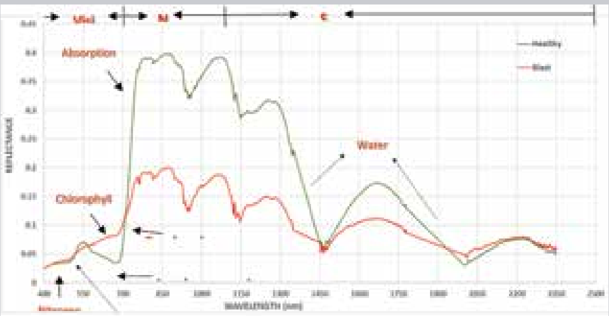


Fig. 3.7. Spectral reflectance between healthy and blast disease infected leaves

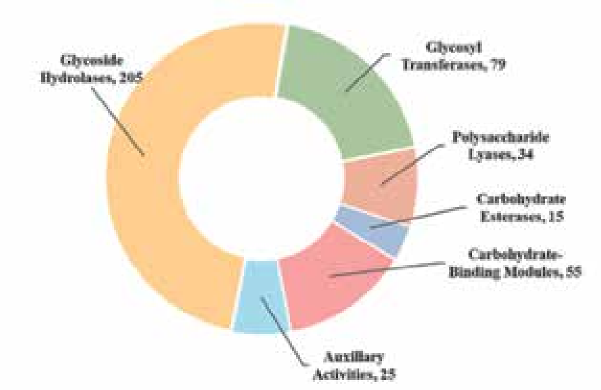


Fig. 3.8. The percentage distribution of various enzyme classes identified by CAZymes in *T. erinaceum* CRRI T2 genome

Imidacloprid treatment alters the bacterial community structure of *Nilaparvata lugens*

Present study analyzed gut microbiome changes across six generations (F0–F5) of *N. lugens* exposed to imidacloprid using 16S rRNA gene sequencing. Sequencing of the V3–V4 regions via Illumina HiSeq revealed 28 phyla, 67 classes, 166 orders, 292 families, and 575 genera. Core microbiota included Proteobacteria, Actinobacteria, and Firmicutes, with dominant genera such as *Arsenophonus, Pseudomonas, Wolbachia, Arthrobacter,* and *Enterobacter.* Untreated groups maintained diverse microbial communities dominated by nutrient-cycling families (e.g., Rhodobacteraceae, Comamonadaceae), while imidacloprid-treated groups showed reduced diversity and an increase in resistant taxa like Enterobacteriaceae and Caulobacteraceae (Fig. 3.9).

Phylogeny of Hymenopteran parasitoids associated with paddy

Genetic group determination was performed using DNA barcodes generated and sequences retrieved from the NCBI database. The distinctiveness of the genetic groups was further established through phylogenetic and molecular evolutionary analyses using well-curated sequences of

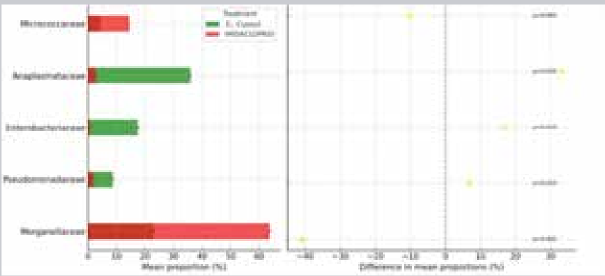


Fig. 3.9. Average dissimilarity in bacterial community composition between untreated and imidacloprid-treated populations for five (F5) generations.

parasitoid groups from the reference sequence database. Tree robustness was evaluated by bootstrapping with 1,000 replicates for *Telenomus dignus*, *Xanthopimpla flavolineata*, *Platyscelio* sp., and *Habrobracon syzygiumae*. Sequences of *Bracon nigricans*, *Baryconus europaeus*, *Platyscelio* sp., *Ateleute* sp., and *Phytodietus* sp. from the NCBI database were incorporated into the phylogram construction. The phylogenetic analysis of mitochondrial COI sequence data, including 26 taxa, using the Maximum Likelihood approach resulted in the formation of four distinct clades. The phylogenetic tree indicated that all scelionid egg parasitoids are more closely related to each other than to the remaining groups (Fig. 3.10).

Elucidating genetic diversity and population structure of *Fusarium* spp. associated with rice bakanae disease

Fusarium spp. causing bakanae disease from 20 regions across six Indian states showed significant diversity. TEF-1α gene sequencing identified four species: *F. fujikuroi*, *F. verticillioides*, *F. proliferatum*, and *F. sacchari*. Genetic analysis using URPs and ISSR markers revealed 96% variation within populations and random distribution. MAT analysis found *F. fujikuroi* and *F. proliferatum* isolates with both MAT-1 and MAT-2, while no mating types were detected in *F. verticillioides* and *F. sacchari*. This is the first report of these species from Eastern and Northeastern India, providing insights for managing bakanae disease and developing resistant rice germplasm (Fig. 3.11).

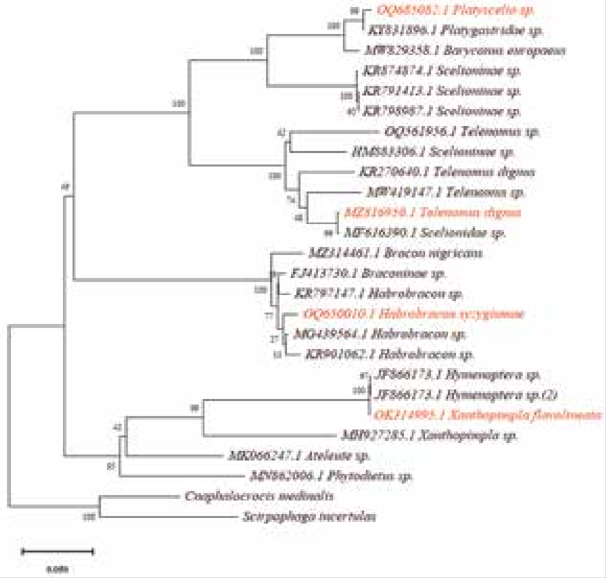


Fig.3.10. Dendrogram shows genomic relations among different Hymenopteran parasitoids associated with paddy

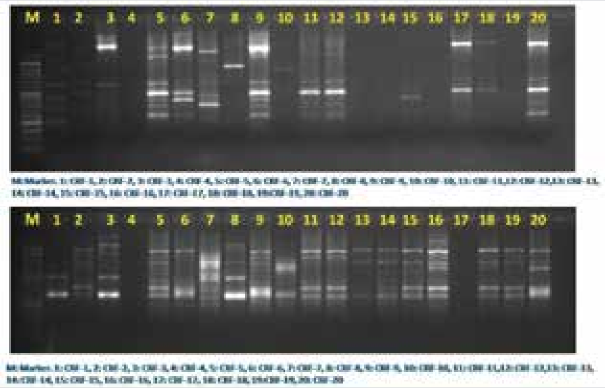


Fig. 3.11. Amplification pattern of 20 *Fusarium* isolates used in this study using URP 2R (above) and ISSR-15 ((GA)8YT) (below)

Plant protection molecules: efficacy, distribution, toxicity and remediation.

Effect of exogenous melatonin application as seed priming against rice root knot nematode

Seeds of the nematode-susceptible rice variety TN1 were primed overnight with melatonin (90 ppm, 120 ppm, 150 ppm and 180 ppm) and grown in *M. graminicola*-infested soil @ 1J2 gm^{-1} of soil. The 150-ppm treatment showed the best results, reducing galls, egg masses, and eggs/egg mass by 82.2, 85.8, and 75.5%, respectively. It also significantly improved root and shoot length, total biomass, antioxidant activities (SOD, H_2O_2, phenols, peroxidase), and chlorophyll content. Additionally, root length, root area, root volume, and root diameter were markedly enhanced compared to the control (Fig. 3.12).

Fig. 3.12. Variation in plant height with different treatments of melatonin

Evaluation of pesticides for management of rice diseases

Seven fungicides were evaluated in a field study for their effectiveness against grain discolouration in the rice variety, TN1. Fungicides were applied at panicle initiation and 15 days after flowering. Disease incidence in the untreated control was 33.57%. Azoxystrobin 18.2% + difenoconazole 11.4% SC achieved the highest disease reduction (80.44%), followed by tebuconazole 50% WG + trifloxystrobin 25% (77.77%) (Fig. 3.13).

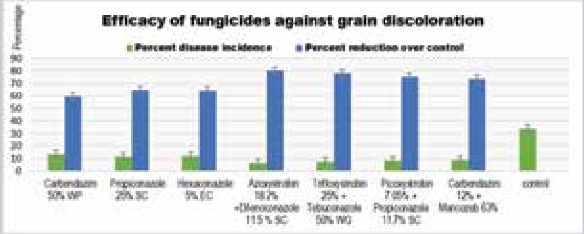


Fig. 3.13. Efficacy of fungicides against grain discoloration in rice

In another study, seven fungicides were tested against sheath blight disease (*Rhizoctonia solani* Kuhn) under artificial inoculation. The fungicide azoxystrobin 5.1% + tebuconazole 9.1% + prochloraz 18.2% EC at 3.5 mL/L was the most effective, reducing sheath blight severity by 76.4% and disease incidence by 81.5%, with a maximum grain yield of 5.17 t/ha.

Detoxifying gene expression during different insecticide exposure in the F_0 and F_5 generations of *N. lugens*

To investigate the genetic response of *N. lugens* to insecticides, the expression of 18 P450 genes and 2 GST genes were analysed using qRT-PCR. Insects were exposed to lethal concentrations of various insecticides for 72 hours across F0 and F5 generations. All 20 genes showed significantly higher expression in F5 than F0, indicating the impact of repeated insecticide exposure. Notably, three P450 genes CYP6ER1vA, CYP6CS1v2, and CYP6AY1 showed marked upregulation, with expression levels increasing over 70-fold in response to imidacloprid, buprofezin, dinotefuran, and pymetrozine treatments. Among the two GST genes analyzed, NlGSTe1 showed greater responsiveness to insecticide exposure than NlGSm1, with fold changes ranging from -6.83 (dinotefuran) to 24.47 (buprofezin) for NlGSTe1, and from -8.01 (triflumezopyrim) to 2.62 (pymetrozine) for NlGSm1. Interestingly, the induction of resistance-related genes in populations treated with triflumezopyrim was less than that of other insecticides. The highest fold change observed for triflumezopyrim ranged from 20.66 (CYP4FB1) in the F0 population to 46.65 (CYP6ER1vB) in F5. By contrast, the F5 population exhibited fold changes exceeding 100 in response to imidacloprid, dinotefuran, and pymetrozine treatments. These findings highlight the superior efficacy of triflumezopyrim in controlling *N. lugens* populations across multiple generations.

Transgenerational toxicity of Imidacloprid on demography and behavior of key larval parasitoid, *Habrobracon hebetor* (Say)

Study explores the effects of LC_5, LC_{30}, and LC_{50} concentrations of imidacloprid on the demographic as well as the behavioral traits for two generations (F_1 and F_5) of the larval parasitoid, *Habrobracon hebetor* (Say). Imidacloprid exhibited profound toxicity in the bioassay experiments, with an LC_{50} of 40.75 mg/L, while LC_5 was 0.27 mg/L and LC_{30} was 8.27 mg/L. Among the biological parameters, a significant enhancement was observed in the developmental period of eggs and larvae for F_5 individuals exposed to both LC_5 and LC_{30}, compared to the F_1 generation. Concerning the population parameters, the net reproductive rate (R_0) ($P = 0.0238$), gross reproductive rate (*GRR*) ($P = 0.00118$), and mean generation time (T) ($P = 0.02575$) of F_5 individuals were found significantly lower than the F_1 generation. In LC_{30} concentration, it was evident that most of the population parameters were significant when compared across generations. F_5 individuals exposed to LC_{50} concentration had a notable difference in the developmental periods of eggs, larvae, and pupae compared to F_1 individuals. Moreover, a significant reduction was noted in the longevity of males, fecundity, and oviposition period of F_5 individuals. On the other hand, LC_{50} exposed *H. hebetor* resulted in notable differences in all population parameters except the intrinsic rate of increase (r) and the finite rate of increase (λ). A significant difference was observed in walking behavior between individuals treated with LC_5 concentration and those treated with LC_{30} and LC_{50} concentrations (Fig. 3.14). LC_5-treated individuals exhibited no significant variation in walking speed compared to the control group. The findings indicate that imidacloprid exerted more adverse effects on both the biological and population parameters, as well as the walking behavior of *H. hebetor*, emphasizing the need for comprehensive field studies to assess its impact on the parasitoid.

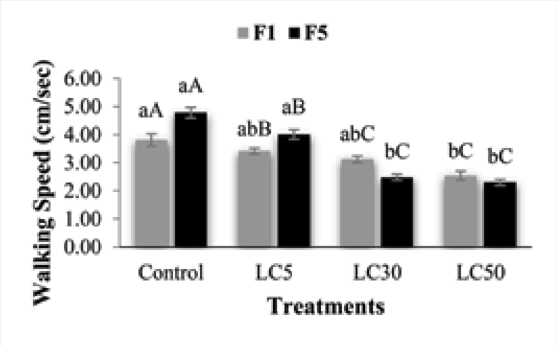


Fig. 3.14. Walking behavior of *H. hebetor* adults treated with acetone and imidacloprid in F_1 and F_5 generations. Different lower-case letters indicate significant differences between control and imidacloprid treatments in each generation ($P < 0.05$, one-way ANOVA), while upper-case letters indicate significant differences between F_1 and F_5 generations within each treatment group ($P < 0.05$, two-way ANOVA).

Degradation of tetracycline and streptomycin by fungi isolated from rhizosediment of rice

The purpose of this study was to look at the possibility of microbes isolated from rhizosediment of rice (*Oryza sativa* L.) in biodegrading two widely used antibiotics, tetracycline (TC) and streptomycin (STR). Eight distinct fungal strains were isolated through enrichment experiment, and it was found that they were able to remove an average of 80-90% of the supplemented TC and STR (Fig. 3.15). It was found that strains *Aspergillus fumigatus* and *Fusarium oxysporum* had superior TC degrading ability, whereas strains *Fusarium oxysporum* and *Phanerodentia* sp. had superior STR degrading capacity.

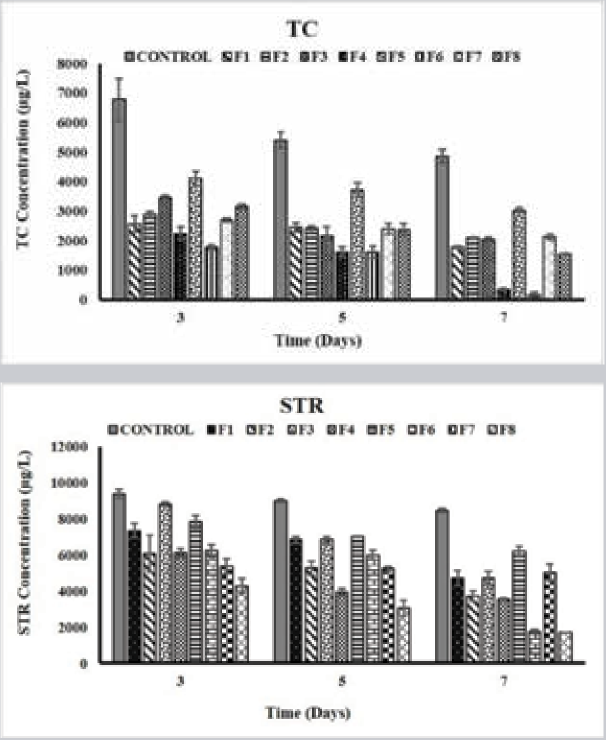


Fig. 3.15. Biodegradation of tetracycline and streptomycin

Dissemination of integrated pest management strategies for insect pests, diseases and nematodes in rice

Eco-friendly pest management in rice cultivation using zinc oxide nanoparticles

Rice productivity is severely affected by pests like BPH. To address this, nano-based agrochemicals, including zinc oxide nanoparticles (ZnO NPs), have emerged as sustainable alternatives to traditional pesticides. ZnO NPs were synthesized using zinc hydroxide precipitation, resulting in nanoparticles averaging 30–50 nm in size, as confirmed by DLS and XRD analyses. A study evaluated the efficacy of ZnO NPs in controlling *N. lugens*. Rice plants treated with 1000 ppm ZnO NPs showed the most effective pest resistance, with only 39% survival of planthoppers after 7 days, compared to 82% in the control group. Lower concentrations (500 ppm, 300 ppm, and 100 ppm) also reduced survival rates to 45%, 51%, and 56%, respectively, demonstrating a dose-dependent effect. ZnO NPs enhanced pest resistance and plant health, highlighting their potential for eco-friendly pest management and sustainable agriculture. Future research should optimize formulations and assess environmental impacts for wider adoption in rice farming.

Assessment of *Nilaparvata lugens* (Stål) population dynamics through temperature-dependent model

The brown planthopper is a major rice pest in Asia and the Pacific, causing significant yield losses and transmitting rice viruses. Its outbreaks in India, particularly in Odisha, Punjab, and Tamil Nadu, are exacerbated by climate change, monocropping, and insecticide resistance. Rising temperatures favor its development, influencing population dynamics. This study developed temperature-based models using ILCYM software to predict *N. lugens* populations under varying climatic conditions, aiding pest management strategies. Temperature significantly impacted developmental stages, with faster development at higher temperatures. At 34°C, immature stages and adult longevity were shorter compared to 18°C, while egg hatching survivability was highest at 26°C (70%) and lowest at 34°C (40%). Maximum fecundity occurred at 26°C (147 ± 1.45 eggs/female), and life table parameters like net reproductive rate (Ro) and gross reproduction rate (GRR) peaked at 26°C. Temperatures between 26°C and 30°C were optimal for survival, reproduction, and faster generation turnover. Validated phenology models predicted life stages and supported pest management strategies. Linking these models with hotspot data enables risk assessments and climate-adaptive management approaches for *N. lugens*.

Non target effects of bio-pesticides on natural enemies in rice

The non-target effect of commonly used bio-pesticides for rice insect pests *viz., Bacillus thuringiensis* var. *kurstaki* (1.5 kg ha^{-1}), *Bacillus thuringiensis* var. *galleriae* (2 lit ha^{-1}), *Beauveria bassiana* 1.15% WP (2.50 kg ha^{-1}) and azadirachtin 0.15% EC (2.5 l ha^{-1}) were assessed under field condition. Compared to the untreated control, the percent emergence of *Trichogramma japonicum* showed no significant differences. However, the emergence of *Habrobracon hebetor* (58.74%) was significantly reduced in the azadirachtin 0.15% EC treatment compared to other treatments. A similar trend was observed for spider (0.50 ± 0.29) and coccinellid population (0.50 ± 0.29). For *Apanteles* sp. the lowest population was noticed in plots treated with *Beauveria bassiana* 1.15% WP. This study emphasizes the importance of selecting biopesticides based on their compatibility with macrobial bioagents for effective integration in rice fields.

Activities of plant essential oil (PEO) on false smut pathogen (*U. virens*)

Out of the five plant essential oil (PEO) [Lemon oil (LO), Cinnamon oil (CO), Bottle brush oil (BBO), Orange oil (OO), and Eucalyptus oil (EO)], LO and CO were found to be highly effective in inhibiting mycelial growth of *U. virens,* the pathogen causing false smut diseases in rice, following food poison technique. The LD50 values for LO and CO were calculated as 100.6 ppm and 53.6 ppm, respectively (Fig. 3.16a and Fig. 3.16b).

Fig. 3.16a.
LD50 value for LO: 100.6 ppm

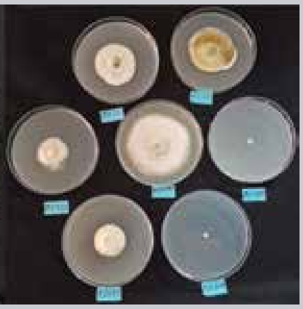


Fig. 3.16b.
LD50 value for CO: 53.6 ppm

Impact of sheath blight (ShB) and bacterial blight (BB) pathogen infection at different rice growth stages on grain production

Sheath blight

To assess the impact of sheath blight pathogen infection at different rice growth stages, artificial inoculation with *R. solani* was conducted on the CR Dhan 317 variety at four stages: early tillering (T1), maximum tillering (T2), 50% flowering (T3), and 100% flowering (T4), with a control treatment (T5) having no infection. Sheath blight (ShB) disease severity was significantly higher when inoculated at the tillering stages compared to the flowering stages (Fig. 3.17a). Grain production was significantly lower when inoculated at the early tillering stage compared to the maximum tillering or flowering stages (Fig. 3.17b). No significant difference in ShB disease severity or grain production was observed when inoculated at the 50% and 100% flowering stages.

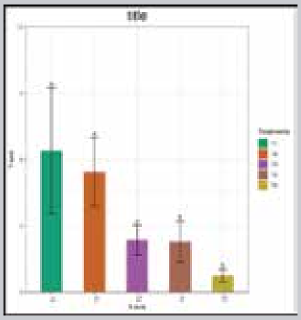


Fig. 3.17a.
Per cent disease progress

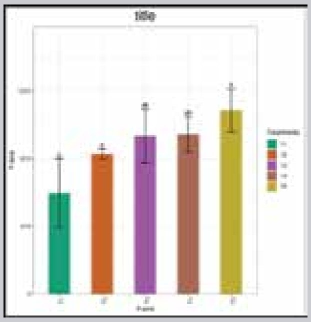


Fig. 3.17b.
Grain production (g/plot)

Bacterial blight

To assess the impact of bacterial blight pathogen infection at different rice growth stages, artificial inoculation with *X. oryzae* pv. *oryzae* was conducted on the CR Dhan 317 variety at four stages: early tillering (T1), maximum tillering (T2), 50% flowering (T3), and 100% flowering (T4), with a control treatment (T5) having no infection. Bacterial blight (BB) disease severity was significantly higher when inoculated at the early tillering stage, followed by the maximum tillering and flowering stages (Fig. 3.18a). Grain production was significantly lower when inoculated at the early tillering stage, followed by the maximum tillering and flowering stages (Fig. 3.18b). No significant difference in BB disease severity or grain production was observed when inoculated at the 50% and 100% flowering stages.

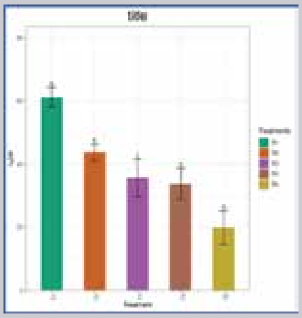


Fig. 3.18a.
Per cent disease progress

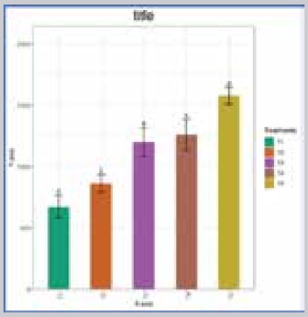


Fig. 3.18b.
Grain production (g/plot)

Validation and promotion of Integrated Pest Management (IPM) module in farmer's fields under shallow low land ecosystem

One field research experiment was conducted in farmers' fields in Talasanga village, Block-Marshaghai, District-Kendrapara, during the 2023 *kharif*. Twenty-five farmers were involved and two rice varieties Swarna and Pooja were taken on a 20-acre plot. IPM practices included seed treatment with *Trichoderma* formulation @10g/kg before sowing (T1) and need-based pesticide application in affected areas (T2). Carbendazim 50 WP (1.0 g/l) was used against brown spot, sheath blight and sheath rot; cartap hydrochloride (1 kg ai/ha) for YSB, leaf folder and BPH; and chlorpyriphos 20% EC (0.5 kg ai/ha) for gundhi bug. Also, sex pheromone traps (8/ha) (T3) and biocontrol agents (*Trichoderma viride* and *Pseudomonas fluorescens*) (T4) were applied. Compared to farmer's practice, IPM-treated fields showed reduced infestations of brown spot (4.8–5.4%), sheath blight (7.4–8.2%), sheath rot (4.4–4.5%), false smut (5.0–7.6%), and insects like dead heart (3.4–3.7%), white ear head (3.1–3.4%) due to YSB, and gundhi bug (4.3–4.4%). Higher grain yield of 5.9-6.1 t ha^{-1}, straw yield of 5.1-5.4 t/ha with B:C ratio 2.29-2.35 were obtained by following IPM practices. Need-based IPM outperformed the farmer's practice, resulting in a grain yield advantage of 0.52–0.58 t ha^{-1}.

Conclusion

The program on biotic stress management in rice involved the evaluation of over 2,100 rice entries against major insects, diseases, and nematodes to identify resistant donors, aiding in the development of biotic stress-resistant rice varieties. Key markers associated with resistance to BPH and gall midge offer valuable resources for marker-assisted breeding. The sequencing of RTBV from Odisha provides critical genomic insights. The studies highlight significant ecological and genetic insights, including enhanced parasitoid diversity in lowland ecosystems and the identification of key genetic patterns in *Ustilaginoidea virens* and yellow stem borer populations. The spectral bands 494, 516, 531, and 680 nm are effective indicators for detecting rice blast with 79.65% accuracy, offering potential for early disease detection through satellite imagery. The whole-genome sequencing of *Trichoderma erinaceum* CRRI T2 revealed valuable insights into its biocontrol potential. Imidacloprid treatment in *Nilaparvata lugens* altered the gut microbiome across generations, reducing microbial diversity and promoting the growth of resistant taxa. Exogenous melatonin application as seed priming significantly reduced root knot nematode infestation in rice. Microbes isolated from rice rhizosediment effectively biodegraded tetracycline and streptomycin. Zinc oxide nanoparticles (ZnO NPs) effectively controlled *N. lugens* in rice, offering a sustainable, eco-friendly pest management solution. Lemon oil and cinnamon oil were found to be highly effective in inhibiting mycelial growth of *U. virens*, with LD50 values of 100.6 ppm and 53.6 ppm, respectively. The rice IPM module was successfully validated and promoted in farmers' fields under a shallow lowland ecosystem.

PROGRAMME

04

Photosynthetic Enhancement, Abiotic Stress Tolerance and Grain Nutritional Quality in Rice

Rain-fed rice cultivation is increasingly vulnerable to environmental challenges, compounded by the accelerating impacts of climate change. These challenges, including drought, submergence, salinity, and stagnant flooding, severely impair photosynthesis, crop growth, and grain nutritional quality. With rice being a staple food for over half the global population, addressing these challenges is essential for ensuring food security. The genetic diversity and vast germplasm resources of rice provide unique opportunities to explore tolerance mechanisms against abiotic stresses, develop resilient genotypes, and enhance grain quality. This report under Programme 4 focuses on advancing photosynthetic efficiency, stress tolerance, and grain nutritional attributes in rice through innovative approaches. Highlights include the development of transgenic rice plants using cutting-edge genome editing technologies such as CRISPR and prime editing to improve photosynthetic pathways. Additionally, physiological, biochemical, and molecular evaluations have identified stress-tolerant genotypes, with a focus on integrating the SUB1 QTL and other traits for combined stress resilience. The research also emphasizes the development of low glycemic index rice varieties, bioactive compound enrichment, and the evaluation of nutritional impacts of processing methods such as parboiling, cooking, and fermentation. Through collaborative efforts, the program aims to contribute to sustainable rice production systems that address global dietary and agricultural challenges.

Photosynthetic efficiency and productivity of rice under changing climate

Enhancing Prime Editing Efficiency and Editing of Endogenous PEPC Gene in Rice

Rice (*Oryza sativa*) utilizes the C3 photosynthetic pathway, which is less efficient under elevated temperatures and water-limited conditions. Attempts to introduce the C4 photosynthetic pathway into C3 rice have met with limited success. Phosphoenolpyruvate carboxylase (PEPC) is a critical enzyme in the C4 pathway, and mutations enhancing its function could improve photosynthetic efficiency. This study focuses on identifying the role of PEPC in rice by CRISPR-mediated knockout of the PEPC gene in rice and also editing the endogenous PEPC gene in rice via prime editing at two specific loci to convert its function from C3-like to C4-like, aiming to achieve precise genomic modifications that could improve enzyme functionality.

In order to evaluate the role of PEPC in a C3 plant such as rice; CRISPR mediated PEPC - knockout line has been generated. Two guide RNAs for disruption of the endogenous PEPC gene were designed. To enhance the editing efficiency, tRNA was fused upstream of each guide RNA. The constructs were transfected into rice protoplast and analysed by deep sequencing. The *Agrobacterium*-mediated rice transformation was performed using the best construct. Regenerated plants were successfully rooted and transferred to soil. Genomic DNA was isolated from the putative edited plants and analysed via sanger sequencing. Sanger sequencing result confirmed the desired deletion in the PEPC gene (Fig. 4.1).

Previous research suggests that acquiring more significant PEP substrate saturation constants and increased tolerance towards feedback inhibition are vital achievements in the evolution of C4 PEPC from the C3 ancestors. The conversion of alanine to serine at position 774 (Ala774 to Ser774) reduces the Km for phosphoenolpyruvate (PEP) in C4 PEPC enzymes (Bläsing *et al.,* 2000). The C3 PEPC isoform from *F. pringlei* has an arginine (884) involved in inhibitor binding and functions as a molecular clamp in the binding pocket that tightens the inhibitory aspartate molecule. In the C4 PEPC isoform from *F. trinervia*, this arginine is replaced by glycine. The replacement reduces the number of protein-inhibitor interactions and offers the inhibitor more steric space to dissociate from the binding pocket (Paulus *et al.,* 2013). The replacement of arginine with glycine at position 884 (Arg884 to Gly884) in C4 PEPC decreases inhibitor binding, enhancing enzyme activity. This study aimed to validate if mutations at Ala774 and Arg884 in rice PEPC can switch its functionality from C3-like to C4-like with the help of precise genome editing. Prime editing offers precision but suffers from low efficiency in plants. Enhancements in vector design are crucial to improve editing success rates. Therefore, enhancing the efficiency of prime editing through vector modifications is another targeted goal in this study.

To achieve this, the study involved multiple vector modifications, including the inclusion of RNA aptamer at the 3' end of prime editing guide RNA (pegRNA), fusion of repair proteins (RP) to existing vectors, integration of nucleocapsid protein, and removal of RNase H domain from reverse transcriptase (RT) enzyme. Additionally, the pegRNA promoter was replaced with a composite promoter for higher PE efficiency, and extra mutations were introduced in the SpCas9 enzyme. Twelve vectors engineered with pegRNA targeting Ala774 and Arg884 were transfected into rice protoplasts. Genomic DNA from transfected protoplasts was amplified and analyzed using deep sequencing, and the vector with the highest efficiency was selected for *Agrobacterium*-mediated transformation (Fig. 4.2).

Significant improvement in prime editing efficiency was observed with modified vectors. One vector demonstrated superior editing efficiency compared to others. Agrobacterium-mediated transformation was performed using the optimized vector. Transformed calli were subjected to selection on hygromycin-containing media, and secondary calli were screened through genomic DNA isolation, PCR, and deep sequencing. Edited plants with the

Fig. 4.2: Rice genome editing with the prime editor. A, Deep sequencing data analysis revealed desired editing achieved from selected calli. B, Image showing selected calli, regenerated plants, and regenerated plants in rooting media

Fig. 4.1: Sanger sequencing data analysis revealed a deletion in the endogenous PEPC gene in the edited rice plant

desired nucleotide changes were identified. Regenerated plants were successfully rooted and transferred to soil. Sanger sequencing confirmed the desired edits in the PEPC gene.

The modifications to the prime editing vectors significantly enhanced editing efficiency, overcoming previous challenges in plant prime editing. The successful editing of Ala774 and Arg884 in the rice PEPC gene marks a critical step towards developing rice plants with improved photosynthetic efficiency under stress conditions (Fig. 4.3).

Future work will involve comparing the biochemical and physiological parameters of wild-type and edited plants, evaluating the functional efficiency of the modified PEPC enzyme under abiotic stress conditions, and investigating potential off-target effects of prime editing in rice.

Evaluation of rice genotypes for new sources of multiple abiotic stress tolerance and understanding the underlying mechanism

Evaluation of rice genotypes for tolerance to submergence and stagnant flooding stresses

Rice production is adversely affected by submergence and stagnant flooding, particularly in lowland and semi-deep rice ecologies. To identify tolerant genotypes to both excess water stress conditions, 60 genotypes comprising landraces and cultivars of lowland ecology were evaluated for both submergence and stagnant flooding stresses. Complete submergence stress (water height: 90 ± 5 cm) was imposed during the early vegetative stage (25 days after sowing), while stagnant flooding stress (water height: 45 ± 5 cm) was imposed on the same set of genotypes from tillering to maturity stages (>60 days).

Among the studied genotypes, FR13A, FR13B, AC1303, Pooja *Sub1*, Sarala *Sub1*, Swarna *Sub1*, and Khoda were found submergence tolerant genotypes based on survival percentage (Fig. 4.4). We found that six genotypes (Varshadhan, AC85, AC39406, Rahaspanjar, JRS5, AC1017A, and Khoda) were tolerant to stagnant flooding conditions based on yield and yield-attributing traits under stress. Among these, AC85 was found to be one of the better genotypes having plant height of >190 cm and tiller number of >8 (per plant) with >28 cm of panicle length under stagnant flooding conditions. Comparing the results under both stress conditions, we found Khoda as a common tolerant genotype to both stresses.

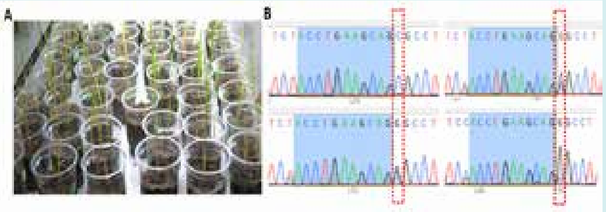


Fig. 4.3: A. Putative genome-edited regenerated plants for OsPEPC. B. Representative Sanger sequencing data analysis revealed precise C-to-G editing.

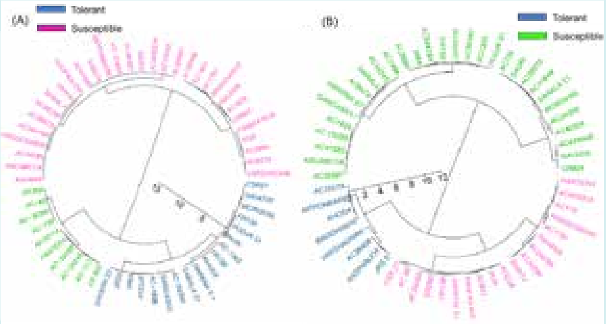


Fig. 4.4: Cluster analysis of genotypes based on survival rate under submergence (A) and grain yield under stagnant flooding (B) conditions

Characterization of *aus* rice accessions for submergence stress

A total of 181 *aus* rice accessions collected from different countries of Southeast Asia were evaluated and characterized for complete submergence stress at the early vegetative stage. The genotypes were genotyped for the presence of favourable allele of Sub1A1 using gene-specific markers viz. AEX1 and Sub1BC2. Among 181 lines, only 62 were scored as Sub1 positive by both molecular markers. Apart from underwater survival and elongation traits, these lines were also evaluated for their leaf carbohydrate reserve, leaf gas film thickness, and epicuticular wax concentration. The total starch content varies from 129.3 to 38.9 mg g^{-1} out of which six high starch-containing genotypes were AUS-143, 113, 102, 90, 100, and 106 having >100 mg g^{-1} leaf starch content after de-submergence. Genotypes like AUS-106, 102, 100, and 143 had high contents of both starch and sugar in their leaves. The epicuticular wax content varied from 2.18 to 0.03 units in the tested lines. Among them, AUS-22, 26, 32, 29, and 28 showed higher epicuticular wax contents (>1.9 units). The leaf gas film (LGF) thickness varied significantly between different *aus* accessions where we found AUS-106, 81, 178, 50, and 152 had higher initial values of LGF.

Understanding the molecular mechanism of salt tolerance in *Oryza nivara* and *Oryza sativa* sub sp. *indica*

Two previously identified moderately salt tolerant (at the seedling stage) *Oryza nivara* lines, W118 (AC100042/ IC-336715) and W119 (AC100042A) were compared with *Oryza sativa indica* lines FL478 (tolerant to salt stress) and IR29 (susceptible to salt stress) through the expression of key genes associated with sodium exclusion and compartmentalization process. The molecular evidence for sodium exclusion-related genes (*SOS1* and *HKT1.5*) confirmed the high leaf and root sodium exclusion for *Oryza sativa* rice genotype FL478, followed by W118, W119, and IR29 (Fig. 4.5a, b). Contrastingly, leaf sodium compartmentalization (in terms of *NHX1* gene expression) was found dominant in the case of IR29 and *Oryza nivara* accessions W119, and W118. Further, sequencing the coding region (CDS) of *HKT1.5* by Sanger's sequencing method suggested the presence of *Saltol/SKC1* QTL in FL478, W118, and W119. We also found changes in nucleotide sequences like guanine in the 994th and 1183rd positions for FL478, W118, and W119, which were not present in salt susceptible IR29. It may be considered crucial for maintaining salt tolerance (Fig. 4.5c). Overall, it suggests that sodium exclusion was dominant in FL478, while *O. nivara* accessions i.e., W118 and W119 use the combination of sodium exclusion and compartmentalization to withstand salt stress.

Assessing the impact of *SUB1* QTL introgression on the submergence tolerance ability of different rice cultivars

The *Sub1* QTL identified from FR13A in chromosome 9 was incorporated in popular rice cultivars to get improved submergence tolerance. However, the overall genotypic effects after receiving *Sub1* in genetic makeup are not the same for all. To study the variations in genotypic effect *Sub1* QTL, we tested the relative performance of *SUB1* introgressed lines into 10 different genetic backgrounds i.e. Varshadhan, Pooja, Savitri, IR 64, Bahadur, Swarna, Ranjit, Sarala, Gayatri, and Samba Mahsuri. These 10 genotypes along with their non-*Sub1* counterparts were subjected to 14 days of complete submergence stress at the early vegetative stage during *kharif* season. Among different genetic backgrounds, the influence of *Sub1* QTL was found to be highest in Swarna, where its *Sub1* introgressed lines i.e., CR Dhan 801, CR Dhan 802, and Swarna *Sub1* reported a significant improvement in survival rate and grain yield over the recurrent parent (Fig. 4.6). This was followed by Savitri and Pooja. The improvement in survival rate and grain yield of these genotypes was much higher than the rest of the genotypes. This may be attributed to a higher wax content and leaf gas film thickness at both the adaxial and abaxial surfaces of the leaf along with a higher starch and sugar content in the leaf of these genotypes at the end of the stress period.

Effect of melatonin on drought tolerance and recovery in rice varieties

A study evaluated the impact of melatonin (100 µM) [the concentration of the melatonin was standardized in the earlier study] on three rice varieties (Pooja, Swarna,

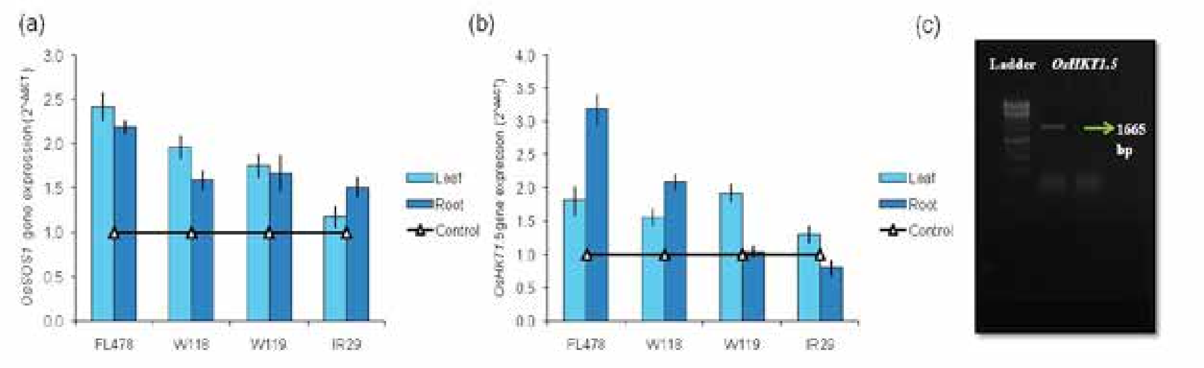


Fig. 4.5: *SOS1* (a) and HKT1.5 (b) gene expression under control and salt stress (12 dS m^{-1}) conditions with four different rice genotypes-FL478, W118, W119 and IR29 and full-length coding sequence amplification of *HKT1.5* gene (c).

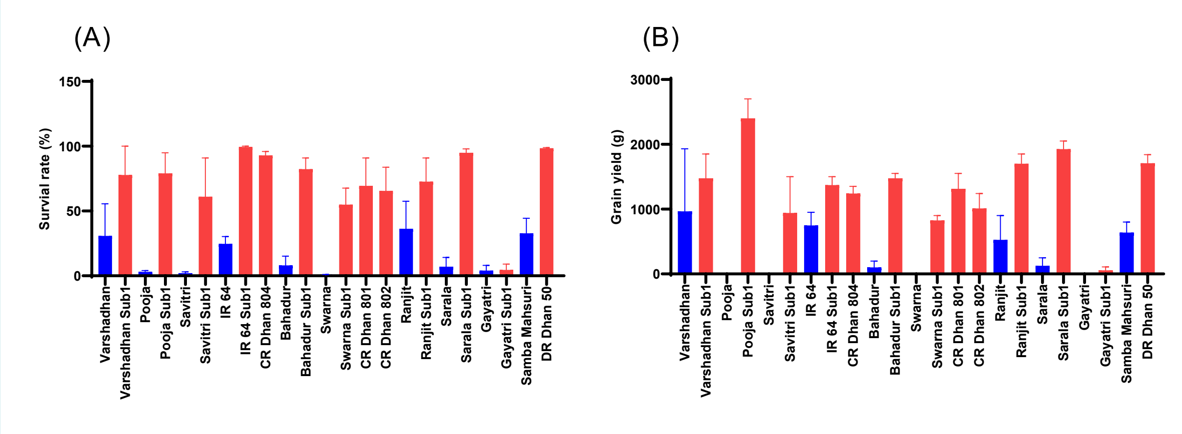


Fig. 4.6: Survival rate (A) and grain yield (B) of rice genotypes and their *Sub1* introgressed lines after 14 days of complete submergence stress.

and N22) under drought stress across different growth conditions (pot culture, rainout shelter, and hydroponics) during flowering and seedling stages. Key parameters assessed included the leaf rolling score (LRS), leaf drying score, and drought recovery score. Under drought stress, N22 consistently exhibited the lowest LRS, indicating higher tolerance compared to Pooja and Swarna. Melatonin application significantly reduced LRS in all varieties, with reductions up to 48% in Swarna under pot culture and 60% in N22 under hydroponics. Similarly, melatonin mitigated leaf drying scores, with reductions of up to 70.59% in N22 and 78.95% in Swarna, highlighting its ability to reduce leaf damage under stress. Drought recovery scores also improved significantly with melatonin. Under pot culture, melatonin reduced scores by 57.14% in N22 and 52.17% in Swarna (Fig. 4.7). In hydroponics, Swarna's recovery score was reduced by 90.91% (from 3.7 to 0.3), demonstrating melatonin's significant positive effect. Statistical analysis confirmed significance at P<0.05 and P<0.01 levels. Melatonin's protective effects are linked to its antioxidant properties, which mitigate oxidative stress, maintain cellular homeostasis, and regulate osmolyte accumulation. These findings suggest that melatonin is a promising tool to enhance drought tolerance and recovery in rice crops.

Effect of Melatonin on morphological traits under drought stress in rice varieties

The study evaluated the effects of melatonin (100 µM) on root and shoot lengths of three rice varieties—Pooja, Swarna, and N22—under drought stress in pot culture, rainout shelter, and hydroponic conditions. In pot culture at the flowering stage, melatonin significantly increased root lengths in N22 (31.83 cm), Swarna (25.08 cm), and Pooja (23.83 cm), representing increases of 25.41%, 10.34%, and 15.51%, respectively, compared to controls. Under drought, root lengths were reduced to ~19 cm but were mitigated to 21.53 cm by melatonin treatment. Similarly, melatonin increased shoot lengths in N22 (36.18 cm), Swarna (35.78 cm), and Pooja (35.88 cm), with drought reductions partially restored to ~30 cm by melatonin. In rainout shelter conditions, melatonin enhanced root lengths to 35.53 cm in N22, 30.28 cm in Swarna, and 28.53 cm in Pooja, with improvements of 18.12%, 10.39%, and 12.63%, respectively (Table 4.1). Drought stress reduced root lengths to ~22–24 cm, which were improved to ~25–26 cm with melatonin. For shoots, melatonin increased lengths to 40.38 cm in N22, 36.98 cm in Swarna, and 35.58 cm in Pooja, partially mitigating drought-induced reductions. In hydroponics at the seedling stage, melatonin improved root lengths by 19.91% (N22), 33.03% (Swarna), and 24.62% (Pooja) under normal conditions. Under drought, melatonin alleviated reductions, increasing root lengths to 7.9 cm (N22), 8.0 cm (Pooja), and 7.7 cm (Swarna). For shoot lengths, melatonin enhanced growth to 13.3 cm (N22), 12.0 cm (Swarna), and 12.0 cm (Pooja), with significant improvements under drought. Statistical analyses confirmed significant effects (P<0.05, P<0.01).

Characterization of rice genotypes for improved Physico-chemical and Nutritional properties

Rice grain biochemical properties are the prime factors for consumers preference. These properties are even more important to millers and farmers to get better market price. Along with higher amylose content, high resistant

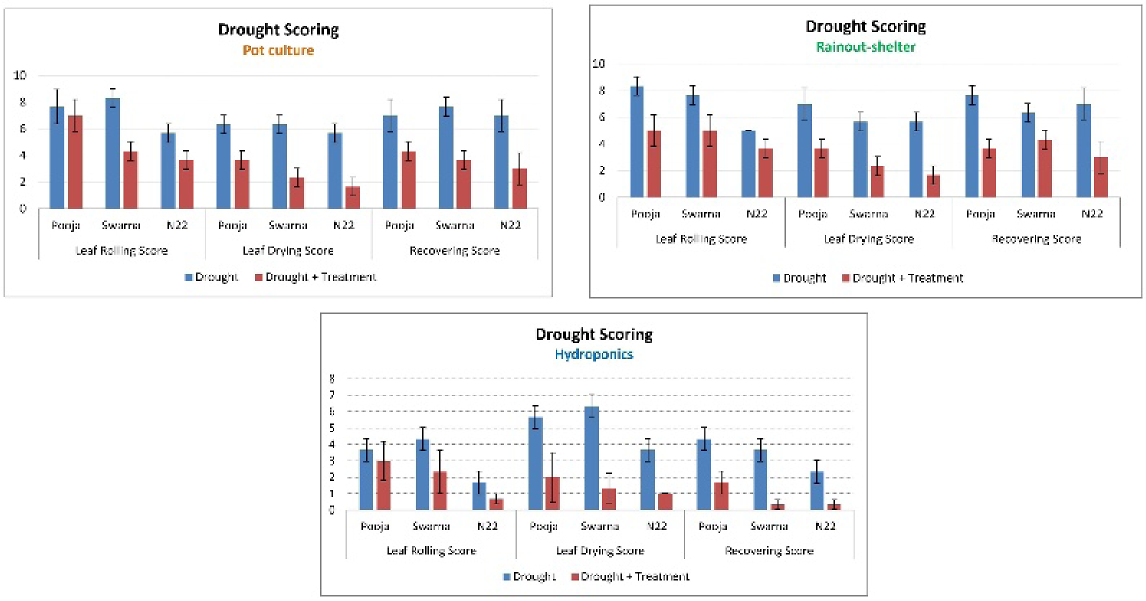


Fig. 4.7: Drought scoring (leaf rolling score, leaf drying score, and recovering score) during drought stress and melatonin treatment at the seedling stage in the pot culture, rain out shelter, and hydroponics experiment. Vertical bars indicate ± standard error of the mean (n=3)

Table 4.1: Effect of drought stress and melatonin on root and shoot length (cm) at different stages of rice varieties

Variety	**Treatment**	**Root Length (cm)**			**Shoot Length (cm)**		
		Seedling stage	Flowering stage		Seedling stage	Flowering stage	
		Hydroponics	**Pot Culture**	**Ros**	**Hydroponics**	**Pot Culture**	**Ros**
Pooja	Control	7.20 ± 0.29	20.63 ± 0.57	25.33 ± 2.43	12.57 ± 0.79	31.93 ± 0.62	33.27 ± 1.75
	Melatonin (100µM)	8.63 ± 0.71	23.83 ± 0.57	28.53 ± 2.43	9.50 ± 0.32	35.88 ± 0.79	37.22 ± 1.82
	Drought	5.87 ± 0.88	18.13 ± 0.87	20.33 ± 0.64	8.67 ± 0.27	28.88 ± 0.74	30.22 ± 1.79
	D + M	8.00 ± 0.36	20.13 ± 0.67	24.83 ± 2.31	8.20 ± 0.21	30.23 ± 0.35	31.57 ± 1.67
Swarna	Control	7.27 ± 0.55	22.73 ± 1.20	27.43 ± 1.73	12.03 ± 0.64	32.43 ± 0.82	34.27 ± 1.96
	Melatonin (100µM)	9.67 ± 0.23	25.08 ± 0.85	30.28 ± 2.40	11.27 ± 0.77	35.78 ± 0.64	38.62 ± 2.19
	Drought	4.07 ± 0.92	19.03 ± 0.72	23.73 ± 2.25	8.57 ± 0.73	29.43 ± 0.52	30.77 ± 1.71
	D + M	7.73 ± 1.67	21.53 ± 0.98	26.23 ± 1.96	9.93 ± 1.14	30.88 ± 0.59	32.22 ± 1.74
N22	Control	8.80 ± 1.42	25.38 ± 0.50	30.08 ± 3.26	13.33 ± 3.84	34.58 ± 0.42	35.92 ± 1.69
	Melatonin (100µM)	10.97 ± 1.71	31.83 ± 0.67	35.53 ± 2.89	14.03 ± 1.46	36.18 ± 0.50	42.02 ± 2.08
	Drought	5.90 ± 1.36	18.28 ± 0.59	22.98 ± 3.38	12.90 ± 0.91	29.28 ± 0.42	30.62 ± 1.69
	D + M	7.91 ± 0.67	21.53 ± 0.41	25.73 ± 2.83	14.43 ± 0.98	30.58 ± 0.33	31.92 ± 1.67
SEm		1.03	0.75	2.48	1.36	0.59	1.82
SEd		1.46	1.06	3.50	1.93	0.83	2.57
CD 5%		3.01	2.18	7.23	3.98	1.71	5.31
CD 1%		4.07	2.96	9.79	5.39	2.32	7.20
Significance		**	**	*	*	**	**

starch (RS) content of rice results in slower digestion and consequently low GI value. Rice GI value is altered by the protein, fat and other substances present in the added food condiments. It is observed that grain processing like cooking, parboiling and fermentation with different milling times shows effect on nutritional parameters. Among the various bioactive compounds present in rice, antioxidants have been shown to play a crucial role in reducing the risk of chronic diseases. The potential health benefits of rice, particularly pigmented varieties, are of increasing interest. Rice bran oil is gaining popularity among other traditionally used cooking oils because of its better cooking qualities like very high burning point, neutral taste and delicate flavor. Besides, its well-balanced fatty acid composition, along with the presence of antioxidant components makes it nutritionally rich. Therefore, rice grain with optimum quality parameters plays an important role in the success of any rice varieties for farmers as well as consumers.

Efficacy of tuber crops as potential food component in lowering the Glycemic index of rice.

Rice is rarely consumed alone; rather, with other food condiments like vegetables, pulses, tubers and roots. Among the food condiments, tuber crops are high in fibre and contain several health beneficial compounds. Starch rich root and tuber crops are considered second after cereals as global sources of carbohydrates. They contribute significantly to the global food supply and are a significant source of processed goods for both industrial and human use as well as animal feed. In India, tropical tuber crops such as sweet potato, cassava, yams, elephant foot yam and taro hold significant importance in ensuring food and nutritional security, particularly for the communities residing in the North-Eastern Hill region. Twelve rice genotypes from four categories (high protein, scented, general and pigmented) were analysed for glycemic index (GI) and resistant starch (RS) content. Among the genotypes, Improved Lalat had the lowest GI (53.12) with relatively higher RS content (2.18%), while Hue showed the lowest RS (0.20%) with the highest GI (76.30) value. Ten tuber crops were procured from the Regional Centre of ICAR-Central Tuber Crops Research Institute, Bhubaneswar and used for their impact on starch digestibility of rice. The addition of tuber crops to rice caused a significant lowering of GI where the maximum beneficial effect was shown by elephant foot yam followed by yam bean and taro (Table 4.2). The study suggests that combining rice with suitable tuber crops can significantly reduce its GI value and potentially reducing the burden of diet-associated lifestyle diseases particularly diabetes.

Study the effect of different ratio of rice-pulses mix on Glycemic index and Glycemic load value of rice

Addition of protein rich pulses with rice-based food interferes with the coalescence of starch molecules in the

Table 4.2: Changes in glycemic index value and RS content of rice after mixing with tuber crops.

Rice Genotypes	Tuber crops	Glycemic index	Resistant starch (%)
Hue (GI: 76.3, RS: 0.19 %)	Cassava (C)	55.64±1.60***	2.88±0.08***
	Yam Bean (YB)	53.07±1.56***	3.51±0.11***
	Elephant Foot Yam (EFY)	52.37±1.43***	3.81±0.12**
	Taro (T)	54.43±1.58***	3.47±0.11***
	Arrowroot (A)	58.17±1.71***	2.48±0.1**
	Purple Sweet Potato (PSP)	56.95±1.64***	2.48±0.07***
	Orange flesh Sweet Potato (OSP)	57.51±1.66***	2.57±0.07***
	White Sweet Potato (WSP)	58.95±1.70***	2.24±0.07***
	Greater Yam (GY)	55.03±1.59***	3.43±0.1***
	Chinese Potato (CP)	63.7±1.84***	1.75±0.08***
Improved Lalat (GI: 53.12, RS: 2.17 %)	Cassava (C)	52.80±1.55***	3.69±0.12**
	Yam Bean (YB)	51.64±1.57***	4.32±0.13***
	Elephant Foot Yam (EFY)	50.27±1.55**	4.49±0.16**
	Taro (T)	51.42±1.50**	4.30±0.15**
	Arrowroot (A)	52.27±1.43**	3.64±0.18**
	Purple Sweet Potato (PSP)	52.91±1.50**	3.48±0.16**
	Orange flesh Sweet Potato (OSP)	52.52±1.43*	3.56±0.15**
	White Sweet Potato (WSP)	52.69±1.49*	3.18±0.13**
	Greater Yam (GY)	52.11±1.61**	4.29±0.15**
	Chinese Potato (CP)	59.56±1.58***	2.84±0.09***

food matrix system along with the endogenous proteins and hence increases the resistance of starch to digestion. Protein present in pulses forms cross linkages with starch through disulfide bonds. When the rice-pulse combination is cooked, the network of proteins probably gets matted with the starch granules, inhibiting their expansion. This also constitutes stearic hindrance which prevents the hydrolytic enzymes to act on starch (Table 4.3). Keeping view of above facts, three ratios of pulse-rice mix (30:70, 40:60, 50:50) were taken for the study of its impact on GI and glycemic load (GL) values of rice with contrasting GI value (Improved Lalat and Hue). Out of three, 40:60 was found the most appropriate ratio of rice-pulses combination for maximum lowering impact on GI and GL value of rice. Pigeon pea resulted in maximum GI and GL lowering effect as compared to other pulses.

Impact of processing on rice grain quality

The impact of different grain processing methods like cooking, parboiling and fermentation on various bioactive components, antioxidant activity, glycemic index (GI), resistant starch (RS) along with pasting properties in three rice cultivars were investigated. Grain processing significantly increased the DPPH (1-3.3%) and FRAP (29-79%) antioxidant activity, total soluble sugars (TSS) (57-222%), Phenolics, flavonoids (12-37%) and zinc (2.4 to 23.9%) content, while protein (15-20%), amylose (1.3-10.0%), iron (21.9-42.4%) content and ABTS antioxidant activity decreased as compared to raw unprocessed rice. Percent decrease of these components was minimum in case of parboiling as compared to raw rice. The percent increase of TSS was highest in raw fermented rice while lowest in parboiled fermented rice. Scanning electron micrograph of grain showed that cultivar CR Dhan 310 contains higher amount of protein bodies and after parboiling it increased non-significantly. The processing significantly decreased the pasting viscosity as compared to raw rice. The average GI value of parboiled cooked rice was lowest while raw fermented was highest. Parboiled cooked rice of Naveen showed highest RS content (2.7%) whereas fermented rice of Manipuri black showed lowest value (0.31%). These findings will help rice consumers to select appropriate processed rice for getting maximum value addition in terms of nutritional quality.

Table 4.3: Impact of rice-pulses mix on glycemic index and glycemic load value of rice.

Varieties	Pulses	30:70 combinations		40:60 combinations		50:50 combinations	
		GI	GL	GI	GL	GI	GL
Improved Lalat (GI :53.12) (GL:16.88)	Pigeon pea	51.25±0.8	14.75±0.23	50.43±0.74	14.51±0.22	50.39±0.68	14.45±0.20
	Chickpea	52.75±0.89	16.59±0.28	51.42±0.64	16.17±0.21	51.4±0.85	16.11±0.27
	Lentil	52.25±0.58	15.54±0.18	51.33±0.84	15.27±0.25	51.28±0.66	15.21±0.20
	Mung bean	52.38±0.49	16.34±0.16	51.77±0.91	16.15±0.29	51.69±0.77	16.12±0.24
Hue (GI :76.30) (GL:22.54)	Pigeon pea	59.21±0.5	16.26±0.33	58.15±0.88	15.97±0.27	58.01±1.23	15.89±0.17
	Chickpea	61.14±0.83	19.87±0.20	60.18±0.81	19.46±0.34	60.1±0.83	19.41±0.48
	Lentil	60.46±1.22	17.18±0.44	59.38±1.0	16.91±0.25	59.36±0.61	16.76±0.24
	Mung bean	60.58±1.53	18.79±0.27	59.62±0.17	18.48±0.27	59.08±0.83	18.45±0.27

Rice processing like cooking, parboiling and fermentation and its effect

The impacts of different methods of rice grain processing like cooking, parboiling and fermentation on various bioactive components, antioxidant activity, predicted glycemic index (pGI), resistant starch (RS) along with pasting properties in three rice cultivars were investigated. Results showed that processing significantly increased the DPPH (1 to 3.3%) and FRAP (29 to79%) antioxidant activity, soluble sugars (TSS) (57 to 222%), Phenolics, flavonoids (12 to 37%) and zinc (2.4 to 23.9%) content, while protein (15 to 20%), amylose (1.3 to 10.0%), iron (21.9 to 42.4%) content and ABTS antioxidant activity decreased as compared to raw unprocessed rice. Percent decrease of these components was minimum in case of parboiling as compared to raw rice. The percent increase of TSS was highest in raw fermented rice while lowest in parboiled fermented rice. Scanning electron micrograph of grain showed that cultivar CR Dhan 310 contains higher amount of protein bodies and after parboiling it increased non-significantly. The processing significantly decreased the pasting viscosity as compared to raw rice. The average pGI value of parboiled cooked rice was lowest while raw fermented was highest. PCR of Naveen showed highest RS (2.7%) content whereas fermented rice of Manipuri black showed lowest value (0.31%). This finding will help rice consumers to select appropriate processed rice for getting maximum value addition in terms of nutritional quality.

Effect of different milling times on physical and nutritional qualities of rice

The physical parameters (length, breadth, height and weight) of the rice grain decreased after milling but non-significantly varied ($p>0.05$) with respect to grain milling time (30, 60, 90 s). Milling led to increase in L* values (whiteness) up to 13-21% and decreased in a* (38- 72%) and b* (10-24%) as compared to brown rice. Brown rice possess highest antioxidant activity. However, antioxidant activity was at par in 30s milling and raw cooked rice. Around 57 CRRI and poplar rice cultivars studied for Fe and Zn content at different milling times. Bindli possesses highest Fe content at brown rice and 30s milling (i.e 33.9 and 16.5ppm respectively). Overall, at 30s milling 34.9-52.9 %, 60s milling 49-59%, 90s milling 52-73% reduction of Fe was observed. Highest Zn content was found again in Bindli (39.7 ppm and even after 90s milling it was 27.4ppm). The reduction of Zn content was observed at 30s (3.8-27%), 60s (13.3 to 44.1%) and 90s milling (19 to 44%).

Evaluation of rice genotypes for antioxidant content/ medicinal value

India's North-eastern states, are known for their rich genetic diversity in agricultural crops, making them an invaluable resource for screening rice genotypes with enhanced antioxidant properties. Despite the importance of these bioactive compounds, systematic nutritional profiling of the germplasm collections from this region remains limited. The germplasm of Arunachal Pradesh, collected and preserved in the CRRI gene bank, are being evaluated for their antioxidant potential. Approximately 100 germplasm accessions have already been screened, and this year, an additional 100 germplasm have been assessed for their bioactive components (Total Phenol Content, Total Flavonoid Content and Total Antioxidant Activity). AC-9338 and AC-9340 were found to have high antioxidative potential, AC-9308 was found to be high in phenol and AC-9307 was found to have high flavonoid content.

Effect of cooking on antioxidant properties of pigmented and non-pigmented rice genotypes

The effect of cooking on the antioxidant properties of rice is a critical factor in determining the retention of these beneficial compounds. Both pigmented and non-pigmented rice genotypes were analysed for their total phenolic content (TPC), total flavonoid content (TFC), and antioxidant activity pre and post cooking. The analysis revealed a decrease in the levels of bioactive compounds and a reduction in antioxidant capacity in the cooked rice samples when compared to the raw rice samples. Specifically, total antioxidant activity was found to decrease by 50-70% in pigmented rice and by 60-85% in non-pigmented rice samples whereas phenols and flavonoids decreased to the tune of 40-60% in pigmented rice and 50-75% in non-pigmented rice samples. Despite the reduction in bioactive compounds and antioxidant capacity due to cooking, pigmented rice maintained a higher nutritive value than non-pigmented rice which can be attributed to the inherently higher levels of bioactive compounds present in pigmented rice.

Oxidative stability and shelf-life evaluation of popular rice varieties

The oil content has been estimated in 21 popular rice varieties. Further, the gamma oryzanol content and total antioxidant activity (TAA) by using DPPH scavenging activity has been estimated. The gamma oryzanol content ranges from 1.52%-2.34% whereas TAA varies from 58%-75% scavenging. The acid value, peroxide value and Iodine value was also estimated in the extracted oil samples which tells about the keeping quality of the oil. The highest Acid value (0.48 mg/g) and peroxide value (2.3 meq/kg) was observed in Lalat and Taraori Basmati, respectively. The lowest Iodine value was observed in Annapurna (98 g/100g) whereas highest value was recorded in ARC10075 (106 g/100g). Overall, by comparing all the parameters studied, it has been found that Sahabhagidhan and Geetanjali showed best keeping quality with high gamma oryzanol content and DPPH activity along with presence of low carbonyl compounds.

Conclusion

The research initiatives under Programme 4 have yielded significant strides in improving rice productivity and resilience against abiotic stresses. Innovations like genome editing to enhance photosynthetic efficiency and the identification of stress-resilient genotypes have provided new solutions for climate-adaptive rice cultivation. Moreover, insights into the nutritional enhancement of rice, such as developing low glycemic index varieties and optimizing processing techniques, address pressing health concerns in rice-dependent populations. These achievements demonstrated the potential of integrated scientific approaches to improve rice's sustainability and nutritional value. Moving forward, continued advancements in genomics, molecular biology, and collaborative research will be pivotal in addressing the challenges of global food security while promoting health and sustainability.

PROGRAMME

05

Socio-Economic Research to Aid Rice Stakeholders in Enhancing Farm Income

The Social Sciences Division focuses on technology dissemination and socioeconomic research by developing, testing, and refining innovative extension models, approaches, and strategies. Its primary objective is to engage in outreach activities that introduce new technologies to end users while also providing valuable feedback to technologists. With a dedicated team comprising five scientists and twelve technical staff, the division executes its research mandate through two in-house and seven externally funded research projects. In 2024, the division successfully showcased nine newly released rice varieties across eight states in collaboration with KVKs, NGOs, and participating farmers under the INSPIRE 1.0 and INSPIRE 2.0 models.

The division organized 22 diverse training programs, benefiting 763 participants, including farmers, extension functionaries, administrators, and other stakeholders in the rice sector. One of its notable achievements was the design of the *arORIce* rice value chain model, aimed at producing high-quality aromatic rice seeds to boost export-quality non-Basmati aromatic rice production. The division identified key challenges faced by rice farmers and assessed the economic potential of CRRI varieties, specialty rice, and premium seed varieties. It also conducted in-depth analyses of consumer preferences in rice consumption and current trends in rice production.

Further enhancing its outreach, the division developed an online training and information management system. It participated in national exhibitions, where it showcased CRRI technologies, offered advisory services to visitors, and provided agro-advisory through multiple communication channels. A critical responsibility of the division is the efficient management of rice databases, ensuring timely report generation and submission. Additionally, the division plays an essential role in delivering targeted benefits to marginalized groups through programs such as the Scheduled Caste Sub-Plan (SCSP), Tribal Sub-Plan (TSP), NEH, Farmer FIRST, and MeraGaonMera Gaurav (MGMG) initiatives.

Reaching stakeholders to Enhance their socio-economic CAPacities (RECAP) through rice technologies

Modelling Willingness-To-Adopt (WTA) CRRI rice varieties mediated by the INSPIRE extension model

This study analyzed 305 demonstrations across 23 districts in 8 states, involving 9 CRRI rice varieties. The improved rice varieties developed by the institute were demonstrated on a large scale under the INSPIRE extension model in *kharif* 2023, following which data were collected through household surveys, telephonic interviews, and focus groups. The structural equation modelling (SEM) approach was followed to examine the relationships between hypothesized factors affecting WTA. Given the observed imperfect adoption, the model explores factors influencing WTA holistically. An exploratory factor analysis (EFA) helped grouping 26 variables into six factors: field performance of demonstrated variety (VAR) (F-1), marketing potential (MAR) (F-2), extension support (EXT) (F-3), farmer capabilities (CAPA) (F-4), attitude change (ATTI) (F-5), and willingness to adopt (WTA) (F-6). A confirmatory factor analysis (CFA) confirmed the factor structure with all necessary fit measures satisfied (CFI = 0.93, TLI = 0.92, SRMR = 0.06, RMSEA = 0.07). The SEM results show that the first four factors, VAR, MAR, EXT, and CAPA contribute to a positive change in attitude (F-5), which drives willingness to adopt (F-6). All coefficients are significant at the 0.01 level, with R^2 values of 0.27 and 0.15 for the first two causal relationships. The model's fit measures (CFI = 0.92, TLI = 0.91, RMSEA = 0.07, SRMR = 0.08) confirm its robustness and credibility (Fig. 5.1). The study concludes that integrating marketing potential (MAR), farmer capabilities (CAPA), and extension support (EXT) alongside varietal performance (VAR) significantly enhances the accuracy of predicting attitude change and WTA.

Qualitative assessment of farmers' perception about CRRI varieties

The study, conducted through a sample survey (n=258) across six states—Odisha, West Bengal, Chhattisgarh, Maharashtra, Jharkhand, and Bihar—assessed 8 CRRI rice varieties following the Kharif demonstrations. Varietal superiority was evaluated based on perceived traits. The CRRI varieties were perceived as superior to farmers' adopted varieties in terms of tillering capacity, plant type, pest and disease resistance, salt and weed tolerance, and marketability, as indicated by significant t-test results (Table 5.1). However, no significant differences were observed in cooking quality, grain type, or lodging resistance. All 8 varieties demonstrated a yield advantage over farmers' adopted varieties, ranging from 2.97% to 37.49%. Notably, the yield differences between farmers' adopted varieties

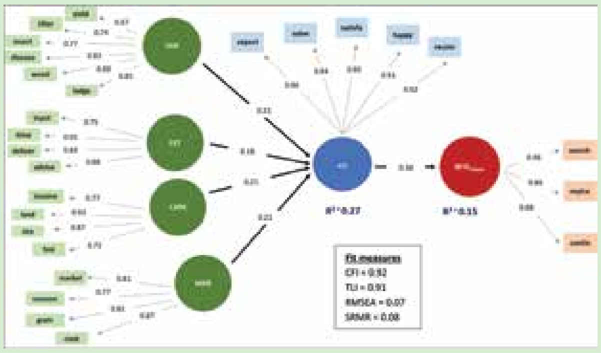


Fig. 5.1. A Structural Equation Model depicting the factors, pathways, and interconnections in willingness-to-adopt (WTA) CRRI varieties

Table 5.1. Aggregated analysis of perceived difference/ superiority in varietal traits (n = 258)

Trait	% farmers perceiving		Mean difference	t value
	Superior	Inferior		
Tillering capacity	86.05	13.95	0.70 ± 0.11	4.87***
Plant type	84.50	15.50	0.74 ± 0.14	5.74***
Grain type	57.36	42.64	0.36 ± 0.20	0.88
Insect pest resistance	77.52	22.48	0.44 ± 0.13	4.39***
Disease resistance	83.72	16.28	0.59 ± 0.15	6.24***
Salt tolerance	100.00	0.00	1.65 ± 0.22	4.81***
Weed tolerance	71.32	28.68	0.41 ± 0.19	2.01*
Lodging resistance	60.47	39.53	0.29 ± 0.18	1.71.
Cooking quality	58.91	41.09	0.49 ± 0.21	1.45
Marketability	68.99	31.01	0.52 ± 0.17	2.31*

Demo varieties = CR Dhan 206, 310, 314, 315, 319, 412, 414, 510
***sig. at 0.001, *sig. at 0.05, ·sig. at 0.10

Table 5.2. Yield performance of demonstrated varieties at farmers' fields

Variety	Avg. farmer field yield (t/ ha)	Avg. yield difference# (in %)	t-value	w-value
CR Dhan 206	4.28	2.97	-	2.50
CR Dhan 310	4.58	6.53	-	8.00
CR Dhan 314	6.48	36.07	13.72***	-
CR Dhan 315	5.03	4.22	-	4.50
CR Dhan 319	6.14	37.49	-	0.01*
CR Dhan 412	4.10	17.79	-	37.5
CR Dhan 414	4.23	12.48	-	27.00**
CR Dhan 510	5.74	25.39	6.76***	-

#Demo. variety v/s farmer's adopted variety ***sig. at 0.001; **sig. at 0.05*; sig. at 0.10

and two CRRI varieties (CR Dhan 314 and CR Dhan 510) were statistically significant (Table 5.2).

Exploratory analysis of YouTube based agro advisory, CRRI Barta

The analysis covers 76 episodes, with a total of 20,801 views and 400 hours of watch time. On average, each video receives 274 views, with the highest reaching 1,457 and the lowest at 54. The data reveals that CRRI Barta is primarily viewed by males aged 25-34 years. Viewers, on average, watch 1 minute and 6 seconds of each video, with a maximum watch time of 1 minute and 32 seconds and a minimum of 34 seconds. The total watch time per video averages 5 hours and 16 minutes, ranging from a minimum of 1 hour and 15 minutes to a maximum of 25 hours and 39 minutes. Each episode, on average, generates 7 new subscribers. CRRI Barta videos received more comments and likes than other CRRI videos, and their impression click-through rate and watch time ratio were significantly higher (Fig. 5.2).

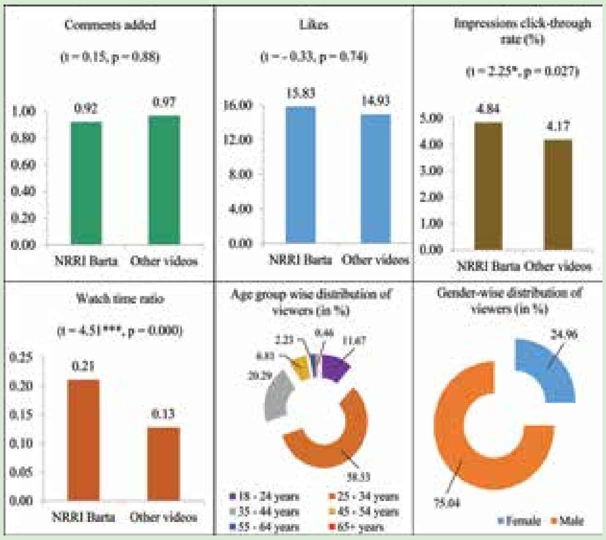


Fig. 5.2. Results of the analysis of CRRI Barta on key parameters

Development of a Rice Value Chain (RVC) model based on existing models

The ARORICE RVC model was designed to produce high-quality aromatic rice seeds, contributing to the production of export-grade non-basmati aromatic rice. The model engaged 899 farmers across five districts in Odisha: Koraput (92), Kalahandi (152), Nayagarh (420), Kandhamal (120), and Cuttack (115), collectively cultivating 8915 acres of land. During the reporting period, a total of 22654 tons of premium seeds from various non-basmati aromatic rice varieties were successfully produced.

Designing the CRRI Training Information & Management System

A web-portal (https://CRRItraining.in/) has been developed to streamline the management of training programmes, extension activities, and other outreach events organized by the institute. This structured approach not only organizes the data effectively but also ensures quick and easy access to information on all training, extension, and other outreach activities. By consolidating these details in one platform, the portal enhances efficiency, accountability, and the ability to track the institute's efforts in this direction.

Aggregated analysis of problems faced by farmers in rice cultivation

An aggregated analysis was conducted with 213 rice farmers (n = 213) across five Indian states: Odisha, Chhattisgarh, Jharkhand, Madhya Pradesh, and Maharashtra, to identify the challenges faced in rice cultivation. The findings revealed that the most significant issues were pests (51%), diseases (40%), irrigation (29%), seed availability (17%), lack of technical knowledge (12%), and high cost of cultivation (12%). These challenges highlight the key areas that need attention to improve rice farming in these

Fig. 5.3. A snapshot of the portal (https://CRRItraining.in/)

regions.

Working to Increase farm Net Gain through Socioeconomic research (WINGS)

Estimation of socioeconomic contribution of climate resilience varieties developed by CRRI

Attempting to quantify the societal value of climate-resilient rice varieties developed by the Institute, we employed the economic surplus approach, which encompasses the incremental returns resulting from technological advancements originating from research, including both producer and consumer surplus. For this purpose, we selected 21 non-basmati rice varieties exhibiting six different climate-resilient features viz. aerobic, submergence tolerance, drought tolerance, drought and submergence tolerance, salinity tolerance, and biotic stress tolerance.

Horizontal coverage of climate-resilient rice varieties

Horizontal area coverage (in million hectares, M ha) of different group of climate-resilient rice varieties were calculated from breeder seed supply considering appropriate multiplication factor, supply chain losses and technology discontinuance rate. The data shows a total gross cultivation area of 6.264 million hectares (M ha) for climate-resilient rice varieties, with notable variation across categories (Table 5.3). In the estimation year 2022-23, the area under climate-resilient rice varieties constitutes about 13.10 per cent of the gross cropped area under rice. Submergence-tolerant varieties dominate at 3.382 M ha, accounting for approximately 54% of the total area under climate-resilient rice varieties. Drought-tolerant varieties (1.090 M ha, 17%) and aerobic varieties (0.806 M ha, 13%) follow, focusing on managing water-related stresses. Biotic stress-tolerant varieties and others addressing salinity or combined stress conditions account for smaller shares.

Economic surplus from climate-resilient rice varieties

The findings underscore the critical economic and environmental role of climate-resilient rice varieties in addressing the challenges posed by climate change. These varieties span 6.26 million hectares (M ha), generating an economic surplus of ₹69,779.59 crores, with a net benefit of ₹64,549.05 crores and a net present value (NPV) of ₹34,748.24 crores (Table 5.4). Submergence-tolerant rice, grown on 3.38 M ha, stands out with the highest economic

Table 5.3: Trait-specific cumulative area under different climate-resilient rice varieties

S. No.	Climate-Resilient Rice Varieties	Area (M ha)	Proportionate share
1.	Submergence Tolerant	3.382	**53.99**
2.	Drought Tolerant	1.090	**17.40**
3.	Aerobic	0.806	**12.87**
4.	Biotic Stress Tolerant	0.428	**6.83**
5.	Drought & Submergence Tolerant	0.319	**5.09**
6.	Salinity Tolerant	0.239	**3.82**
	Gross Cultivation Area	6.264	100.00

Table 5.4. Economic surplus and Net benefits due to climate-resilient rice varieties (in Crore Rs.)

CRRI Varieties	Producer Surplus	Consumer Surplus	Total Economic Surplus	Net Benefits	Net Present Value
ARV	5896.35	5626.60	11522.96	11491.13	5712.48
STRV	22516.39	21486.28	44002.67	39570.97	21221.75
DTRV	2408.81	2298.61	4707.41	4444.46	2191.54
DSTRV	2650.64	2529.38	5180.02	5173.20	3425.97
SalTRV	2217.25	2115.81	4333.06	3843.21	2184.37
BSTRV	17.13	16.35	33.48	26.08	12.13
Total	35706.57	34073.03	69779.59	64549.05	34748.24

ARV: Aerobic Rice Varieties, STRV: Submergence Tolerant Rice Varieties, DTRV: Drought Tolerant Rice Varieties, DSTRV: Drought and Submergence Tolerant Rice Varieties, SalTRV: Salt Tolerant Rice Varieties, BSTRV: Biotic Stress Tolerant Rice Varieties

surplus (₹44,002.67 crore) and NPV (₹21,221.75 crore), highlighting its importance in flood-prone regions. The significant economic surplus and net benefit arise from its widespread adoption in flood-risk areas, delivering substantial welfare gains for both producers and consumers (₹39,570.97 crore). Aerobic rice, cultivated on 0.81 M ha, generates an economic surplus of ₹11,522.96 crores and a net benefit of ₹11,491.13 crores, reflecting its value in water-scarce regions by reducing reliance on groundwater. Drought-tolerant varieties, covering 1.09 M ha, contribute a net benefit of ₹4,444.46 crores, while combined drought and submergence-tolerant varieties, grown on 0.32 M ha, offer a net benefit of ₹5,173.20 crores. Salinity-tolerant varieties, cultivated on 0.24 M ha, provide ₹3,843.21 crores in net benefits, addressing the challenges of coastal salinization. However, biotic stress-tolerant varieties, grown on 0.43 M ha, show a modest impact, with a net benefit of just ₹26.08 crores, suggesting that further research and broader adoption are needed to unlock their full potential. From a policy perspective, the results emphasize the importance of prioritizing high-performing varieties, such as submergence-tolerant and drought-tolerant rice. To accelerate adoption, targeted strategies, including subsidies, farmer education programs, and strategic investments, should be implemented, particularly in areas most vulnerable to severe climate risks.

Estimation of economic value of specialty rice and premium seed varieties

Specialty rice and premium seed varieties, despite exhibiting price variations at market outlets, failed to yield significant financial returns to the farmers. Moreover, markets for high-protein rice and other specialty rice types are not well-established. In an effort to rationalize market prices and enhance returns for farmers, we shifted our focus from the actual prices paid by people to measuring their willingness to pay (WTP). Employing the contingent valuation method, we conducted a field survey in the states of Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh and Maharashtra utilizing choice cards to gather responses from various respondent categories. The analysis of the collected data revealed that people express a willingness to pay extra for specialty rice and premium seeds. The average increment in WTP was observed to be Rs. 5.60, 6.50 and 10.20 for high-protein rice, scented non-basmati rice, and premium seeds, respectively, compared to the rates of similar products within the same category (Fig. 5.4).

Assessing the impact of extension programmes

An attempt was made to assess the impact of major flagship extension programmes run by the institute viz. Mera Gaon Mera Gaurav (MGMG), Scheduled Caste Sub-Plan (SCSP) Programme, Tribal Sub-Plan (TSP) Programme and Farmer FIRST Programme. Data collected by personal interview and tele-communications through surveying 150 farmers under MGMG programme, 120 farmers under SCSP programme and 245 farmers from Farmer FIRST villages. Selected respondents have attended many training programmes, participated in demonstration and adopted use of machines in rice cultivation. Analysis of data indicated that attending training programmes increased the likelihood of getting an extra yield of 6.97 kg/ha, participation in demonstration influenced to get an extra yield of 43.90 kg/ ha and use of standard machinery increased the potential yield by 17.96 kg/ha (Table 5.5).

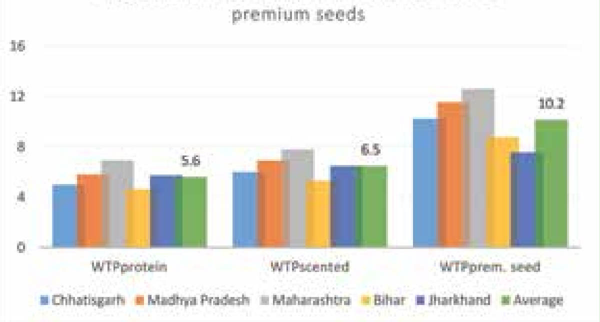


Fig. 5.4. WTP for high protein/scented rice & premium seeds

Estimation of a regression equation indicated that all the 3 extension interventions contributed significantly for yield increment and participations in demonstrations showed larger attribution.

Shift in rice area in different states of India and reasons thereof

The compound annual growth rate (CAGR) for rice area was calculated decade-wise for major rice-producing states in India, revealing significant shifts in rice area over different decades (Table 5.6). From 1971 to 2020, many states experienced a decline in rice area, while some states such as Assam, Karnataka, Punjab, Haryana, West Bengal, Nagaland, Arunachal Pradesh, and Manipur saw an increase in rice area. Through focus group discussions during demonstrations, training sessions, and field visits, several factors contributing to these changes were identified, which were categorized into ecological, socioeconomic, and institutional factors. A comprehensive survey was later conducted, with responses collected and analyzed using appropriate scoring and weighting methods. The results showed that rice cultivation in upland areas or problem soils was a major reason for the shift or decline in rice area (Table 5.7). Other contributing factors included limited access to the Minimum Support Price (MSP) or low prices in the open market, high labor costs or labor shortages, delayed or erratic monsoons, and the non-availability of quality seeds.

Table 5.5. Attribution of extension interventions in terms of yield increment

Particulars	**Basis of indices**	**Regression coefficient**	**Magnitude of effect (kg/ha)**
Training effect (Extn_{trg})	Σ [No. of trainings, hours, mode of training]	0.83^{**}	6.97
Demonstrations effect ($\text{Extn}_{\text{demonst}}$)	Σ [Area, enterprise, technology/practice]	5.21^{*}	43.90
Machine use effect ($\text{Extn}_{\text{machine}}$)	Σ [Owned, custom hiring, hours of use]	2.13^{*}	17.96

*Significant at 5% level; **Significant at 1% level

Table 5.6. State wise decadal growth (CAGR) in the harvested rice area (%)

States	**1971-1980**	**1981-9090**	**1991-2000**	**2001-2010**	**2011-2020**	**1971-2020**
Assam	1.1	0.68	0.13	-1.21	-0.55	0.38
Bihar	0.33	0.07	-0.26	-0.4	0.23	-1.31
Odisha	-0.34	0.31	0.23	-0.08	-1.26	-0.17
West Bengal	0.53	1.13	0.51	-0.24	-0.04	0.21
Jharkhand	-	-	-	0.43	5.00	0.32
Madhya Pradesh	0.91	0.43	0.9	-0.37	4.23	-2.55
Maharashtra	1.3	-0.14	-0.64	0.2	-0.27	0.2
Chhattisgarh	-	-	-	-0.20	0.04	-0.03
Haryana	5.62	2.12	5.56	0.95	2.08	3.56
Punjab	11.01	5.12	2.37	0.6	0.97	3.84
Uttar Pradesh	0.96	0.17	0.6	-0.09	0.35	0.52
Andhra Pradesh	2.04	-0.2	-0.43	0.44	-8.68	-0.41
Karnataka	-0.42	0.09	1.6	0.54	-4.27	0.39
Tamil Nadu	-0.33	-2.82	1.45	-0.96	-0.67	-0.95
Tripura	-0.33	-2.82	1.45	-0.96	0.86	-0.29
Sikkim	-	2.06	-1.86	-1.1	-3.56	-1.21
Nagaland	2.61	3.11	1.63	1.58	2.45	2.51
Meghalaya	8.76	0.78	-0.03	-0.14	0.32	0.16
Arunachal Pradesh	3.35	5.04	-0.36	0.4	0.94	1.58
Mizoram	23.83	1.98	2.71	-0.67	-1.14	-0.81
Manipur	2.43	-0.28	0.14	0.86	2.87	0.56
Gujarat	-0.38	0.05	1.73	2.55	1.43	1.42
Himachal Pradesh	-1.11	-1.15	-0.51	-0.56	-0.84	-0.65
J & K	1.9	-0.06	-0.06	0.51	0.91	0.23
Kerala	-0.61	-3.59	-4.9	-4.52	-1.92	-3.73

Rajasthan	5.38	-4.1	3.46	-3.19	5.45	0.08
Uttarakhand	-	-	-	-0.64	-1.54	-1.08
Telangana	-	-	-	-	1.36	1.36
India	1.58 (7)	0.27 (9)	0.51 (8)	-0.13 (15)	0.21 (12)	0.33 (12)

Note: Figures in parentheses indicate number of states where area has been decreased in overall

Table 5.7. Reasons for shifting of rice area: Empirical results

Reasons	Category	Respondents	Weights	Score	Final score	Rank
Upland/ problem soils	Ecological	65 (23.55%)	0.12	8.5	24.02	I
Low access to MSP/ low price in open market	Institutional	63 (22.83%)	0.10	9.0	20.54	II
High labour cost/ labor shortage	Socio-economic	56 (2029%)	0.08	9.5	15.42	III
Delayed/ erratic monsoon	Ecological	50 (18.82%)	0.08	7.5	10.87	IV
Non-availability of quality seeds	Institutional	37 (13.41%)	0.08	8.0	8.58	V
Crop substitution to diversify	Socio-economic	35 (12.68%)	0.08	8.0	8.12	VI
Small farm size / low mechanization	Socio-economic	32 (11.59%)	0.10	6.5	7.54	VII
Resurgence of new diseases/ pests	Ecological	20 (7.25%)	0.10	5.5	3.99	VIII
Migration for alt. employment	Socio-economic	18 (6.52%)	0.05	5.5	1.79	IX
Untimed release of canal water	Institutional	21 (7.61%)	0.05	4.0	1.52	X
Provision of food security entitlements	Institutional	16 (5.80%)	0.05	4.0	1.16	XI
Natural calamities	Ecological	12 (4.35%)	0.05	5.5	1.20	XII
Remote area/ low infrastructure	Institutional	9 (3.26%)	0.04	6.0	0.78	XIII
Low access to institutional credits	Institutional	10 (3.62%)	0.02	5.0	0.36	XIII

Note: *Total Respondents = 276; Multiple responses; Weights by experts; Scoring by respondents on 10-point scale*

Conclusion

The program aims to accelerate the dissemination of CRRI varieties and technologies through a combination of demonstrations, awareness campaigns, and capacity-building initiatives. Its primary objective is to influence policies that address the needs of various rice stakeholders. Beyond government involvement, the program has empowered private entities such as NGOs, CSR Units, and FPOs, fostering profitable and sustainable rice-based cropping systems.

An assessment of the economic impact of the institute's developed varieties and technologies along with the value of specialty and premium seed varieties will inform future research priorities and crucial decisions in the rice sector. By analysing trends in rice consumption and examining fluctuations in rice cultivation, yield, production, paddy cultivation costs, and rice exports, the program will provide valuable policy insights. These insights will guide the allocation of land for rice cultivation, promote crop diversity, and ensure the long-term sustainability of rice production.

PROGRAMME

06

Development of Climate Resilient Rice Technologies for Rainfed Upland, Rainfed Lowland and Coastal Saline Ecologies

Abiotic and biotic stresses are projected to worsen under climate change, particularly in rainfed ecologies, threatening rice production and livelihoods of resource-poor farmers. To address this, diverse rice germplasm has been characterized, identifying novel donors and genomic loci for stress tolerance. GWAS integrating drought, submergence, and low-P trial data identified candidate genes and promising accessions like Binnaful and AUS301 for multiple stress tolerance. Cold-tolerant germplasm from Northeastern India has also been screened. New rice varieties such as CR Dhan 804, CR Dhan 808, and CR Dhan 214 were released& notified, with additional promising entries identified. Urea nano-formulations were evaluated for rainfed dry-DSR, while organic and INM practices improved soil carbon sustainability. Resistant rice accessions with different resistance gene combinations were identified for blast and brown spot through multilocation trials. The native *Trichoderma* isolates of Jharkhand were characterized for mycelial growth inhibition of Blast and Brown spot pathogens. New climate-resilient varieties and production technologies were demonstrated along with organizing farmers training and a National Seminar to improve the livelihood of farmers in rainfed drought-prone regions. Rice is cultivated widely under rainfed lowland and productivity in the rainfed lowland is less than national average. Low temperature at seedling stage in *boro* season prolongs the crop harvest and recurrent pre-monsoon flood cause heavy loss to *boro* and early *ahu* paddy cultivated in lowlands of Assam. Developing thermo-insensitive *boro*, photo-insensitive *sali* and short duration *ahu* rice varieties, coupled with pest management tactics and dissemination of rice-based technologies can improve the production and productivity of rice in rainfed lowlands of Assam.

Rainfed Upland

Development of resilient production technologies for rice under rainfed drought-prone agro-ecosystems

Germplasm characterization and Varietal development for rainfed drought-prone agro-ecosystems

Genetic stock registration

A multiple stress (drought, submergence and blast) resistant genetic stock CRR751-1-12- B-B (IET 28033) (Fig. 6.1) was registered with Plant Germplasm Registration Committee, ICAR-NBPGR under registration number INGR 23073.

Fig. 6.1. Multiple stress tolerant genetic stock CRR751-1-12-B-B (INGR23073)

Germplasm characterization

In 2023 kharif, a total of 758 rice accessions were characterized for multiple abiotic and biotic stresses. The germplasm panels consisted of rice landraces from 3000 rice genome project, and accessions from Northeastern and Eastern India. Eighty seven landraces of different cultivar groups (*Bao, Bora, Sali*, and *Joha*) from Majuli, Dhemaji, and North Lakhimpur districts of Assam were characterized by assessing 36 agro-morphological traits, submergence tolerance, and microsatellite diversity (Fig. 6.2A). Multivariate analyses revealed that the cultivar groups could be differentiated primarily based on grain and leaf characteristics, plant height, and tillering. Population structure analysis using 66 SSR markers (271 alleles with 4.1 alleles per marker) classified the accessions into two clusters (allele frequency divergence of 0.124) (Fig. 6.2B). The *bao* or deep-water landraces displayed the highest phenotypic and genetic diversity, with potential genetic links to the *aus* and wild species. *Sali* (winter rice) and *bora* (sticky rice) landraces were predominantly *indica* types (Fig. 6.2C). Nearly 47% of the studied germplasm exhibited submergence tolerance and the *SUB1A-1* and *SNORKEL* genes in a frequency of 64% and 57%, respectively. Furthermore, screening of 211 genotypes for cold tolerance at seedling stage under field condition using the tolerant check ‘Kalinga III’, revealed that a total of 71 genotypes showed low seedling mortality and nine genotypes were found to bear spikelet with filled grain during the late crop season.

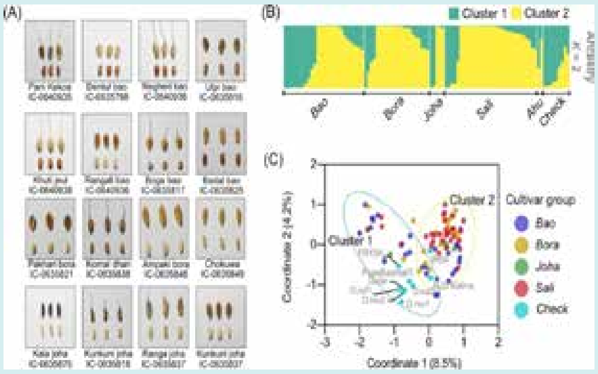
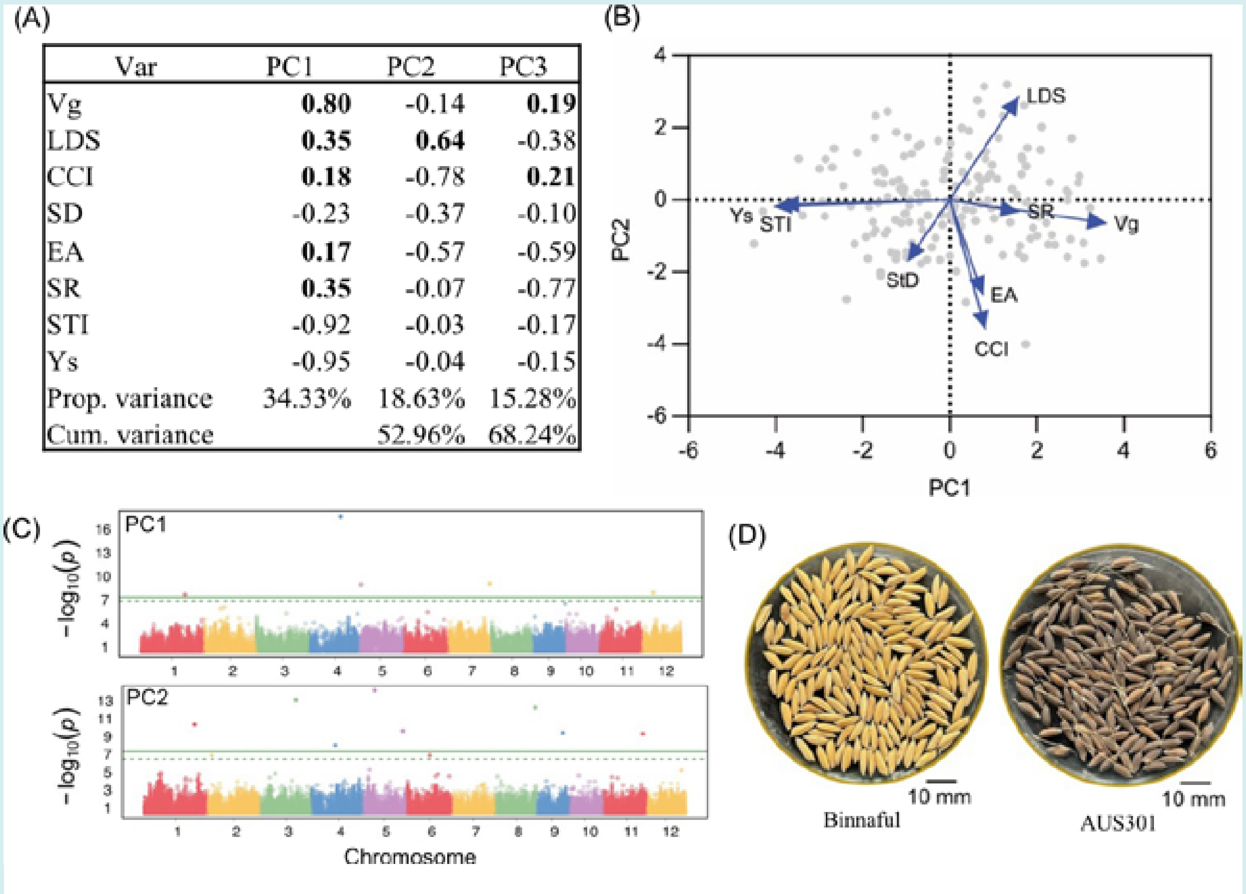


Fig. 6.2. Genetic diversity in rice germplasm from Assam. (A) Grain phenotypes, (B) STRUCTURE analysis, (C) Principal coordinate analysis.

Identification of multiple abiotic stress tolerant germplasm & genomic regions associated

Correlations among eight traits from multiple stress trials, such as under drought: vegetative vigour (Vg), drought score (LDS), chlorophyll content index (CCI), stomatal density (SD), under submergence: elongation ability (EA), and survival rate (SR), and under low-P: stress tolerance index (STI), and grain yield (Ys) in 181 *aus* rice accessions were analysed. Principal component analysis (PCA) was done to understand trait relationships. Trait loadings on the principal components (PCs) were: PC1 (drought, submergence), PC2 (drought), and PC3 (early vigour, chlorophyll content) (Fig. 6. 3A). The accessions were distributed based on PC1 and PC2 and selection could be done for multiple stress tolerance (Fig. 6. 3B). GWAS using the PCs (Fig. 6. 3C) identified many important genes like for PC1: *OsMDP1, qCCFJ-4, OsMKP1*; for PC2: *OsETOL1, FON3,* for PC3: *qChla4-1, OsDREB1C* and *OsGLU3.* Based on multilocational trials under AICRIP 2023, Binnaful and AUS 301 (Fig. 6. 3D) were found tolerant to osmotic stress, submergence and salinity.



(A)

Var	PC1	PC2	PC3
Vg	**0.80**	-0.14	**0.19**
LDS	**0.35**	**0.64**	-0.38
CCI	**0.18**	-0.78	**0.21**
SD	-0.23	-0.37	-0.10
EA	**0.17**	-0.57	-0.59
SR	**0.35**	-0.07	-0.77
STI	-0.92	-0.03	-0.17
Ys	-0.95	-0.04	-0.15
Prop. variance	34.33%	18.63%	15.28%
Cum. variance		52.96%	68.24%

Fig. 6.3. Genetic variability for multiple abiotic stress. (A) Trait loadings on three principal components. (B) Biplot showing distribution of 181 genotypes. (C) Manhattan plots generated from GWAS analysis using PC1 and PC2 using 458 K SNPs. (D) Promising multiple stress tolerant *aus* accessions.

Identification of promising *aus* accessions for DSR using yield stability analysis

Forty seven *aus* accessions and three check varieties (Vandana, IR64 and Sadabahar) were evaluated in 2023 under four predefined conditions of water and agronomic management like rainfed DSR (E1), rainfed DSR under low-P with supplementary irrigation (E2), transplanted puddled rice under well-watered conditions (E3), and DSR with supplementary irrigation (E4). Stability analysis of yield data was conducted using AMMI and GGE biplot methods. AMMI analysis partitioned Genotype*Environment Interaction into three axes and identified superior genotypes with high yield stability (Fig. 6.4A). Overall, AMMI and GGE (Fig. 6. 4B) identified 'Jabor sail', 'Kalia', 'ARC 12021', and 'Sada aus' as the most promising accessions.

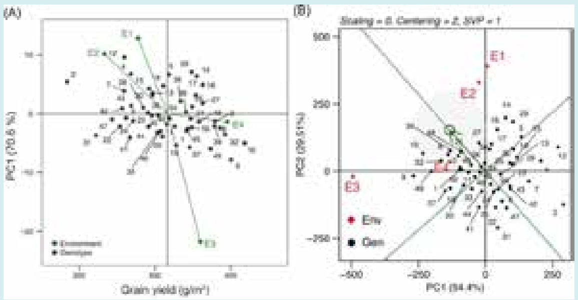


Fig 6.4. Stability analysis (A) AMMI biplot showing the main and principal component 1 (PC1) effects of both genotypes and environments on grain yield. (B) Comparison of *aus* rice accessions to an "ideal genotype" for grain yield and stability of performance across the environment.

Varietal development

Three rice varieties such as CR Dhan 804, CR Dhan 808 and CR Dhan 214 were notified during 2024 (Fig. 6.5). IET 30020 (CRR 842-IR14L159) found promising for Haryana based on three year trials, and IET 31286/CRR 744-74-41-B found promising under NIL-DRT (2022 and 2023). Other promising entries were IET31185 (CRR514-6-1-1-1-12), IET 30694 (CRR 778-B-B-2-2), IET 30687 (CRR-DH64). Twelve new entries have been nominated for initial varietal testing under AICRIP trials in 2024. A set of 16 climate resilient varieties and check varieties were evaluated under drought stress and non-stress conditions and highest grain yield under stress was recorded in CR Dhan 808 followed by CR Dhan 804 and IR 64 Drt1 (Table 6.1).

CR Dhan 804
Yield : 5.61 t/ha.
Duration: 115-120 days.
Grain quality: LS grains, high Milling (65.8%) and HRR (61.0%), AC (25.93%)
Notified for: JH, UP, TN, MP, CG, AP,TS
Remarks: MAS for $qDTY_{2.2}$, and *Sub1*

CR Dhan 808
Yield : 3.05 t/ha.
Duration: 90-95 days.
Grain quality: Short bold grains, high HRR (62.5%), AC (20.51%), GC (47.5) and ASV (3.5)
Notified for: JH, BI
Remarks: MAS for $qDTY_{3.1}$, $qDTY_{12.1}$

CR Dhan 214
Yield : 5.76 t/ha.
Duration: **110** days.
Grain quality: Milling (70.0%) and HRR (62.3%), LS grains, very occasionally chalkiness, low GT (ASV-7.0), AC (23.07%) and soft GC of 44.5.
Notified for: OD, BI
Remarks: Aerobic variety

Fig. 6.5. Rice varieties notified in 2024

Table 6.1. Performance of selected climate resilient rice varieties under drought

Designation	Days to 50% Flw.		Plant Ht. (cm)		Yield (kg/ha)		Sterility (%)	
	Drought	Control	Drought	Control	Drought	Control	Drought	Control
CR Dhan 801	103	94	89.5	107	1050	4028	26.5	23.8
CR Dhan 802	104	103	81.9	92	883	3924	17.6	31.9
CR Dhan 804	84	87	65.4	87	1167	3924	16.4	21.5
IR64 Drt1	83	87	70.0	104	1125	3819	16.5	19.4
IR64	85	85	69.7	104	617	3819	43.1	23.9
CR Dhan 808	69	65	96.5	119	1400	3611	33.9	12.8
Anjali	68	66	105.9	124	742	3264	51.3	14.7
Sahabhagi Dhan	79	83	62.7	120	975	3854	14.1	13.6
5% LSD	*1.0*	*1.1*	*7.3*	*3.0*	*169.0*	*527.4*	*7.2*	*5.1*
CV(%)	*1.0*	*0.7*	*6.2*	*1.8*	*12.1*	*9.2*	*12.3*	*12.0*

Nutrient Management options for sustainable rice production under direct seeded rainfed ecology

Study on the effect of urea nano formulation in rainfed dry-DSR demonstrated comparable grain yield, N uptake, and benefit-cost (BC) ratio with respect to recommended dose of N (RDN) (Table 6.2). The highest agro-physiological efficiency of N (kg grain increased kg^{-1} N uptake) and N response were observed with T2 and T1 (RDN), respectively.

Table 6.2. Effect of nano-urea application on yield, N uptake and profitability of rainfed dry-direct seeded rice

Treatments	Grain yield (t ha^{-1})	Increase over Control (%)	Grain N uptake (kg ha^{-1})	Total N uptake (kg ha^{-1})	Cost of Cultivation (Rs.)	Gross return (Rs.)	Net return (Rs.)	B:C
T_1	2.83	111.2	29.4	54.6	42974	71505	28531	0.66
T_2	2.77	106.3	28.5	51.4	44076	69600	25524	0.58
T_3	2.36	75.8	24.5	48.6	45184	60556	15372	0.34
T_4	1.86	38.5	19.4	41.8	45028	48577	3549	0.08
T_5	1.97	46.7	21.4	47.4	46328	51311	4983	0.11
T_6	2.13	58.7	24.5	50.9	46328	55047	8719	0.19
T_7	1.34	-	13.3	25.3	39200	35147	-4053	-0.10
SEm±	0.11	-	1.5	2.6	-	2641	2641	0.06
CD (*P*=0.05)	0.34	-	4.5	8.0	-	8139	8139	0.18

Note: T1: RDN in three splits (basal, 20-25 DAS and AT) (recommended P and K); T2: 75% RDN in three splits (basal, 20-25 DAS and AT) + 1 FS Nano-urea; T3: 50% RDN in two splits (basal and 20-25 DAS) + 2 FS Nano-urea; T4: 30% RDN (basal) + 2 FS Nano-urea; T5: 30% RDN (basal) + 3 FS Nano-urea; T6: 30% RDN (basal) + LCC based N management using Nano-urea; T7: Control

Analysis of soil carbon indices under rice-based cropping system

Soil carbon indices such as lability index (LI) and carbon pool index (CPI) was estimated on the basis of different soil organic C pools (very labile, labile, less labile and non-labile) under rice-sole *vis-a-vis* rice-pigeon pea intercropping as affected by different nutrient management practices (Table 6.3). Under both systems, LI and CPI is higher in organic and INM practices over inorganic treatments. The quality and quantity of soil organic C as reflected through a higher C management index (CMI).

Table 6.3. Lability index (LI), carbon pool index (CPI) and carbon management index (CMI) as affected by nutrient management practices in rice-sole and rice-pigeon pea intercropping

Treatment	Rice			Rice-pigeon pea		
	LI	CPI	CMI	LI	CPI	CMI
T_1	1.34^{c}	1.00^{e}	134^{c}	1.76^{a}	1.01^{d}	176^{d}
T_2	1.48^{bc}	1.39^{d}	206^{b}	1.60^{ab}	1.23^{c}	196^{c}
T_3	1.72^{a}	1.65^{c}	285^{a}	1.62^{ab}	1.38^{b}	224^{b}
T_4	1.54^{abc}	1.78^{ab}	274^{a}	1.72^{a}	1.56^{a}	268^{a}
T_5	1.65^{ab}	1.73^{bc}	285^{a}	1.51^{b}	1.53^{a}	231^{b}
T_6	1.58^{ab}	1.75^{bc}	277^{a}	1.65^{ab}	1.57^{a}	259^{a}
T_7	1.57^{ab}	1.87^{a}	293^{a}	1.64^{ab}	1.63^{a}	265^{a}
T_8	1.58^{ab}	1.87^{a}	295^{a}	1.59^{ab}	1.57^{a}	250^{a}

Note: T_1 Control; T_2 100% RDF (40:30:30); T_3 50% RDF +FYM @5 t / ha; T_4 50% RDF +FYM @5 t / ha +VAM 1.5 q/ ha+ PSB 4 kg/ha; T_5 50% RDF +RI; T_6 100% FYM @10 t/ ha; T_7 100% FYM @10 t/ ha + VAM 1.5 q/ ha+ PSB 4 kg/ha; T_8 100% FYM @10 t/ ha +RI

The pH and SOC map of CRURRS Massipirhi campus (20 acres) was developed by sampling 35 soil samples. The pH varied from 4.8 to 6.2, whereas soil organic carbon ranged between 0.75 to 0.98% (Fig. 6.6).

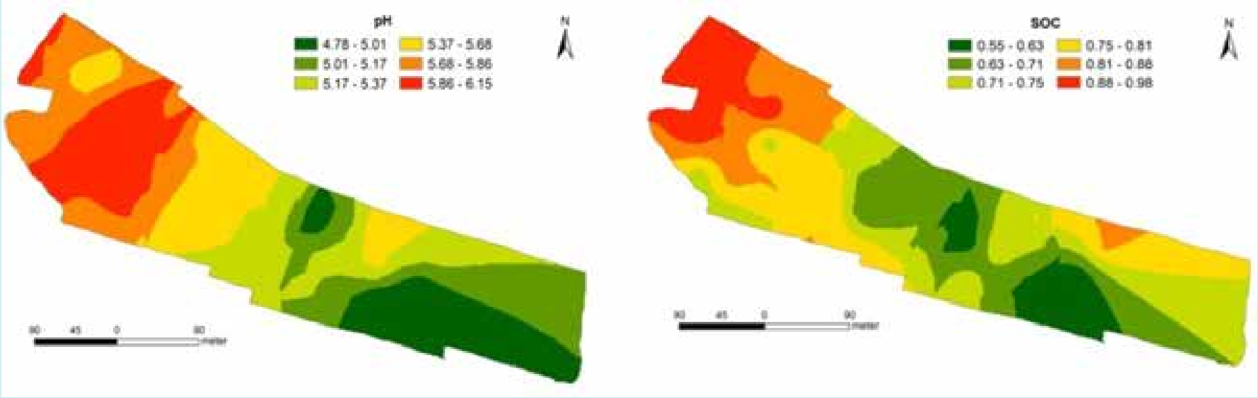


Fig. 6.6. pH and SOC map of CRURRS Massipirhi campus

Biotic stress management and pathogen variability studies

Isolation and characterization of native isolates of Trichoderma from Jharkhand

Twenty eight native isolates of *Trichoderma* were collected from Jharkhand, and *in vitro* studies revealed that most of the isolates were highly effective against both *Magnaporthe oryzae* and *Bipolaris oryzae.* Although most of the isolates have resulted in >50% inhibition in mycelial growth of *M. oryzae*, the isolatesTh5, Th3, Th-77, Th-54, Th-2, Th-1, Th-99, Th-19, Th-37, and Th-15 were the most effective with > 70% growth inhibition. Similarly, the isolates likeTh5, Th3, Th-77, Th-54, Th-2, Th-1, Th-99, Th-83, Th-37, Th-90 and Th-78 were most effective (>70% inhibition) against *B. oryzae*.

Identification of the new sources of resistance against rice blast and brown spot

Multilocation trials of total 13 and 12 accessions showing resistance to blast and brown spot, respectively were conducted across four diverse locations in *kharif* 2022 and 2023. In case of blast, 'ChahaPota' with seven blast *R* genes (*Pi2, Pi9, Pi5, Pi54, Pita2, Pit,* and *Pid2*) and 'Malbhog Sali' having *Pita2* showed resistance across all locations (Table 6.4). For brown spot, CRR 771-B-B-18 and 'Ampakibora' showed resistance across three locations, whereas 'Ranga Sali' showed moderate resistance at three locations (Table 6.5).

Table 6.4. Disease reaction of selected entries against leaf blast in five environments across India

#	Name	Gene combination	Loc1	Loc2	Loc3	Loc4	Loc5
1	Ranga Sali	*Pi5*	3	3	2	6	3
2	Maguri Bao	*Pi2 + Pi5 + Pi54 + Pita2 + Pid2*	3	1	3	*	3
3	Komal Dhan	*Pi2*	3	3	6	*	3
4	Depa Bao	*Pi5 + Pi54 + Pita2 + Pit + Pid2*	3	1	1	*	3
5	Jol Bao	*Pi2 + Pi5 + Pi54 + Pita2 + Pid2*	3	3	3	*	2
6	Ranga Joha	*Pi9 + Pi5 + Pita2*	3	3	8	1	3
7	Malbhog Sali	*Pita2*	3	3	3	1	3

8	Ngoba	NIL	3	3	4	*	3
9	Khorü	*Pi2*	3	3	2	*	2
10	Amusumicheghe	*Pi54*	2	5	4	*	3
11	Khrisü	*Pi54*	3	5	3	*	3
12	Matikhrürie	NIL	2	7	2	1	3
13	Chaha Pota	*Pi2 + Pi9 + Pi5 + Pi54 + Pita2 + Pit + Pid2*	3	3	2	3	2
14	Susceptible check**		9	9	9	9	9

Note: Loc 1: Hazaribag, 2021; Loc2: Imphal, 2022; Loc 3: Gangavathi, 2023; Loc 4: Jagdalpur, 2023; Loc 5: Hazaribag, 2023; *Data not available due to poor germination; ** Co39 (Hzb) and HR12 (Rest of the location)

Table 6.5. Disease reaction of selected entries against leaf blast in five environments across India

#	**Name**	**Loc1**	**Loc 2**	**Loc 3**	**Loc 4**	**Loc 5**	**Loc 6**
1	Ranga Sali	1	4	3	5	5	7
2	Til Bora	2	4	4	9	6	7
3	Kalajoha	2	4	3	7	5	7
4	Depa Bao	1	5	*	9	*	*
5	Ampaki Bora	2	3	2	7	3	5
6	Teri Shye	2	4	*	9	*	*
7	Jondre	2	4	*	9	*	*
8	Zacuta ha	3	3	*	7	*	*
9	CRR 771-B-B-18	1	4	2	7	2	4
10	CRR 772-B-B-47	2	3	2	9	4	7
11	CRR 778-B-B-1-1	2	4	5	9	6	7
12	CRR 803-B-B-2	2	4	3	9	3	7
13	Susceptible Check**	9	9	9	9	9	9

Note: Loc1: Hazaribag, 2020; Loc 2: Hazaribag, 2021; Loc 3: Hazaribag, 2023; Loc 4: Gangavathi 2022; Loc 5: Jagdalpur, 2023; Loc 6: Ludhiana, 2023; *Data not available due to poor germination; ** GNV-05-01 (Gangavathi) and HR12 (rest of the locations)

Evaluation of fungicides against blast and brown spot

Nine fungicides have been evaluated against blast and brown spot of rice under field condition and found that Azoxystrobin 5.1% + Tebuconazole 9.1% + Prochloraz 18.2% (Almagor) @3.5 ml/l, was most effective against leaf blast of rice whereas Thifluzamide 15% + Difenoconazole 20% EC @0.5/l, was most effective in management of brown spot of rice. Nativo was found on par with the best treatment for the management of both blast and brown spot of rice.

Breeder seed production

During 2023 *kharif* a total 77.73 q of breeder seeds was produced for 16 varieties with the highest share for Sahbhagidhan followed by CR Dhan 320.

Performance of rice varieties in farmers' fields

Performance of new rice varieties developed was assessed in farmers' fields (Fig. 6.7). Based on data from five villages, CR Dhan 320 was found superior to the hybrids (3 locations) cultivated. Under drought conditions, CR Dhan 808 yielded 1.4 t/ ha.

Fig. 6.7. Performance of rice varieties in farmer's fields. Field photo of CR Dhan 320

Rainfed Lowland

Rice production and productivity improvement in Rainfed lowland ecosystem

Rice is a vital cereal crop in Assam and serves as the staple food for the people of the north-eastern region. In this area, rice cultivation predominantly takes place under rainfed conditions, with farmers preserving local landraces to meet their preferences and needs. Dedicated to addressing the unique challenges faced by rainfed rice farmers in Northeast India, the Regional Rainfed Lowland Rice Research Station (RRLRRS), Gerua focuses on enhancing rice productivity and resilience in the region. The station has made significant effort for promoting climate-smart varieties such as CR Dhan 801 and 802, bio-fortified varieties like CR Dhan 310 and 311, aromatic rice CR Dhan 909 and the high-yielding CR Dhan 307 in Assam. These varieties are disseminated through Front Line Demonstrations (FLDs) and seed distribution programs conducted across various locations in Assam. By conducting **All India Coordinated Rice Improvement Project (AICRIP)** trials, frontline demonstrations, organizing farmers' training programmes, Kisan Mela and distributing essential agricultural inputs, RRLRRS plays a pivotal role in improving rice cultivation practices and boosting farmers' livelihoods in Assam and others Hilly States of Northeast.

Maintenance of germplasm

Seventy one rice germplasm were preserved at RRLRRS, Gerua, during the *Boro* season of 2023-24, along with 763 rice germplasm maintained during the *Kharif* season of 2024. *Joha* rice germplasm exhibited 5.6 to 10.4 ear-bearing tillers, with plant heights ranging from 97.4 to 141.4 cm (Table 6.6). Out of the 37 *Joha* rice germplasm, Tulsi Joha recorded the lowest yield of 1.05 t/ha, while Chini Kamini yielded the highest of 3.5 t/ha. Stem borer incidence was minimal in Bokul Joha (0.82% WEH) and highest in Gopal Bhog (12.81% WEH).

Table 6.6. Performance of *Joha* rice during kharif 2024

Variety	Plant height (cm)	Effective bearing Tiller	Per cent WEH	Yield (t/ha)
Bhaboli Joha	120.8	8.2	3.39	1.60
Bokul Joha	97.4	6.8	0.82	3.00
Keteki Joha	137.0	6.6	7.56	2.64
Kharika Joha	137.0	9.4	5.33	1.60
Kola Joha	130.0	6.8	6.94	2.33
Kola Joha-2	120.8	8.0	5.56	2.45

Kon Joha	137.2	8.6	4.52	1.73
Kunkuni Joha	129.2	6.6	4.20	1.58
Mem Joha	132.6	5.6	6.93	2.60
Pilpelia Joha	129.0	6.6	7.56	3.03
Tulsi Joha	134.0	7.4	9.77	1.05
Manikimadhuri	133.0	6.6	4.62	2.77
Gopal Bhog	127.0	7.8	12.81	1.73
Prashad Bhog	121.0	7.6	5.84	2.70
Bhog	129.4	6.0	6.02	1.20
Tulsi Prashad	133.4	7.0	4.76	2.00
Pimpudi Basa	138.0	8.0	3.82	3.20
Atma Shital	137.4	8.6	3.55	2.30
Tulsi Amrit	136.2	8.6	9.35	1.15
Chini Kamini	124.0	7.2	4.63	3.50
Adam Chini-6	131.8	7.8	4.63	2.00
Sona Chur	135.8	7.4	3.38	1.45
Kanak Jeera	139.0	7.2	5.41	1.22
Jeera Jwain	123.6	8.2	3.05	1.60
Jeera Jwain-1	134.4	8.2	5.76	1.80
Jeera Jwain-2	127.0	8.0	4.86	1.10
Jeera Jwain-2	129.4	7.6	2.55	2.22
Jeera-32-1	141.4	8.4	4.30	2.44
Jeera-32-2	121.2	6.8	8.16	2.78
Jeera-32-3	129.4	10.4	3.21	1.30
Jeera-32-27	133.8	8.4	4.64	2.20
Jeera Bati	138.4	7.6	5.47	3.24
F 120	137.6	7.8	4.27	2.00
T-120	132.2	8.8	4.10	1.45
SR-67	139.0	8.4	5.63	2.00
Nagri-C	133.8	8.4	4.30	1.53
Nagri-C (black)	125.8	10.2	4.90	1.38

Among the 13 *Bora* rice germplasm evaluated during *Kharif* 2024, Assam Bironi recorded the highest yield at 2.94 t/ha, while Nal Bora had the lowest (1.13 t/ha) (Table 6.7). Plant height of germplasm ranged from 83.8 to 134.2 cm, with ear- bearing tillers (EBT) varying between 5.8 and 8.8 per hill. Incidence of rice stem borer was the lowest in Jupa Bora (0.93 % WEH) and highest in Aghoni Bora (4.93% WEH).

Table 6.7. Performance of Bora rice during , 2024

Variety	Plant height (cm)	No. of Effective Tillers	Per cent WEH	Yield (t/ha)
Nal Bora	132.6	6.8	1.63	1.13
Aghoni Bora (Gerua)	83.8	5.8	3.35	2.57
Aghoni Bora (Cuttack)	95.2	6.2	4.93	2.81
Aghoni Bora (Assam)	86.6	7.2	4.63	2.75
Ghiu Bora	134.2	6.4	3.48	2.32
Assam Bironi	125.8	8.8	1.89	2.94
Bokul Bora	113.8	7.2	1.59	2.22
Jupa Bora	106.6	6.4	0.93	2.11
Kaati Bora	109.2	7.8	1.39	2.75
Dimow Bora	110.4	7.8	1.04	2.77
Til Bora	121.2	6.4	1.39	1.40
Maut Bora	121.0	7.2	1.98	2.50
Jenguni Bora	97.2	8.6	1.23	1.80

Table 6.8. Performance of Black rice during 2024

Variety	Plant height (cm)	No. of Effective Tillers	Per cent WEH	Yield (t/ha)
Black Chakoa	77.8	5.0	2.22	1.63
Black Rice (Awn)	120.6	5.6	0.99	1.20
Black Rice-1	119.8	6.0	0.93	2.00
Chakhao	122.0	4.4	1.90	1.30
Black rice (H3)	119.6	9.6	0.58	2.90
Moran Black	119.2	7.0	2.38	2.60

Plant height of black rice varied from 77.8 cm to 122.0 cm and EBT varied from 4.4 to 9.6 numbers per hill (Table 6.8). Steam borer infestation was highest in Moran Black (2.38 per cent WEH) and lowest in Black Rice (H3) (0.58 per cent WEH). Highest yield in Black Rice (H3) was 2.90 t/ha and lowest in Black Rice (Awn) was 1.20 t/ha.

Table 6.9. Performance of Boka Rice during kharif 2024

Variety	Plant height (cm)	No. of Effective Tillers	Per cent WEH	Yield (t/ha)
Santi Boka	134.6	6.4	1.74	3.27
Seka Boka	143.8	7.0	1.98	2.55
Panta Boka	134.4	6.6	1.68	4.09
Kartik Boka	131.8	6.8	1.63	4.67
Boka Jahingia	129.8	6.6	1.68	4.65
Boka 14	129.4	6.6	1.26	3.86

Six Boka (soft) rice were maintained during kharif 2024 (Table 6.9). The plant height of boka rice germplasm ranged from 129.4 to 143.8 cm and the EBT varied from 6.4 to 7.0 . Infestation of stem borer was lowest in Boka 14 (WEH 1.26 %) and highest in Seka Boka (1.98 % WEH). Kartik Boka recorded the highest yield 4.67 t/ha and Seka Boka recorded the lowest 2.55 t/ha.

Seed production

A total of 670 kgs of Breeder seeds of CR Dhan 310 & CR Dhan 909 and 718 kgs of Truthful Leveled (TL) seeds were produced during *Boro* season, 2023-24 (Table 6.10).

Table 6.10. Seed production at RRLRRS, Gerua in Boro season 2023-24

Sl. No.	Variety	Breeder Seed	TL Seed
1.	CR Dhan 310	490 kg	
2.	CR Dhan 909 (Aromatic Rice)	180 kg	
3.	CR Dhan 601		105 kg
4.	CR Dhan 315		250 kg
5.	Naveen		330 kg
6.	Chandrama		33 kg
Total		**670 kg**	**718 kg**

Front Line Demonstration

Climate smart rice varieties CR Dhan 801 and 802, bio-fortified CR Dhan 310 and 311, aromatic CR Dhan 909 and high yielding CR Dhan 307 were demonstrated in farmers' field of 23.15 ha in Lakhimpur, Dhemaji, Kamrup, Nalbari and Goalpara districts of Assam (Fig. 6.8). CR Dhan 307 recorded the highest yield of 5900 kg/ha in Goalpara district of Assam (Table 6.11).

Fig. 6.8. FLDs on CR Dhan 310 and 311 at Lakimpur and Dhemaji districts of Assam

Table 6.11. Front line demonstration during *kharif*, 2024

Variety	Location	Area (ha)	Yield (kg/ha)
CR Dhan 310	Chandmari, Bherekichuk, Pukhuriporia in Lakhimpur district	0.875	4425
	Nilokh Tarani and Moridhal villages in Dhemaji district	3.00	4135
	Goldighala in Nalbari district	5.00	5280
CR Dhan 311	Padumoni, Bongalmora, Pukhuria, Karson villages in Lakhimpur district	0.875	4542
	Sitolmari, Nilokh Tarani and Moridhal villages in Dhemaji district	2.00	4050
CR Dhan 801	Dalgoma and Kadamtola in Goalpara district	4.00	4350
Dakhin Kulabali, Mohaijan Potia, Chandmari, Nizlaluk, Bherekichuk in Lakhimpur district		1.00	4820
CR Dhan 802	Rakhapara and Amguri in Goalpara district	2.00	4750
CR Dhan 307	Dalgoma and Kadamtola in Goalpara district	4.00	5900
CR Dhan 909	Pakorkona, Hajo in Kamrup district	0.40	5106
Total		**23.15**	

Coastal Saline

Evaluation of the rice varieties suitable for the coastal ecosystems: Evaluation of CRRI rice varieties in coastal ecology revealed that the varieties like CR Dhan 402 (4.33 t/ha), CR Dhan 403 (5.05 t/ha), CR Dhan 406 (4.67 t/ha), CR Dhan 412 (4.41 t/ha), CR Dhan 414 (5.15 t/ha) yielded at par with saline tolerant variety CSR 36 (5.98 t/ha). Similarly, irrigated varieties like CR Dhan304 (5.11 t/ha), CR Dhan 307 (4.49 t/ha), CR Dhan 312 (5.81 t/ha), CR Dhan 317 (4.45 t/ha) yielded at par with local popular irrigated varieties like MTU 7029 (5.89 t/ha) and MTU 1061 (5.19 t/ha).

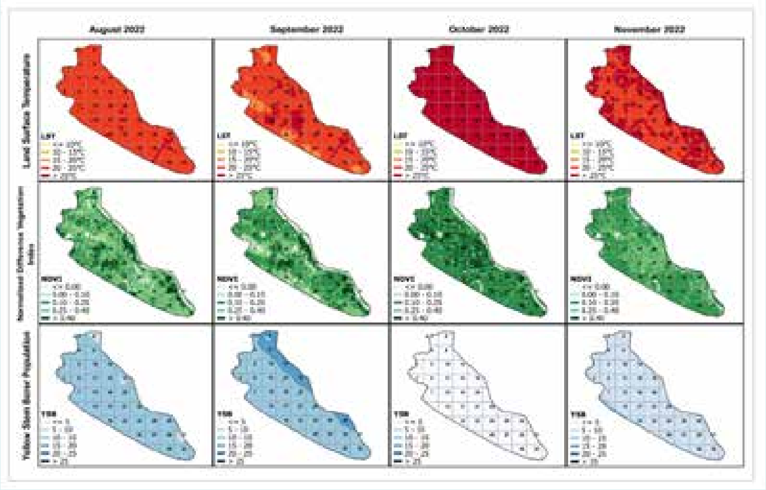


Fig. 6.9. Imagery/maps of Land Surface Temperature, Normalized Difference Vegetation Index, and yellow stem borer population in study area during 2022

Seasonal patterns and forecasting rice pest in coastal ecosystem: The yellow stem borer (YSB), *Scirpophaga incertulas*, poses a significant threat to rice cultivation, causing 'deadheart' and 'whiteheads' damage. Our study integrates YSB pheromone trap data with Landsat 8-derived LST and NDVI maps to explore their relationship in India's East Coast Plain and Hills zone over two crop seasons (2021–2022). Weekly YSB counts from 32 grids revealed a negative correlation between YSB populations and both LST and NDVI, with LST showing a stronger association. Peak YSB counts occurred in Aug-21 and Nov-21, highlighting the potential of geospatial tools for efficient YSB monitoring and management in rice ecosystems (Fig. 6.9).

Light trap based prediction of yellow stem borer: A study was carried to integrate light trap YSB data with weather variables (temperature, humidity, rainfall) and employs artificial intelligence (AI) models—Multilayer Perceptron (MLP) and Long-Short Term Memory (LSTM)—to predict YSB populations. Results show LSTM outperformed MLP based on RMSE, MAE, and R^2 metrics. The LSTM model enables early warning of YSB outbreaks in the Eastern Coastal Plains and Hills agro-climatic zone of India, providing stakeholders critical lead time for pest management, minimizing yield losses and enhancing rice crop protection (Fig. 6.10)

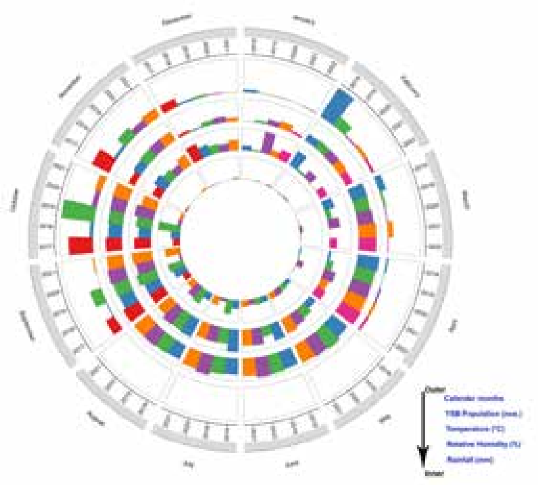


Fig. 6.10. Annual Cycle of Yellow Stem Borer light trap catches in rice along with climate variables during the sampling

Nematode community interactions in Coastal Rice Ecology: Nematodes dominate terrestrial metazoans, yet their responses to soil factors remain underexplored in coastal crop ecosystems. In Srikakulam district of Andhra Pradesh, 30 soil samples were analyzed along a salinity gradient (saline vs. non-saline soils). Significant differences in pH, electrical conductivity, Na, Mg, and Ca were observed. nMDS ordination revealed distinct nematode taxa clustering between soil groups, with Cephalobidae contributing most to dissimilarity. RDA analysis linked soil salinity to bacterial guilds and organic carbon to predatory guilds. Saline soils exhibited stressed food webs, while non-saline soils showed structured, mature webs. Salinity significantly reduced nematode diversity and ecological functioning.

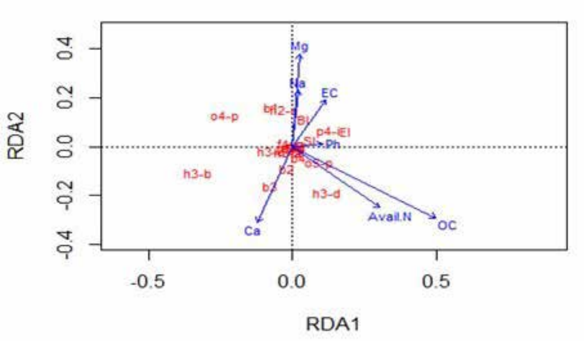


Fig. 6.11. Redundancy analysis (RDA) of soil factors, functional guilds, and ecological indices.

Conclusion

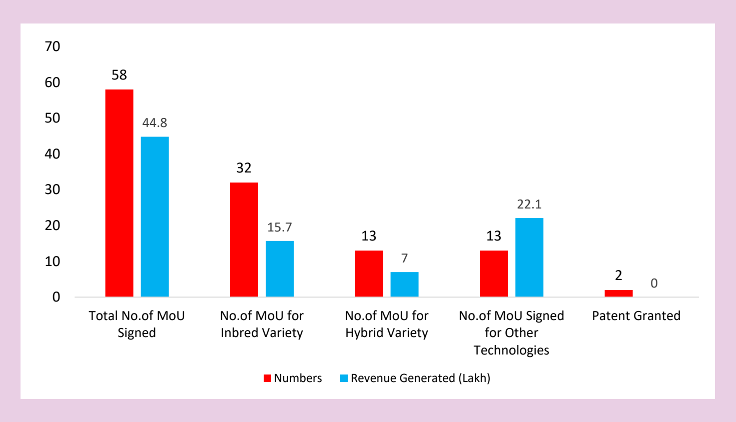
CRRI Research Stations situated at Hazaribag, Gerua and Naira have developed and validated several rice varieties suitable to improve the climate resilience of rice production. The comprehensive characterization and evaluation of rice germplasm under different stress conditions have identified promising landraces and breeding lines with significant tolerance to abiotic stresses such as drought, submergence, and cold, as well as biotic stresses like blast and brown spot. Advanced genomic tools, including GWAS and marker-assisted screening, have facilitated the identification of key genetic regions and genes associated with multiple stress tolerance. Varietal development efforts have resulted in the notification of climate-resilient rice varieties like CR Dhan 804 and CR Dhan 808, which exhibit superior performance under drought and other stress conditions. Studies on soil carbon dynamics and pathogen variability have further enriched the understanding of sustainable and resilient rice production systems. Collectively, these efforts contribute significantly to the development of resilient rice varieties and sustainable management practices for drought-prone, rainfed ecologies. RRLRRS, Gerua has produced breeder seeds of many HYV of rice suitable for the region and supplied to the seed chain of Assam state. Plant protection technologies evolved at the research station benefited the rice farmers in managing insect-pests and diseases of rice in rainfed ecologies. The research and extension activities undertaken through the Program has greatly supported this objective. The farming communities in the target ecologies along with the students have also been benefited through regular demonstrations, workshops and hands on training organized on various aspects of crop management.

PUBLICATIONS & PARTICIPATION IN SCIENTIFIC EVENTS

During the year 2024, the institute has published research, technology and extension materials which is shown by the below given figure.

Participation in Conference/ Workshop/ Exhibition/Kisan Mela/Radio & TV talks/ Media Coverages.

COMMERCIALIZATION OF ICAR-CRRI TECHNOLOGIES



ACTIVITIES AND EVENTS UNDERTAKEN

During the year 2024, ICAR-CRRI has organized several events and conducted diverse set of routine and extracurricular activity to comply with the council's vision and the Government of India programmes. The brief account of the undertaken events and activities are as follow-

A. Activities:

Activities	Distinguished participants
Research Advisory Committee (RAC) Meeting of ICAR-CRRI was held during 29-30 January 2024	Dr. T. Mohapatra, Chairperson, PPV&FRA, Govt. of India (C), Dr. Shashidhar H.E., Ex-professor, University of Agricultural Science, GKVK Campus, Bangalore; Dr. D.K. Sharma, Ex-Director, ICAR-CSSRI, Karnal; Dr. U.S. Singh, South Asia Advisor for Research & International Rice Research Institute (IRRI), Philippines; Dr. V. Chinnusamy, Joint-Director (Research), IARI, New Delhi; Dr. N.P. Singh, Member Commission for Agricultural Costs and Prices (CACP), Govt. of India; Dr. S.K. Pradhan, ADG (FFC), ICAR, New Delhi; Dr. A.K. Nayak, Director, ICAR-CRRI, Cuttack; Shri Pawan Kumar Sahu, Farmer Representative from Jharkhand; Shri Amareswar Mishra, Farmer Representative from Odisha and Dr. R.M. Sundaram, Director, IIRR, Hyderabad as special invitee; Dr. (Mrs.) Sanghamitra Samantaray, Head, Crop Improvement Division, CRRI, Cuttack (Member Secretary)
44th Institute Research Council (IRC), 14 to 17 May 2024	Dr. A.K. Nayak (C), Dr. B Mondal (S, IRC & I/c PME Cell), Head of Divisions and Scientists of the Institute and KVKs

36th Institute Management Committee (IMC) Meeting was held on 5 March 2024	Dr. A.K. Nayak (C)
The 25th Scientific Advisory Committee meeting of KVK, Cuttack, 4 October 2024	Dr. A.K. Nayak (C)

C: Chairman; M: Member; S: Secretary

B. Programmes and Events

Sl. No.	Events	Participants
1	ICAR-CRRI celebrated New Year Meet – 2024, 1 January 2024	200
2	Swachhata Pakhwada-2023	30
3	Senior Journalists – Scientists interaction Meet on 9 January 2024	50
4	Press Meet 17.01.2024	45
5	The Society for Agricultural Research & Management (SARM), Cuttack in collaboration with the ICAR-Central Rice Research Institute, Cuttack (CRRI) organized the 6th International Conference with a theme "Economic Development through Sustainable Agriculture Practices–Together We Make it Possible" from 19 to 21 January 2024	500
6	Dr. T.R. Sharma, DDG (Crop Science) visited the ICAR-CRRI, Cuttack on 19 January 2024 and interacted with the IARI-CRRI Hub students, inaugurated newly developed different units	400
7	23 January, 2024, on the occasion of the 127th birth anniversary of Netaji Subhas Chandra Bose (Parakram Diwas)	60
8	On January 26, 2024, the ICAR-Central Rice Research Institute (CRRI) observed the 75th Republic Day on its main campus	200
9	32nd Dr. Gopinath Sahu Memorial Lecture was organized on 13 February 2024	80
10	Kisan Mela-cum-Exhibition organized by ICAR-Central Rice Research Institute, Cuttack was held at Titrapanga village of Khajuripada Block, Kandhmal district on 21 February 2024 under Tribal Sub-plan	600
11	Secretary, DARE and DG, ICAR, Dr. Himanshu Pathak visited ICAR-CRRI-CRURRS, Hazaribag campus on 1 March 2024	50
12	International Women's Day on 8 March 2024	80
13	A confluence and interface of researchers, state departments and industry leaders was organized at ICAR-Central Rice Research Institute, Cuttack on 15th March, 2024 entitled as "SANGAM-2024"	400
14	A six-member delegate headed by Mrs. Neena Grewal, Project Director, UCRRFP, Watershed Management Directorate, Dehradun, Uttarakhand visited ICAR-CRRI, Cuttack on 19 March 2024	20
15	Dr. S. K. Chaudhari, Hon'ble Deputy Director General, Natural Resources Management (NRM), Indian Council of Agricultural Research (ICAR), New Delhi visited ICAR-CRRI, Cuttack on 23 March 2024	80
16	International Seed Expert, Dr. Hiqmet Demiri had a meeting and discussions with the Scientist of RRLRRS, Gerua on 10 April 2024	10
17	The first Board of Studies (BoS) Meeting of IARI-CRRI Cuttack Hub was held on 12 April 2024	50
18	The ICAR-Central Rice Research Institute, (CRRI) Cuttack celebrated its 79th Foundation Day and Dhan Diwas on 23rd April, 2024	200
19	Akshya Tritiya Celebration on 10 May 2024	50
20	A workshop on "Towards Renewable energy based technologies in rice based farming" was organized by ICAR-Central Rice Research Institute, Cuttack in collaboration with SELCO Foundation on 10 May 2024	60
21	ICAR-Central Rice Research Institute, Cuttack celebrated the International Day of Plant health (IDPH) on 12 May 2024 under the theme "Plant health, Safe Trade, and Digital Technology"	50
22	The one-month induction and orientation programme for newly recruited Technicians (T-1) of Crop Science and NRM commenced at ICAR-CRRI, Cuttack on 13 May 2024	80
23	Mission LiFE aligned with the theme of World Environment Day 2024 on 3 June 2024	60
24	One-day workshop and training on "An introduction of eddy covariance technique from theories to instruments and to data processing" on 7 June 2024	27

25	PM Kisan Utsav Diwas Celebration on 18 June 2024	400
26	ICAR-Central Rice Research Institute, Cuttack celebrated the 10th International Yoga Day (IYD) on 21 June 2024	30
27	A workshop on the prospects of conservation agriculture in India was jointly organized by the ICAR-CRRI, Cuttack on 10 July 2024	30
28	Dr. H. Pathak, Hon'ble Secretary, DARE, and Director General, ICAR, visited ICAR-CRRI, Cuttack on 13 July 2024	200
29	ICAR-CRRI, Cuttack, in collaboration with the Rotary Club of Cuttack District, organized a Farmer's Fair and Paddy Seed Distribution Programme under the SCSP programme on 13 July 2024	100
30	ICAR-Central Rice Research Institute, Cuttack is organizing a high end workshop on "GC-MSMS for quantification of pesticides and profiling of metabolites" during 22-31 July, 2024	30
31	Dr. Tilak Raj Sharma, Deputy Director General (Crop Science) visited Central Rainfed Upland Rice Research Station, Regional Station of ICAR-Central Rice Research Institute at Hazaribag, Jharkhand on 31 July 2024	50
32	CRRI Rice Varieties Dedicated to the Nation by Hon'ble Prime Minister on 11 August 2024 CR Dhan 108, CR Dhan 810, and CR Dhan 416	80
33	78th Independence Day was celebrated on 15th August 2024	100
34	19th Parthenium Awareness Week at ICAR-Central Rice Research Institute, Cuttack, was held from 16-22 August 2024	200
35	27th Meeting of ICAR Regional Committee-II was held on 23rd August 2024 at ICAR-Central Rice Research Institute, Cuttack	400
36	एक पेड़ मां के नाम: Plantation Drive on 29th August 2024	50
37	Launching of website for 3rd Indian Rice Congress 2024 at CRRI, Cuttack	30
38	Hindi Fortnight and Hindi Day Celebration on 13 September 2024 at ICAR-Central Rice Research Institute, Cuttack	60
39	Visit of Her Excellency Ambassador of Norway to India on 16 September 2024	55
40	ICAR-CRRI, Cuttack, organized the "Swachhata Hi Sewa-2024" campaign from September 15-26, 2024, focusing on the theme "Swabhav Swachhata - Sanskar Swachhata"	500
41	Visits of the Delegates from Gates Foundation and IRRI on 21 September 2024	20
42	A team of scientists from ICAR-CRRI, Cuttack conducted a comprehensive survey in six districts of Odisha on 24 September 2024	20
43	NASF-funded project, launching workshop "Developing Simulation Model of Technology Diffusion (TechSIM), Adoption, and Impact for Forecasting Using Techno-Socio-Psycho-Economic-Ecological Factors" was held at ICAR-CRRI, Cuttack from 30 September to 5 October 2024	200
44	Poshan Maah from 1-30 September 2024 at KVK, Koderma	50
45	The Student Induction Programme (SIP) for newly admitted students at IARI-CRRI Cuttack Hub titled Deeksharambh 2024 initiated on 15 October 2024	50
46	The ICAR-Central Rice Research Institute, Cuttack, demonstrated remarkable sportsmanship at the ICAR Inter Zonal Sports Tournament, hosted by CAZRI, Jodhpur, from October 14 to 17, 2024, a flag-handing-over programme on October 30, 2024	30
47	ICAR-CRRI, Cuttack observed Vigilance Awareness Week from 28th October to 3th November 2024 with the theme 'Culture of Integrity for Nation's Prosperity'	80
48	An awareness prorogramme on Popularization of BPH resistant varieties and Demonstration programme of Drone application in rice at Goudagop village in Mahanga block in Cuttack district, Odisha on 12 November 2024	100
49	ICAR-Central Rice Research Institute, Cuttack in association with Adarsha Prayas Foundation Trust organized Awareness and Demonstration Programme on Drone Application in Pest management in rice at Tunpur village of Salipur block in Cuttack district on 12 November 2024	100
50	The ICAR-Central Rice Research Institute (CRRI), Cuttack organized a Kisan Mela and Kisan Goshti on Organic Farming at the Kalawangpo Convention Hall in Tawang under its NEH program on 27 November 2024	300
51	The two-day Eastern Zone Scientist Meet and National Conference on "Holistic Approaches for Biotic and Abiotic Stress Management in Crops for Sustainable Agriculture" was organized by ICAR-CRRI-CRURRS and the Indian Phytopathological Society at ICAR-CRRI-CRURRS, Hazaribag, during 28-29 November 2024	200

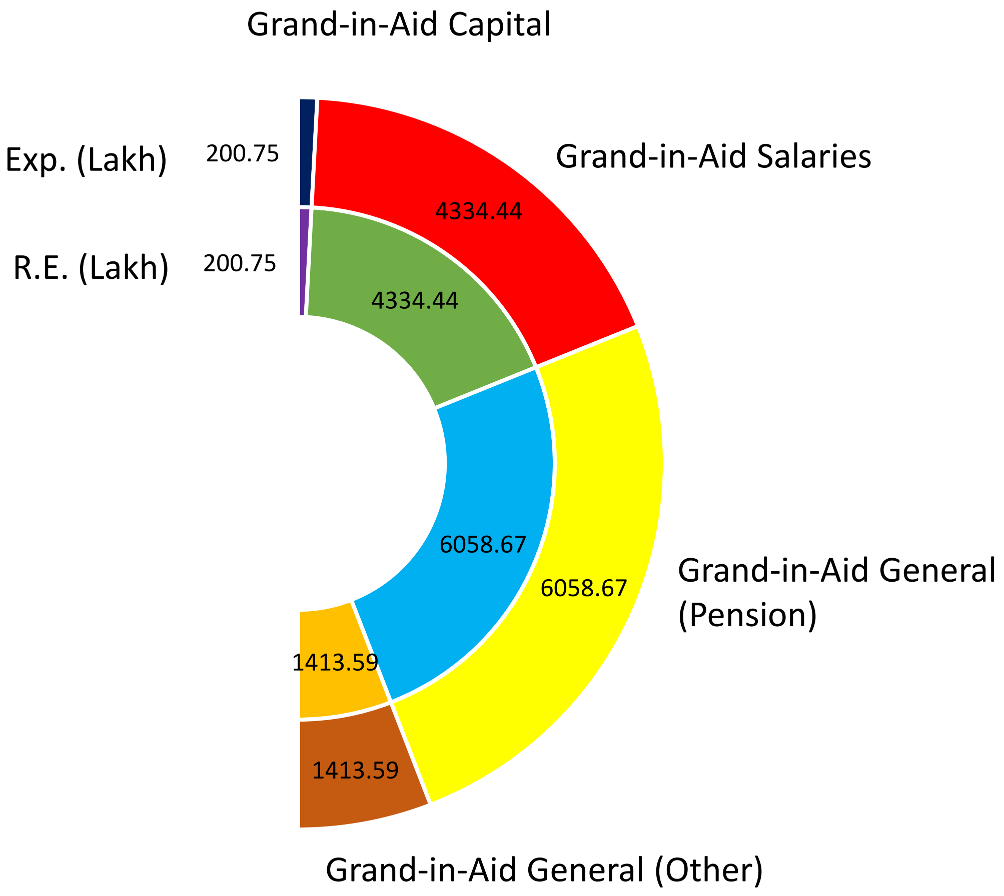
52	The 3rd Indian Rice Congress (IRC-2024) organized by the Association of Rice Research Workers (ARRW) at the ICAR-Central Rice Research Institute (CRRI), Cuttack, during 5-7 December 2024	400
53	33rd Dr. Gopinath Sahu Memorial Lecture was organized at ICAR-CRRI, Cuttack on 19 December 2024	60
54	A Regional Training Camp on Annual Survey of Unincorporated Services Enterprises (ASUSE) and Periodic Labour Force Survey (PLFS) was held from December 23 to 24, 2024, at ICAR-CRRI, Cuttack, organized by the National Statistics Office (Field Operation Division), Regional Office, Bhubaneswar, in collaboration with ICAR-CRRI, Cuttack	100
55	Swachhata Pakhwada-2024 organized at ICAR-Central Rice Research Institute, Cuttack from 16-31 December, 2024	200

AWARDS AND RECOGNITION

During the year 2024, ICAR-CRRI and its staff members have bagged several prestigious awards and recognitions. The details of the awards are given below.

1	Dr. A.K. Nayak was honoured with Lifetime Achievement Award 2024 by Pragati International Scientific Research Foundation, India
2	Dr. A.K. Nayak was honoured with Dr. MS Swaminathan Agriculture Excellence Award by Society for Agricultural Research & Management (SARM), Cuttack at Agri Vision-2024
3	Dr. S. Samantaray was honoured with prestigious Samanta Chandra Sekhar Award-2024 from Odisha.
4	Dr. S. Samantaray was selected as ISGPB Fellow, 2024 of The Indian Society of Genetics & Plant Breeding, New Delhi.
5	Dr. S. Samantaray was selected as Elected Member of Plant Tissue Culture Association at 45th Annual Meeting of Plant Tissue Culture Association (2024)
6	Dr. K. Chattopadhyay received ICAR-CRRI Best performer award under Principal Scientist category in 2024.
7	Dr. Kutubuddin Molla has been featured in the top 2% highly- cited scientists in Stanford/Elsevier Top 2% Scientists List 2024.
8	Dr. Kutubuddin Molla conferred the Prof. Sushil Kumar Innovation Award-2024 by the Flora and Fauna Science Foundation, Lucknow at CSIR-NBRI, Lucknow.
9	Dr. Pratap Bhattacharyya and Dr. P.Panneerselvam have been recognized as World top 2.0 % Scientist in the field of Agriculture by Stanford University (Year 2024).
10	Dr. Pratap Bhattacharyya and Dr. P.Panneerselvam have been recognized as World top 2.0 % Scientist in the field of Agriculture by Stanford University (Year 2024).
11	Dr. Basana Gowda received NAAS Associate in Plant Protection category during 2024.
12	Dr. Guru-Pirasanna-Pandi G awarded NASI Membership for the Year 2024
13	Dr. Guru-Pirasanna-Pandi G received Best Worker Award in Scientist Category during 79th CRRI Foundation Day on April 23, 2024
14	Dr. Koushik Chakraborty was elected as Zonal Secretary (East Zone) of the Indian Society for Plant Physiology (ISPP).
15	Dr Milan Kumar Lal was awarded the IPA-Kausalya Sikka Team Award from the Indian Potato Association, Shimla, for outstanding work in the area of abiotic stress and glycemic index.
16	Dr. S Bhagat, Principal Scientist and Dr. Amrita Banerjee, Senior Scientist are serving as Member of Executive Council, Indian Phytopathological Society, New Delhi.
17	Young Scientist Award-6
18	Fellow Award-5
19	Editor in Referred Journals-4
20	Best Poster Award-10

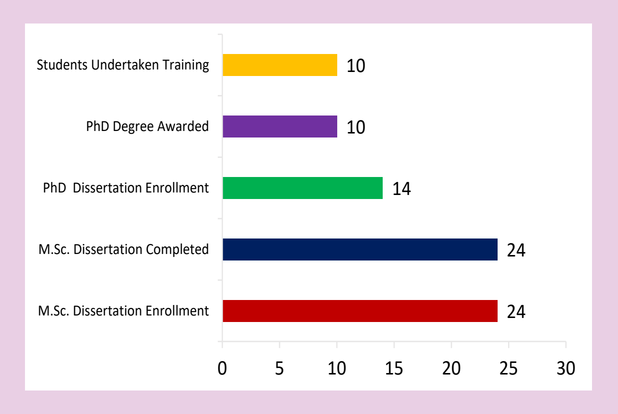
FINANCIAL STATEMENT (JANUARY-DECEMBER 2024)



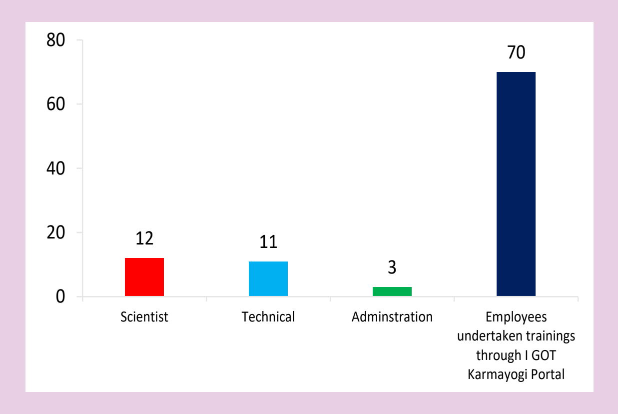
HUMAN RESOURCE DEVELOPMENT AND CAPACITY BUILDING

Human Resource Development (HRD) Cell of CRRI has been established to strengthen and facilitate the training and capacity building of the students/scientists/other staffs to work in the emerging areas of rice research and management. The financial targets and achievements of HRD cell of the institute is 11.15.

Achievements of the HRD programmes for the students during 2024



Physical targets and achievements of HRD Cell



EXTENSION/OUTREACH ACTIVITIES

To impart knowledge and develop skill to various groups of stakeholders, ICAR-CRRI, Cuttack had undertaken several extension activities during 2024 as detailed below:

Field demonstrations

Three hundred five demonstrations of newly released rice varieties and crop production as well as protection technologies in the farmers' field were conducted. About nine promising rice varieties were demonstrated with 305 farmers in about eight states of the country which include Uttar Pradesh, Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Maharashtra, Odisha, and West Bengal. The CRURRS, Hazaribag also conducted Front Line Demonstrations on drought tolerant rice variety IR 64 *Drt1* under ICAR-IRRI Collaborative project.

Exhibitions

The institute participated in 25 exhibitions at different locations of the country and promising technologies and significant milestones were showcased to the visitors in the exhibitions.

Visitor's advisory services

A total of 3672 visitors comprising of farmers & farm-women, students and agriculture officers from the states of Jharkhand, Karnataka, Odisha, Andhra Pradesh, Tamil Nadu, Telangana, Bihar, Assam, Uttar Pradesh, Madhya Pradesh, Maharashtra and West Bengal visited experimental sites and demonstration plots, net houses, agricultural implement workshop and *Oryza* museum of the institute and regional stations during the year.

Fortnightly agro-advisory services

Overall 26 agro-advisories on rice were issued on fortnightly basis in English as well as Odia language during the year 2024. The advisories were sent by e-mail to the officials of agriculture and related departments of the state as well as uploaded in Institute website for public awareness and reference. In addition, block wise weather forecast based agro-met advisory bulletins of Cuttack district were issued 4-5 times per month. Advisories were also issued through 'CRRI Video *Barta*' every fortnight and circulated through social media for wider reach.

Training programmes for farmers and extension professionals

A total of 7368 participants including farmers, extension officials, administrative personnel and others were trained through 169 programmes of different durations (2-8 days) conducted physically or through virtual mode on various aspects of rice production and protection technologies.

Mera Gaon Mera Gaurav (MGMG) Programme

A group of 4-5 scientists has been constituted for a cluster of five villages who provide technical backstopping, training, advisories, etc. There are 21 such multi-disciplinary teams working at 21 clusters of villages (comprising 5 villages each) covering eight districts of Odisha.

Tribal Sub-Plan (TSP) Programme

Tribal Sub-Plan (TSP) is operational in five districts Odisha (Kandhamal, Gajapati, Rayagada, Mayurbhanj and Koraput) and two districts of Jharkhand (Ranchi and Khunti) covering >1500 tribal households. The main objective of the programme is all-round development of the socio-economic status of tribal farmers and farm women. Through trainings, frontline demonstrations, supply of critical agricultural inputs and value addition of agricultural produce, farmers were made aware of latest technologies and varieties. Keeping in mind the harmony of progress and environment, the TSP-programme especially focused on nature-based solutions in agriculture.

Scheduled Caste Sub-Plan (SCSP) Programme

During the year 2023-2024, under SCSP programme villages in Odisha and West Bengal were covered to strengthen the local seed chain. A total 17 tonn of CRRI paddy seed were distributed in the different villages of Cuttack, Jagatsinghpur, Khurdha, Kendrapada and Cooch Behar districts covering a total 1900 beneficiaries in the *kharif* 2024. The varieties like Pooja, Sarala, Varsadhan, Gayatri, Savitri, Pradhan, CRDhan 800, Swarna sub1, CR1009 sub1, CR Dhan 312, CRDhan 316, Shatabdi, Minikit, Khitish, CRDhan 320, CR Dhan 321 and CD Dhan 602 were promoted in these districts. CRRI Bifertilizer of 1000 L was distributed to promote organic farming in these areas. Total 30 User Groups (UGs) were created (a group of farmers), twenty self-help groups (SHGs) were provided with solar thresher, power weeder, sewing machines and mini rice mills. A total number of 588 medium equipment/machinery like power weeder, solar thresher, mini rice mill, power thresher, sickles, spades, etc. were distributed to promote farm mechanization in these areas.

NEH Programme

Under the NEH Component, 1,000 kg of paddy seeds from CR Dhan varieties (307, 310, 311, 312, 317, 801, 802, 909) and local Joha and Bora rice were distributed to 686 farmers across multiple districts of Assam, including Kamrup, Nalbari, Barpeta, Baksa, Bongaigaon, Jorhat, Tinsukia, Darrang, Sonitpur, Lakhimpur, Dhemaji, Goalpara, and Karbi Anglong. Additionally, CR Dhan 310 seeds were supplied in Pasighat, Arunachal Pradesh, to promote the horizontal expansion of these varieties. To support rural livelihoods, 650 ducklings and 650 poultry chicks were provided to 136 farmers in Kamrup and Karbi Anglong districts. Furthermore, more than a thousand farmers across the Northeast received plant saplings of Assam lemon, arecanut, coconut, and black pepper, along with agricultural tools such as leaf color charts, spraying machines, garden tool kits, and irrigation hose pipes. Protective gear, including raincoats and tarpaulins, as well as infrastructure materials like vermibeds and shed nets, were also distributed to enhance farming practices in the region.

PERSONNEL (JANUARY-DECEMBER 2024)

Dr. Amaresh Kumar Nayak, Director

Emeritus Scientist - Dr. BC Patra

CROP IMPROVEMNENT DIVISION

Scientist								
S Samantaray (Head)	MK Kar	L Behera	LK Bose	K Chattopadhyay	SK Dash	J Meher	M Chakaraborti	JL Katara
RL Verma	RP Sah	BC Marndi	P Sanghamitra	K Ali Molla	S Sarkar	Parameswaran C	Devanna	Reshmi Raj K.R.
Anil Kumar C								
Technical Staff								
B Nayak	JS Anand	PL Dehury	LK Singh	N Barik	KC Mallik	B Mondal	B Mishra	D Nayak
D Samal	B Behera	A Parida	D Majhi	B Hembram	S Barik	B Ray	M Patra	S Sarkar
R Rana	B Sethi	KC Munda						
Administrative Staff								
Nil								
Skilled Support Staff								
J Biswal								

CROP PRODUCTION DIVISION

Scientist								
P Bhattacharya (Head)	A Poonam	P Panneer selvam	R Tripathi	S Mohanty	M Shahid	D Bhaduri	U Kumar	A Kumar
S Munda	D Chatterjee	PC Jena	NT Borkar	S Chaterjee	M Debanath	R Khanam	M Sivashankari	BR Goud
S Priyadarsani	K Kumari							
Technical Staff								
KK Suman	B Ghritalahre	JP Behura	B Das	AK Moharana	P Moharana	SK Ojha	P Behera	BC Behera
KC Palaur	PK Jena	R Jamunda	S Panda	PK Parida	SC Sahoo	SP Lenka	P Samantaray	EV Ramaiah
S Baskey	G Mandi	PK Ojha	D Parida	D Baral	D Behera	G Bihari	S Mohanty	CK Ojha
S Pradhan	R Beshra	SK Sethi	JK Sahu	S Kumar	KK Meena	SP Sahoo	TK Behera	AK Suman
A Choudhary								
Administrative Staff								
Nil								
Skilled Support Staff								
S Biswal	G Singh							

CROP PROTECTION DIVISION

Scientist								
SD Mohapatra (Head)	PC Rath	S Mondal	AK Mukherjee	MK Bag	S Lenka	T Adak	NKB Patil	Raghu S
Keerthana U	GP Pandi G	Basan Gowda G	Prabhu Karthikeyan SR	M Annamalai	G Prasanthi	Jeevan B	Rupak Jena	
Technical Staff								
PK Sahu	R Swain	EK Pradhan	H Pradhan	A Mohanty	S Biswal	AK Naik	MN Das	D Dash
JP Das	KC Barik	S Das	Md Shadab Akthar					
Administrative Staff								
Nil								
Skilled Support Staff								
D Naik								

CROP PHYSIOLOGY & BIOCHEMISTRY DIVISION

Scientist								
MJ Baig (Head)	K Chakraborty	TB Bagchi	A Kumar	N Basak	G Kumar	MK Lal		
Technical Staff								
C Tudu	J Bhoi	J Senapaty	S Banerjee	DB Sahoo	S Haldhar	S Kumar		
Administrative Staff								
Nil								
Skilled Support Staff								
G Sahoo	J Dei	N Naik						

SOCIAL SCIENCE DIVISION

Scientist								
GAK Kumar (Head)	B Mondal	NN Jambhulkar	Sudipta Paul	AK Pradhan				
Technical Staff								
B Behera	AK Parida	A Panda	MK Nayak	SK Sethi	SR Dalal	G Sinha	SK Rout	C Majhi
SK Mohapatra	A Anand	SK Tripathy	AK Panda	SK Roul	HS Sahoo			
Administrative Staff								
L Trivedi								
Skilled Support Staff								
Nil								

CRRI Research Station, Hazaribagh

Scientist								
NP Mandal (Head)	SM Prasad	S Bhagat	BC Verma	S Roy	A Banerjee	Priya Medha	Soumya Saha	Arun Kumar CG
Technical Staff								
S Oran	U Saw	J Kumar	J Prasad	S Akhtar				

Administrative Staff								
R Paswan	S Kumar	CR Dangi	AK Das	SK Pandey				
Skilled Support Staff								
Nil								

RRLRRS, Gerua, Assam

Scientist								
K Saikia (OIC)								
Technical Staff								
S Baruah	D Khan	TK Borah	B Kalita					
Administrative Staff								
J Das								
Skilled Support Staff								
M Das								

CRRI Research Station, Naira

Scientist								
BB Panda (Head)	Kiran Gandhi B	B Gayatri	Shyam CS	KK Rao				
Technical Staff								
RP Rao								
Administrative Staff								
RK Singh								

KVK, Santhpur

Scientist								
RK Mohanta (Head)								
Technical Staff								
S Sethy	DR Sarangi	TR Sahoo	R Kamboj	B Monika	P Pradhan	A Bisoi	K Pradhan	
Administrative Staff								
BB Polai								

KVK, Koderma

Scientist								
AK Rai (Head)								
Technical Staff								
C Kumari	B Singh	B Kumar	N Choudhary	D Ghosh	R Ranjan	M Kumar	S Kumar	BK Khuntia
Skilled Support Staff								
M Ram								

Administrative Section

Administrative Staff								
V Ganesh Kumar (SAO)	RK Singh (SFAO)	D Krishna R (AO)	SK Satapahy	CP Murmu	SK Behera	S Nayak	SK Sahu	RK Behera
RC Das	R Kido	NP Behura	SK Sahoo	M Mohanty	N Mahavoi	D Khuntia	N Jena	MB Swain
SP Sahoo	S Sahoo	SK Nayak	SK Lenka	SK Sahoo	M Das	RC Nayak	S Pradhan	A Sethi
R Sahoo	DK Parida	MK Sethi	KC Behera	PC Das	AK Pradhan	V Kumar	A Anand	S Jareda
R Gupta	R Yadav	D Muduli	SK Bhoi	H Marandi	S Maharana	AK Sinha	RPS Sabarwal	SK Patra
SK Das	J Bhoi	B Daspattanayak						
Technical Staff								
BK Mohanty	DS Acharya	SK Sinha	AK Nayak	PK Sahoo	KC Das	B Pradhan	S Mahapatra	R Behera
S Mishra	S Kumar							
Skilled Support Staff								
B Das	D Das	SR Das	G Singh	S Bhoi	R Soren	R Naik	B Naik	P Naik
B Naik	B Das	R Singh						

Under Training Technical Trainee

A Biswas	KA Masud	AK Maity	A Alam	M Kumar	H Kumar	PK Viswakarma	PM Meena	B Meena
N Singh	PK Mantri	S Roy	S Dawar	MK Raj	RK Meena	S Patwari	D Meena	RK Meena
B Bhukya								

INSTITUTE RESEARCH PROGRAMMES FOR THE YEAR 2024-25

Code No.	Title of the Projects	Programme Leader (PL), Principal Investigator (PI) and Co PIs
Programme 1: Genetic improvement of rice for enhancing yield, quality, and climate resilience		
1.1	Managing Rice genetic resources for sustainable utilization	P Sanghamitra, BC Marndi, S Samantaray, M Chakraborti, JL Katara, NN Jambhulkar, S Roy, Parameswaran C, Devanna, Anilkumar C
1.2	Maintenance Breeding and Genetic dissection of seed Quality Traits.	BC Marndi, RP Sah, Anil Kumar C, A Kumar, NKB Patil, Raghu S, Annamalai M, G Kumar, GAK Kumar
1.3	Pre-breeding for broadening the genetic base of rice by utilizing wild species of *Oryza*	MK Kar, LK Bose, M Chakraborti, S Samantaray, SK Dash, KA Molla, P Sanghamitra, JL Katara, Parameswaran C, Devanna, PC Rath, S Lenka, AK Mukherjee, GP Pandi G, S Sarkar, Priyamedha *Associates:* K Chakraborty, NP Mandal, A Kumar, N Basak, G Kumar, BC Marndi
1.4	Developing genetic solutions for enhancing input use efficiency in rice for rainfed and irrigated ecologies	J Meher, RP Sah, Reshmi Raj KR, C Parameswaran, LK Bose, SK Dash, P Panneerselvam, Prabhu Kartikeyan SR, D Chatterjee, Devanna
1.5	Breeding for Aroma and Grain Quality in Rice	S Sarkar, K Chattopadhyay, P Sanghamitra, SK Dash, M Chakraborti, MK Kar, S Roy, HN Subudhi, J Meher, N Basak, TB Bagchi, A Banerjee, Basana Gowda G, M Sivashankari and Reshmi Raj KR *Associates:* S Samantaray, DR Pani, AK Mukherjee, L Behera, T Adak and G Kumar
1.6	Gene mapping and precision breeding for enhancing climate resilience in lowland varieties	SK Dash, RP Sha, P Sanghamitra, Resmi Raj KR, GP Pandi G, SM Awaji and L Behera *Associates:* AK Mukherjee, MK Bag, PS Hanjagi, K Chakraborty, J Meher, LK Bose, S Lenka, Annamalai M

1.7	Genetic Enhancement for Multiple Stress Tolerance in Rice for Coastal Ecosystem	K Chattopadhyay, BC Marndi, K Chakraborty, LK Bose, A Poonam, KA Molla *Associates:* AK Nayak, AK Mukherjee, SD Mohapatra, Devanna
1.8	Hybrid rice for enhancing yield, quality and sustainability	RL Verma, JL Katara, Reshmi Raj KR, S Sarkar, S Samantaray, Parameswaran C, SK Dash, Devanna, Priyamedha, M Chakraborti *Associates:* AK Mukherjee, SD Mohapatra, BC Marndi, MK Kar
1.9	Development of New Generation Rice for enhancing yield potential in favourable ecology	LK Bose, SK Dash, MK Kar, J Meher, HN Subudhi, RP Sah, S Sarkar, L Behera, JL Katara, Parameswaran C, Devanna, Anilkumar C, RL Verma, S Roy, SD Mohapatra, A Banerjee, NN Jambhulkar, K Chakraborty *Associates:* N Mandal, AK Mukherjee, N Basak, S Lenka, M Chakraborti
1.10	Utilization of genome editing, transgenics and doubled haploid technologies for rice improvement	S Samantaray, Devanna, Parameswaran C, JL Katara, KA Molla, RL Verma, Anilkumar C, Reshmi Raj KR, A Kumar, SM Awaji *Associates:* S Lenka, Raghu S, Basana Gowda G
1.11	Development of Novel Genomic Resources for Rice Improvement	L Behera, Devanna, Parameswaran C, RP Sah, M Chakraborti, J Meher, Anilkumar C *Associates:* GP Pandi G, Raghu S, PS Hanjagi, A Kumar, SK Dash, MK Kar, HN Subudhi
Programme 2: Enhancing the productivity, sustainability and resilience of the rice-based system		
2.1	Enhancing nutrient use efficiency in rice through advance agronomy using smart sensors, models and nano fertilizers	S Mohanty, AK Nayak, R Tripathi, D Bhaduri, D Chatterjee, U Kumar, Anjani Kumar, BC Verma, R Khanam, Md. Shahid, B Raghavendra Goud, Shyam Shiddaiah
2.2	National level zonation of rice ecologies, site specific planning and development of cropping and farming system models	A Poonam, R Tripathy, D Chatterjee, N Jambhulkar, B Raghavendra Goud *Associates:* M. Nedunchezian (RC of CTCRI), G Acharya (CHES), SC Giri (RC of DPR), AK Nayak, S Saha, SM Prasad, Basana Gowda G, U Kumar, S Paul
2.3	Vulnerability analysis and assessment of climate smart agricultural technologies for enhancing resilience in stress prone rice ecologies	M Shahid, AK Nayak, R Khanam, D Chatterjee, S Mohanty, D Bhaduri, S Munda, R Tripathi, P Bhattacharyya, BB Panda, B Mondal, M Debnath and B Raghvendra Gouda
2.4	Developing agronomy for new generation rice and rice-based cropping systems	BB Panda, S Munda, Anjani Kumar, SK Dash, B Raghavendra Gouda and Shyam CS
2.5	Ecosystem services quantification and analysing the nexus of climate change-land use change-food security in rice production systems	R Tripathi, M Debnath, Supriya Priyadarsani, Md. Shahid, JP Bisen, B Mondal, BB Panda, S Mohanty, D Chatterjee, B Raghavendra Goud, D Bhaduri, P Bhattacharyya, AK Nayak
2.6	Environment friendly management of rice straw and value addition for income generation to rice-farmers.	P Bhattacharyya, AK Nayak, D Bhaduri, P Panneerselvam, S Munda, Supriya Priyadarsani, M Shivashankar, BC Verma *Associates:* T Adak, S Lenka
2.7	Harnessing microbiome for enhancing rice productivity and improving soil health.	P Panneerselvam, U Kumar, GP Pandi G, Parameswaran C, Anjani Kumar, AK Nayak
2.8	Development of weed management strategies and assessing the risk of herbicide resistance in rice weeds	S Munda, B Mondal, B Raghavendra Goud
2.9	Development and Refinement of Farm implements, Post-harvest and Value addition Technologies for small farm mechanization	Sivashankari M, PC Jena, M Debnath, Supriya Priyadarsani, A Kumar, TB Bagchi, R Khanam, G Kumar *Associates:* P Panneerselvam, S Sarkar
2.10	Enhancing water use efficiency in rice-based cropping system	Anjani Kumar, AK Nayak, R Tripathi, BB Panda, D Chatterjee, BC Verma, R Khanam, PS Hanjagi, M Debnath, B Raghavendra Goud, D Jena *Associates:* D Bhaduri, S Munda, S Mohanty, P Panneerselvam
Programm 3: Biotic Stress Management in Rice		
3.1	Identification and characterization of donors against biotic stresses	MK Bag, PC Rath, AK Mukherjee, SD Mohapatra, S Lenka, S Mandal, A Banerjee, Raghu S, GP Pandi G, Basana Gowda G, NBK Patil, Prabhukarthikeyan SR, Annamalai M, Keerthana U, P Golive, R Jena, B Gayatri *Associate:* MK Kar

3.2	Ecology, diversity and interaction of plant, pests & natural enemies in rice	Prashanti Golive, SD Mohapatra, Annamalai M, MS Baite, P Golive, MK Bag, G Kumar, Prabhukarithikeyan SR, B Gayatri, Kiran Gandhi B *Associates:* T Adak, Basana Gowda G, GP Pandi G, Keerthana U
3.3	Use of Precision Tools and Techniques in Rice Insect Pest and Disease Management	SD Mohapatra, R Tripathi, Raghu S *Associates:* NN Jambhulkar
3.4	Search for novel mediators in plant defense response to pathogenic infections in rice through molecular techniques	AK Mukherjee, S Mandal, Raghu S, GP Pandi G, Prabhukarthikeyan SR, KA Molla, P Golive, TB Bagchi, Devanna *Associates:* MK Kar, MK Bag, A Banerjee, Parameswaran C, K Chakraborty, T Adak
3.5	Plant protection molecules: efficacy, distribution, toxicity and remediation	T Adak, PC Rath, MK Bag, S Lenka, Prabhukarthikeyan SR, Annamalai M, Raghu S, Basana Gowda G, NBK Patil, GP Pandi G, U Kumar, R Jena, Jeevan B, Keerthana U *Associates:* AK Mukherjee, P Bhattacharyya
3.6	Dissemination of integrated pest management strategies for insect pest, diseases and nematodes in rice	Guru Pirasanna Pandi G, PC Rath, AK Mukherjee, S Mandal, S Lenka, SD Mohapatra, MK Bag, T Adak, Annamalai M, Prabhukarthikeyan SR, Raghu S, Basana Gowda G, NBK Patil, R Jena, Jeevan B, GAK Kumar, Keerthana U *Associates:* A Banerjee
Programm 4: Photosynthetic Enhancement, Abiotic Stress Tolerance and Grain Nutritional Quality in Rice		
4.1	Photosynthesis and productivity of rice under changing climate	MJ Baig, K. Chakraborty, N Basak, Gaurav Kumar, PS Hanjagi, SM Awaji
4.2	Evaluation of rice genotypes for new sources of multiple abiotic stress tolerance and understanding the underlying mechanism	K Chakraborty, MJ Baig, PS Hanjagi, SM Awaji, M Chakraborti, KA Molla, Anilkumar C *Associates:* K Chattopadhyay, A Kumar, BC Marndi, NP Mondal, S Roy
4.3	Characterization of rice genotypes for improved Physico-chemical and Nutritional properties	A Kumar, TB Bagchi, N Basak, G Kumar, RP Sah, Sivashankari M *Associates:* L Behera, S Sarkar, K Chattopadhyay
Programm 5: Research to enhance socio-economic wellbeing of rice stakeholders		
5.1	**R**eaching stakeholders to **E**nhance their socio-economic **CAP**acities (**RECAP**) through rice technologies	S Paul, GAK Kumar, B Mondal, NN Jambhulkar, JP Bisen, AK Pradhan, AK Mukherjee, S Lenka, Anjani Kumar, Supriya Priyadarsani, Sivashankari M, SM Prasad, K Saikia
5.2	Working to Increase farm Net Gain through Socioeconomic research (WINGS)	B Mondal, GAK Kumar, SK Mishra, NN Jambhulkar, S Paul, JP Bisen, AK Pradhan, SM Prasad, K Saikia *Associates:* MK Kar, S Saha, K Chattopadhyaya, SK Dash, S Sarkar, MK Bag, S Roy, BS Satapathy, RP Sah, Basana Gowda G
Programme 6: Development of climate resilient technologies for rainfed upland, rainfed low land and coastal rice ecology		
6.1	Development of resilient production technologies for rice under rainfed drought-prone agro-ecosystems	S Roy, NP Mandal, SM Prasad, S Bhagat, BC Verma, A Banerjee, Priyamedha, Soumya Saha, K Chakraborty, N Basak, L Behera, D Bhaduri
6.2	Rice production and productivity improvement in Rainfed lowland ecosystem	K Saikia
6.3	Development of Resilient technologies for Coastal Rice Ecology	Kiran Gandhi B, B Gayatri, Shyam CS, BB Panda *Associates:* MK Kar, K Chattopadhyay, BC Marndi, R Tripathi, Md Shahid

ONGOING EXTERNALLY AIDED PROJECTS (EAPS) 2024-25

Sl. No.	Project No.	Title of the Project	Source of Funding
1	EAP-27	Revolving fund scheme for seed production of upland rice varieties at CRURRS, Hazaribagh - NP Mandal, Priyamedha	AP Cess
2	EAP-49	Revolving fund scheme for breeder seed production - B C Marndi, RP Sah, Md. Azharudheen, Anil kumar	NSP/Mega seed ICAR
3	EAP-130	All India Network Project on Soil Biodiversity – Biofertilizers – B C Verma	ICAR
4	EAP-139	AICRP on energy in agriculture and agro-based industries - PC Jena Manish Debnath	AICRP (DRET-SET/ DRET-BCT) ICAR
5	EAP-140	Intellectual Property Management and Transfer/ commercialization of agricultural technology under National Agricultural Innovation Fund (NAIF) - GAK Kumar	ICAR
6	EAP-141	DUS Testing of Rice under Centrally sponsored scheme of PPV&FRA under "Sub-Mission on Seeds and Planting Material" - Reshmi Raj KR, Anilkumar C, P Sanghamitra	PPV&FRA
7	EAP-197	Consortia research platform (CRP) on bifortification - K Chattopadhyay, S Samantaray, TB Bagchi, M. Chakraborty, A Kumar, N Basak, LK Bose, A Poonam, S Sarkar, BC Marndi, D Bhaduri	ICAR Plan-CRP
8	EAP-198A	Incentivizing Coordinating Unit - M J Baig	ICAR
9	EAP-198B	Incentivizing Research in Agriculture: Study of rice yield under low light intensity using genomic approaches - L Behera, MJ Baig, A Kumar, SK Pradhan, S Samantaray, N Umakant	ICAR Plan
10	EAP-199	Incentivizing Research in Agriculture: Towards understanding the C3-C4 intermediate pathway in *Poaceae* and functionality of C4 genes in rice - MJ Baig, P Swain, L Behera, Gaurav Kumar, A Kumar, K Ali Molla	ICAR Plan
11	EAP-200	Incentivizing Research in Agriculture: Genetic modifications to improve biological nitrogen fixation for augmenting nitrogen needs of cereals- U Kumar, P Panneerselvam	ICAR Plan
12	EAP-201	Incentivizing Research in Agriculture: Molecular genetic analysis of resistance/tolerance to different stresses in rice, wheat, chickpea and mustard including sheath blight complex genomics - M K Kar, L Behera, A Mukherjee, Mathew Baite, NP Mandal, S Samantaray, Devanna, K A Molla, M Chakraborti, LK Bose	ICAR Plan
13	EAP-204	CRP on Agro-biodiversity: PGR Management and Use of Rice (Component I) - P Sanghamitra, BC Marndi, Raghu S	ICAR-NBPGR
14	EAP-207	Conservation agriculture for enhancing the productivity of rice based cropping system in Eastern India - S Munda, AK Nayak, R Tripathi, BB Panda, M Shahid, S Saha, SD Mohapatra, P Guru, R Khanam, B R Goud	CAP - ICAR
15	EAP-209	CRP on hybrid technology - RL Verma, JL Katara	CRP - ICAR
16	EAP-211	CRP on molecular breeding - M K Kar, L Behera, G P Pandi, A Mukherjee, M Chakraborti, P C Rath, LK Bose	CRP - ICAR
17	EAP-215	Agri-Business Incubation Centre - GAK Kumar, BB Panda, B Mondal, AK Mukherjee, PK Guru, J P Bisen, G P Pandi, N NJambhulkar	NAIF, IP&TM – ICAR
18	EAP-227	Creation of seed hub for increasing indigenous production of pulses in India - S Sethi, DR Sarangi, T R Sahoo, M Chourasia, RK Mohanta	DAC &FW
19	EAP-228	Increasing productivity and sustaining the rice-based production system through Farmer FIRST approach - B Mondal, SK Pradhan, S Saha, S Lenka, SD Mohapatra, BS Satapathy, R Tripathi, JP Bisen, NT Borkar, Supriya Priyadarsani, Lipi Das, GC Acharya, SC Giri, S Paul	ICAR-Farmer FIRST
20	EAP-245	Strategic research component of National Innovation in climate resilient agriculture (NICRA) - P Bhattacharyya, A K Nayak, K Chattopadhya, S Mohanty, D Chatterjee, K Chakraborty	ICAR Net work
21	EAP-260	Development of climate smart practices for climate resilient varieties - Anjani Kumar, H Pathak, A K Nayak, S Saha, B R Goud	IRRI
22	EAP-271	Harvest Plus Programme : Biofortification of rice - K Chattopadhyay, Awadhesh Kumar, P Sanghamitra, G Kumar, L K Bose	IFPRI & CIAT

23	EAP-272	Strengthening entrepreneurs in marketing and export of value added agricultural products by establishing a state of art quality assessment laboratory in Odisha- Sutapa Sarkar, N Basak, P Sanghamitra, T Adak, B Mondal, M Chakraborty, M J Baig, G Kumar, S Priyadarsani, Sivashankari M, T.B. Bagchi	RKVY-Odisha
24	EAP-283	Building climate resilience of Indian small holders through sustainable intensification and agro-ecological farming systems to strengthen food and nutritional security (RESILIENCE) - A K Nayak, BB Panda, SD Mohapatra, R Tripathy, MD Shahid, S Mohanty, S Priyadarshini, S Saha, H Pathak, DR Sarangi	Norwegian Institute of Bioeconomy Research (NIBIO), Norway
25	EAP-284	RKVY-RAFTAAR-Agribusinees incubation - G A K Kumar, A K Mukherjee, B B Panda, Narayan Borkar, M Sivashankari, B Mondal, Rameswar Saha, Sutapa Sarkar, G Prasanthi	RKVY
26	EAP-291	Attracting and Retaining Youth in Agriculture (ARYA) - R K Mohanta, S Sethy, D R Sarangi, T R Sahoo	ICAR
27	EAP-297	Exploration and utilization of endophyte diversity in wild rice for health management of rice crops - Rupalin Jena (A K Mukherjee)	DST Inspire
28	EAP-308	IRRI-ICAR collaborative Project- "Accelerating impact and equity"- Sivashankari. M	IRRI
29	EAP-310	Development of superior haplotype based near isogenic lines (Haplo- NILs) - L Behera, Devanna, Koushik Chakraborty G.P. Pandi, N Basak	DBT
30	EAP-312	Mainstreaming rice landraces diversity in varietal development through genome wide association studies: A model for large scale utilization of gene bank collections of rice - L Behera, J L Katara, B C Marndi, Devanna, Amrita Banerjee, Somnath Ray, Kaushik Chakraborti, Manas Bag, Prasant K S Hanjagi, Gourav Kumar, Aravindan S, Annamalai M, AK Mukherjee	DBT
31	EAP-316	Double haploid breeding in development of rice variety for enhancing resilience against biotic and abiotic stresses - S Samantaray, J L Katara, Parameswaran C, Devanna, R L Verma	BIRAC, India
32	EAP-321	Promotion of pheromone traps for managing fall army worm and related insect pests in various crops - SD Mohapatra (PI from 18.7.23), Korada Rajasekhara Rao (PI upto 17.07.23), M. Annamalai, T Adak, Gaurav Kumar, Bapatla Kiran Gandhi	RKVY
33	EAP-322	Global challenges research fund (GCRF) South Asian Nitrogen Hub (GCRF-SANH Project) - D Chatterjee, S Mohanty, J Meher, B Mondal, A K Nayak, Parameswaran C	GCRF
34	EAP-323	Value chain and nutritional research output: Fish for nutritional and health of women and children - G A K Kumar, Sujata Sethy, R Mahanta, J Pani, P K Sahoo	CGIAR (WorldFish-ICAR W3)
35	EAP-326	Accelerated genetic gain in rice (AGGRI- Alliance)- Irrigated rainfed (Drought, salinity & submergence) and DSR ecologies - S K Dash, N P Mandal, K Chattopadhyay, S Roy, R P Sah, LK Bose	IRRI
36	EAP-328	Creation of seed infrastructure facility (only for construction) - R L Verma	Government of India Ministry of Agriculture & Farmers Welfare
37	EAP-330	Formation and promotion of FPOs in Balasore - G A K Kumar, S K Das, B Mondal, R P Sah, Basana Gowda, A K Mukherjee, Asit Pradhan, S R Dalal, S Paul	NCDC
38	EAP-331	Study on chemical constituents of rice root modulating herbivory by the rice root knot nematode: a chemical ecology perspective - Totan Adak, Rupak Jena	DST
39	EAP-334	Generating C4 like PEPC enzyme in rice via precise genome editing - Sonali Panda (M J Baig)	DST Inspire
40	EAP-335	Exploring AUS rice for drought, submergence and phosphorus starvation tolerance: Mining superior alleles and deciphering mechanism of tolerance - S Roy, N P Mandal, A Banerjee, B C Verma, Koushik Chakraborty Padmini Swain, PS Hanjagi, D Bhaduri	NASF ICAR
41	EAP-337	Formation and promotion of FPOs in Odisha - GAK Kumar, S K Das, R P Sah, B Gowda, A K Mukherjee, A Pradhan, S Dalal, Ankit Anand, S Sethi, S K Rout, B K Jha, S M Prasad, S Paul	Govt. of India (SFAC)
42	EAP-339	Ph.D Dissertation work - Priya Das (M J Baig)	DBT JRF
43	EAP-340	Targeting serotonin and senescence pathways for enhancing brown plant hopper resistance and yield in rice - Bijayalaxmi Sahoo (Parameswaran C)	DST Inspire fellowship
44	EAP-343 (Merger of EAP-36 and EAP-100)	AICRIP on Seed (Crops) - B C Marandi, Anil Kumar, A K Mukherjee, NKB Patil, RP Sah, Md. Azharudheen, Raghu S, Annamalai M	ICAR

45	EAP-344	Development of Steel slag based cost-effective eco friendly fertilizers for sustainable agriculutre and inclusive growth - M Shahid, A K Nayak, Rubina Khanum	Ministry of Steel
46	EAP-350	Biological Nitrification Inhibition (BNI) in Rice: A novel approach to enhance Nitrogen use efficiency vis a vis reducing denitrification N-loss, U Kumar	ICAR (LalBahadurShastri Award)
47	EAP-351	Identification of rice cultivars with low As concentration in grain through As specific study and developing management practices to mitigate As contamination - M Shahid	ICAR (Lal Bahadur Shastri Award)
48	EAP-352	Decrypting the chemical interaction of rice and its specialist herbivore, *Scirpophaga incertulas* - Totan Adak, B Gowda	SERB, DST
49	EAP-353	Network programme on precision agriculture (NePPA) - R Tripathy, A K Nayak, S Mohanty, S D Mohapatra, S R Raghu, B R Goud	ICAR
50	EAP-354	Development of azadirachtin based zinc-oxide nano-formulation for sustainable management of brown plant hopper and other key pest of rice in Odisha - G P Pandi G, T Adak, Raghu S	DST, Odisha
51	EAP-355	Improvement of aromatic indica rice cultivars for bacterial blight disease resistance through marker assisted doubled haploid breeding - Prakash Singh, S Samantaray	SERB-Tare, DST
52	EAP-356	Understanding the effect of aerobic adaptation loci on yield of drought tolerant rainfed shallow lowland cultivar rice using genome editing tool - Parameswaran, Devanna, Sushma M Awaji, P Hanjagi	SERB
53	EAP-357	Identification of genomic region(s) for 21 days submergence tolerance in rice using sequence based trait mapping approach - J L Katara, S Samantray, Parameswaran	SERB
54	EAP-359	Enhancing resilience of smallholders to climate change through sustainable intensification and digital driven knowledge dissemination (E- CHASI) - A K Nayak, S Mohanty, R Tripathi, S D Mohapatra, B S Satpathy, B Mondal, D Maiti, U Kumar, Anjani Kumar, Raghu S, PC Jena, PP Panneerselvam, PS Hanjagi	OIIPCRA, Deptt. Of Water Govt. of Odisha
55	EAP-360	Biodegradable nanofibre encapsulated bio-fertilizer to enhance phosphorus and other micronutrient uptake in rice - P Panneerselvam	DBT
56	EAP-361	National mission mode program on nutritional improvement of digestible protein content and quality in rice - K Chattopadhyay, S Sarkar, TB Bagchi	DBT
57	EAP- 362	Identification and characterization of low starch digestibility rice based on types of resistant starch and cooking quality - Awadhesh Kumar	SERB, DST
58	EAP-364	Improving vegetative stage drought tolerance by integrating Genomic selection, GWAS and QTL mapping in rice - J L Katara	SERB, DST
59	EAP-365	Nanoherbicide: A controlled release formulation to improve rice production - Totan Adak, S Munda	DST
60	EAP-366	Transformative strategy for controlling rice disease in developing countries – Devanna, M Chakraborti (PI in absence of Dr. Devanna), K A Molla, A K Mukherjee	BMGF (collaborative project with Heinrich Heine University, Germany)
61	EAP-367	Development of bacterial blight and sheath blight resistant rice plants through CRISPR/ Cas mediated genome editing of host susceptibility gene - S Karmakar, M J Baig	NPDF, DST
62	EAP-368	Comparative Assessment of Aldor as an Alternative to Urea on Rice growth, Yield, Nitrogen use efficiency and Soil Health - Mohammad Shahid, A. K. Nayak	Sirius Minerals India Pvt Ltd (SMIPL)
63	EAP-369	Popularization of BPH resistant rice variety for uplifting the Odisha rice farmers' income - Guru-Pirasanna-Pandi G, PC Rath,. B Gowda, T Adak, GAK Kumar, Annamalai M Raghu S, MK Kar, N Patil, Parameshwaran, SK Mishra, R Sah, LK Bose	RKVY, Govt. of Odisha
64	EAP-371	AICRIP (Rainfed) - S Samantaray, K. Chattopadhyay, SK Dash, M. Chakraborti, A. Kumar, S. Saha, AK Mukherjee, GP Padhi, Md. Shahid, K. Chakraborty, N. Jambulkar, A. Pradhan, N Basak	ICAR
65	EAP-372	Development of haploid inducer rice lines using CRISPR/ Cas9 gene editing system for high induction frequency - S Samantaray, Devanna, Parameswaran, J L Katara	DBT
66	EAP-373	Sub Mission on agricultural mechanization for implementation of its component No.1 under drone technology demonstration - Basana Gowda Asit Kumar Pradhan (study leave)	DAC
67	EAP-374	Allele mining for the epigenetic regulator NGR5 and other yield associated gene (GRF4) and their modulation using multiple genomic and molecular approaches to enhance rice yield under low nitrogen conditions - Kutubuddun Molla, M J Baig	NASF ICAR

68	EAP-377	Quantitative assessment of soil quality, yield sustainability and grain quality of rice in Eastern India: A unified triangular approach - Debarati Bhaduri	DST-SERB
69	EAP-379	Deciphering and deploying low phosphorus tolerance and nitrogen use efficiency in rice - J Meher, Parameswaran, D Chatterjee	NASF ICAR
70	EAP-380	Blue carbon sequestration and climate change mitigation by managing mangrove-soil-algae system in coastal wetland - Sujit Kumar Nayak, P Bhattacharya	DST-Inspire
71	EAP-381	CRISPR Crop Network: Targeted improvement of stress tolerance, nutritional quality and yield of crops by using genome editing - Parameswaran C, S Samantray, Awadesh Kumar, Kutubuddin Ali Molla, Prabhukarthikeyan SR, Sushma M Awaji, P Hanjagi	NASF ICAR
72	EAP-382	Identification and characterization of fungal effectors and host factors in rice- false smut pathosystem - Devanna, S Samantray (PI in absence of Devanna), M Bag	NASF ICAR
73	EAP-383	Improvement of stress adaptive traits in crops using endophytes under different agroecology - Prashantkumar S. Hanjagi	NICRA ICAR
74	EAP-384	Studying the Effect of Adopting Regenerative Agriculture Practices on Smallholder Farmer Livelihoods - A.K. Nayak, Rahul Tripathi	J-PAL
75	EAP-385	Evaluation of Dammu: Propargite 50% + Bifenthrin 5% SE for bio-efficacy (against Lepidopteran, Hemipteran and Mite pests), phytotoxic effect and impact on natural enemies in coastal rice ecosystem - Kiran Gandhi B	Indofil Industries
76	EAP-387	Computer vision for plant phonemics and smart agriculture" - Rahul Tripathi, S.K. Dash, Prashant Kumar Hanjagi, P. Swain, Sushma M Awaji	IIT, Jodhpur
77	EAP-388	Phyto-toxicity evaluation of Dinetofuran 15% + Pymetrozine 45% WG and Iprobenfos 48% EC on rice crop - Guru-Pirasanna-Pandi G, B Gowda, T Adak, PC Rath	PI Industries Pvt. Ltd.
78	EAP-389	Establishment of hybrid rice seed system and state of art for genetic purity testing in Odisha - RL Verma, JL Katara, S Samantaray, BC Patra, GAK Kumar, AK Mukherjee, U Kumar	RKVY
79	EAP-390	Outscaling of Natural Farming through KVKs - Dillip Ranjan Sarangi, Sujata Sethy, Tusar Ranjan Sahoo, R.K. Mohanta	ICAR
80	EAP-391	4S4R Model for production, marketing and export of Odisha aromatic rice - GAK Kumar, BC Patra, B Mondol, T Adak, S Sarkar, M Chakraborti, S Priyadarshini, S K Dash, S Sethy, JP Bisen, Asit Pradhan	RKVY
81	EAP-392	Improving rice genetics and its ecosystem through genome engineering and bioagents to reduce dependency on chemical N_2 fertilizer - KA Molla, MJ Baig, AK Mukherjee, T Adak, J Meher	Ignite Life Science Foundation
82	EAP-393	Scaling of Natural Farming through KVKs (Kodarma) - Chanchilla Kumari, S Shekhar, B Singh, M Kumar, R Kumar	ICAR
83	EAP-394	Evaluating efficacy of Nano- DAP with respect to P and N nutrition and yield of rice" - Sangita Mohanty	Indian Farmers Fertilizer Cooperative Limited (IFFCO)
84	EAP-396	Engineered mesoporous silica nanoparticle-biochar complex for decontamination of phosphate and glyphosate in water - S Munda	DST
85	EAP-397	Impact of farm mechanization in reduction of cost of cultivation - B Mondal, JP Bisen	Directorate of Agril. & Food Production, Govt. of Odisha
86	EAP-399	Common Laboratory Services at ICAR-CRRI - P Bhattachatyya, T Adak	Service Providing Project
87	EAP-400	Genome editing of rice targeting submergence and reproductive stage salinity tolerance for yield enhancement in coastal ecology - Swetapadma Sahu, S Samantray	INSPIRE DST
88	EAP-401	Transfer of bacterial leaf blight and sheath blight resistant gene(s) / QTL(s) into popular rice variety 'Maudamani' through marker assisted breeding. - Sushree Sangeeta, SK Pradhan, L Behera	INSPIRE DST
89	EAP-402	Assessing the water productivity, GHG emission, yield and economics of rice based cropping systems under transplanted and direct seeded rice - Anjani Kumar, AK Nayak, S Mohanty, B Raghavendra Goud	IRRI
90	EAP-403	Tackling emerging diseases and insect-pest problems in rice through innovative genomic approaches - Amrita Banerjee, NP Mandal, S Roy, Priya Medha, M K Bag	DBT
91	EAP-404	Developing precision nitrogen management protocols for rice using remote sensing and geospatial tools (LBS Award- 2021) - Rahul Tripathy	ICAR

92	EAP-405	Deciphering the role of OsSnRK (Sucrose nonfermenting-1 [SNF1] related kinase) gene family as a potential master regulator governing multiple abiotic stress tolerance in rice - Koushik Chakraborty	ICAR
93	EAP-406	Identification and quantification of different volatiles emitted by Trichoderma and utilization of identified isolates/volatiles for plant growth promotion and soil borne pathogen management - Totan Adak, Arup Kumar Mukherjee	BRNS, BARC
94	EAP-407	Ecosystem, Agribusiness and Institutions Component I: Impact assessment of Agricultural technology - Biswajit Mondal (PI), J P Bisen (PI up to 15.12.2023), Sudipta Paul and Mridul Chakraborti	ICAR-NIAP
95	EAP-408	Demonstration ,capacity building and Up-scaling of Integrated Farming Systems for Livelihood Security of Small and Marginal Farmers in Rainfed Ecosystem of Jharkhand' - SM Prasad, Soumya Saha, Scientist (Agronomy), Bibhash Chandra Verma, Sr.Scientist (Soil Science), Someshwar Bhagat, Pr.Scientist (Plant Pathology), Chanchila Kumari, Sientist (Home Science)& Head(A),KVK,Koderma, Sudhanshu Shekhar, Scientist (Veterinary Science) KVK, Koderma, Bhoopendra Singh ,Scientist (Horticulture),R K Singh,Sr.Scientist (Extn.Edn.)& Head(A), KVK,Chatra and V P Rai Scientist(Animal Science), KVK,Chatra.	RKVY, Jharkhand
96	EAP-409	Strengthening the entrepreneurship in the production, promotion and marketing of biocontrol agents in the rainfed ecosystem of Jharkhand - Dr. Someshwar Bhagat, Co-PIs : (CRURRS): Dr. Amrita Banerjee, Dr. BC Verma, Dr. SM Prasad and Dr. NP Mandal) and CCPIs [Dr. Sushma Saroj Surin – KVK Lohardaga, (BAU), Dr. Arti Beena Ekka – KVK, East Singhbhum (BAU), Dr. Raghav Kumar – KVK, Ramgarh (ICAR RC ER Patna) & Dr. Rajesh Kumar – KVK, Ranchi (Ramkrishna Mission)	RKVY, Jharkhand
97	EAP-410	Sulphur enriched bio-nanoformulation of methanotrophs for greenhouse gas emission, mitigation and sustains production in rice - Monalisha Rath, Pratap Bhattacharyya	BPRF (Govt. of Odisha)
98	EAP-411	Economic and Environment-Friendly Utilization of Basic-slag and Fly Ash as Soil Amendments to Reclaim Acid Soils of Odisha - Pratap Bhattacharyya, Rubina Khanam, Debarati Bhaduri, Mohammad Shahid, G A K Kumar, Amaresh Kumar Nayak	Department of Agriculture and Farmers' Empowerment (DAFE), Government of Odisha
99	EAP-412	Development of liquid formulation of Halotolerant Plant Growth Promoting Rhizobacteria (H-PGPR) Consortia to alleviate salt stress for sustainable rice production in saline coastal soil - U Kumar, G Rastogi (Collaborator- Co- PI), P Panneerselvam, A K Nayak, K Chakroborty, A Poonam, Mahesh Dharne (Collaborator- Co- PI)	DST, Odisha
100	EAP-413	Bio-efficacy of PIX-20002 20% SC and PII 070 70% WG against insect pest of rice and their natural enemies through drone and conventional spraying - Guru Pirasanna Pandi G, Basana Gowda, Totan Adak	PI Industries Pvt. Ltd.
101	EAP-414	Development of jute bags for protection and quality presentation of stored seeds - SD Mohapatra, NKB Patil	NTTM, Govt. of India
102	EAP-415	Atlas of climate adaptation in South Asian Agriculture (ACASA) - Rahul Tripathy, Manish Debnath, NN Jambhulkar	BISA
103	EAP-416	Production, popularization and supply of quality bioinoculants for rice based cropping and farming system of Odisha - Upendra Kumar, P Panneerselvam, GAK Kumar, B Mandol, A K Mukherjee, Annie Poonam, Md. Shahid, D Chatterjee, S Paul, RL Verma, A K Nayak	DAFE, Govt. of Odisha
104	EAP-417	Development and refinement of sensor and AI based tools for enhancing water use efficiency - Anjani Kumar, AK Nayak	Fine trap India
105	EAP-418	Map-based cloning and functional characterization of Pi-42; a novel blast resistance gene from rice genotype 'DHR-9' – Devanna, Parameswaran C, Rajeev Rathour	DST-SERB
106	EAP-419	AICRIP on Bio control - M Annamalai, Prabhukarthikeyan	ICAR
107	EAP-420	Enhancing climate resilience and ensuring food security with genome editing tools - Parameswaran C	ICAR
108	EAP-421	Development of host differentials, pathotyping and identification of genomic regions for bakanae disease resistance in rice - Raghu S	DST-SERB
109	EAP-422	Bio-Nano formulation of methanotrophs for decarbonisation, disease resistance and sustaining productivity in rice-oilseed cropping system - P Bhattacharya	NASF

110	EAP-423	Development, standardization and optimization of microbial and botanical pesticides and their formulations as efficient delivery systems for management of agricultural, stored grain pests, nematodes and ticks parasites - T Adak, NB Patil	NASF
111	EAP-424	Deciphering master regulators governing tolerance to multiple abiotic stresses in rice - K Chakraborty, K Chattopadhyay, K A Molla	SERB-CRG
112	EAP-425	Deciphering the resistance mechanism through leaf volatiles and wax components in rice against bacterial leaf blight disease - AK Mukherjee, T Adak	DST-SERB
113	EAP-426	Integrated direct seeded rice systems for India - BB Panda, J Meher, PC Jena, AK Nayak	IRRI
114	EAP-427	Redevelopment and evaluation of soil revitalizer in rice - Upendra Kumar	Add-X Biotech Pvt Ltd.
115	EAP-428	Ploidy manipulation for developing abiotic stress tolerant neo-tetraploid rice and enhancing wide hybridization efficiency - M Chakraborti	DST-SERB
116	EAP-429	Mainstreaming traditional aromatic quality rice varieties of Jharkhand: Evaluation, conservation and popularization through Farmer Producer Organizations - Somnath Roy, N.P. Mandal, S. Bhagat,. S.M. Prasad,. A. Banerjee,. B.C. Verma, Priyamedha, Sutapa Sarkar, Soumya Saha, Arunkumara C.G., S.B. Chaudhary	RKVY-Jharkhand
117	EAP-430	Popularization of High Yielding Climate-Resilient Rice Cultivars in Aspirational Districts of Jharkhand and Feedback based Genetic Improvement - Priyamedha, N.P. Mandal Somnath Roy, S.M. Prasad, B.C. Verma, Soumya Saha, S. Bhagat, A. Banerjee, Arun kumara C.G. , Chanchila Kumari, Sudhansu Sekhar, RK Singh	RKVY-Jharkhand
118	EAP-431	Establishment of state-of-art biocontrol laboratory for the management of insect-pests in Jharkhand - Arun Kumara C.G., N.P. Mandal, S.M. Prasad, S. Bhagat, Somnath Roy, A. Banerjee, B.C. Verma, Priyamedha,, Soumya Saha	RKVY-Jharkhand
119	EAP-432	Evaluating the bio efficacy and phytotoxicity of Trifloxystrobin 100g/l + Tebuconazole 200g /l SC against dirty panicle and false smut - Raghu S, Basana Gowda G, SD Mohapatra	Bayer Crop Science Ltd.
120	EAP-433	Establishment of advanced soil health laboratory for sustainable agriculture in Jharkhand - Bibhash Chandra Verma, Soumya Saha Shiv Mangal Prasad, Amrita Banerjee, Somnath Roy, Priyamedha Someshwar Bhagat, N P Mandal Arunkumar C.G, A.K.Rai. Sudhanshu Sekhar	RKVY-Jharkhand
121	EAP-434	Evaluating performance of Nano-urea derivative with respect to yield and nitrogen uptake in rice - Sangita Mohanty, AK Nayak	Invati Creations Pvt. Ltd., Kolkata
122	EAP-435	Developing simulation models of technology diffusion (TechSIM), adoption and impact for forecasting using techno-socio-psycho-economic- ecological factors - GAK Kumar	NASF
123	EAP-436	Functional characterization of CAx1C/ NCX5 (Sodium- Potassium Exchanger) gene regulating relative water content under vegetative stage drought stress in rice - Rashmirekha Sahoo, LJ Katara	INSPIRE DST
124	EAP-437	Establishment of Mushroom Spawn Production Unit and Training Centre for Transfer of Technology to Stakeholder and Farmers of Koderma District" - Chanchila Kumari	RKVY-Jharkhand
125	EAP-438	Strengthening KVK Koderma Infrastructure for Creating knowledge hub for Livelihood Security of Small and Marginal Farmers under Rainfed situation of Koderma District (Jharkhand) - Ajay Kumar Rai	RKVY-Jharkhand
126	EAP-439	Quality nursery raising through poly-tunnel & pro tray technology for the weaker section farmers of the Koderma district in Jharkhand. - Bhoopendra Singh	RKVY-Jharkhand

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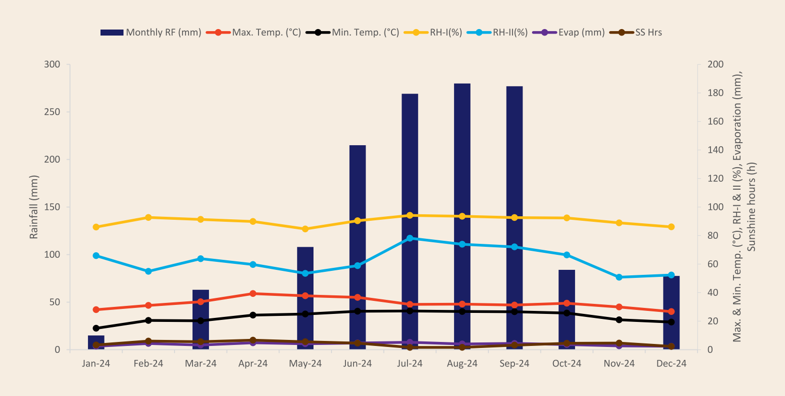

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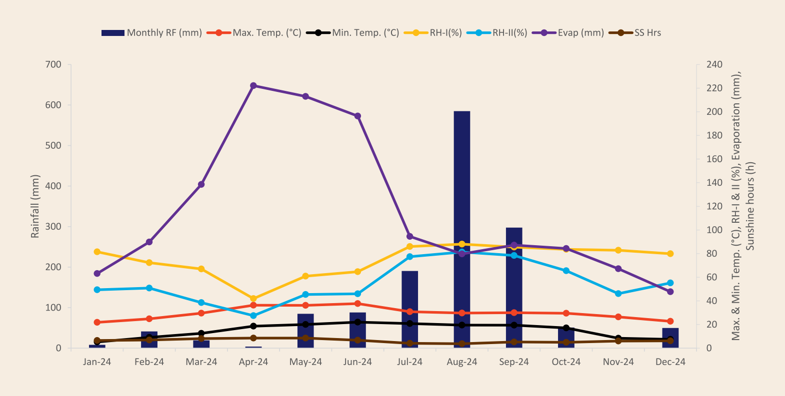

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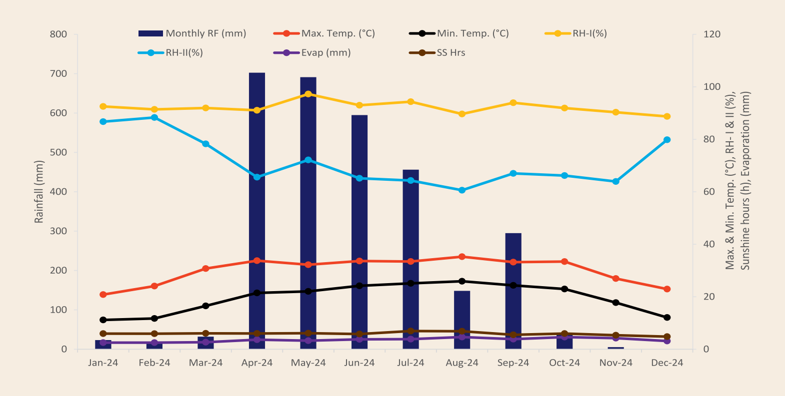

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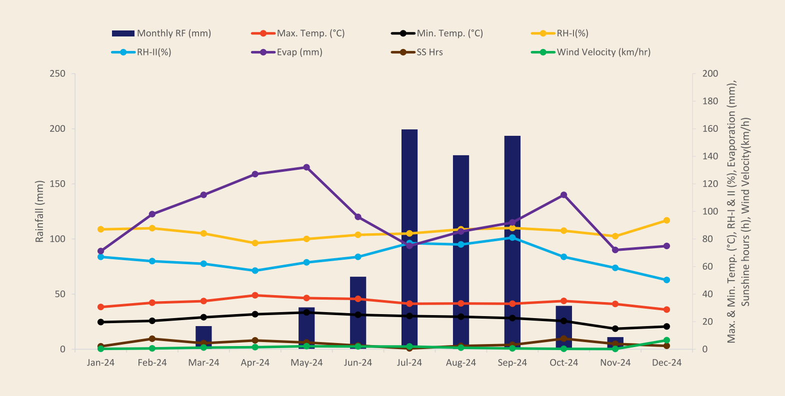

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