ANNUAL REPORT 2021

Azadi Ka Amrit Mahotsav

भाकृअनुप-राष्ट्रीय चावल अनुसंधान संस्थान

ICAR-NATIONAL RICE RESEARCH INSTITUTE

AN ISO 9001:2015 CERTIFIED INSTITUTE

ANNUAL REPORT 2021

NRRI

वार्षिक प्रतिवेदन
Annual Report
2021

भाकृअनुप - राष्ट्रीय चावल अनुसंधान संस्थान
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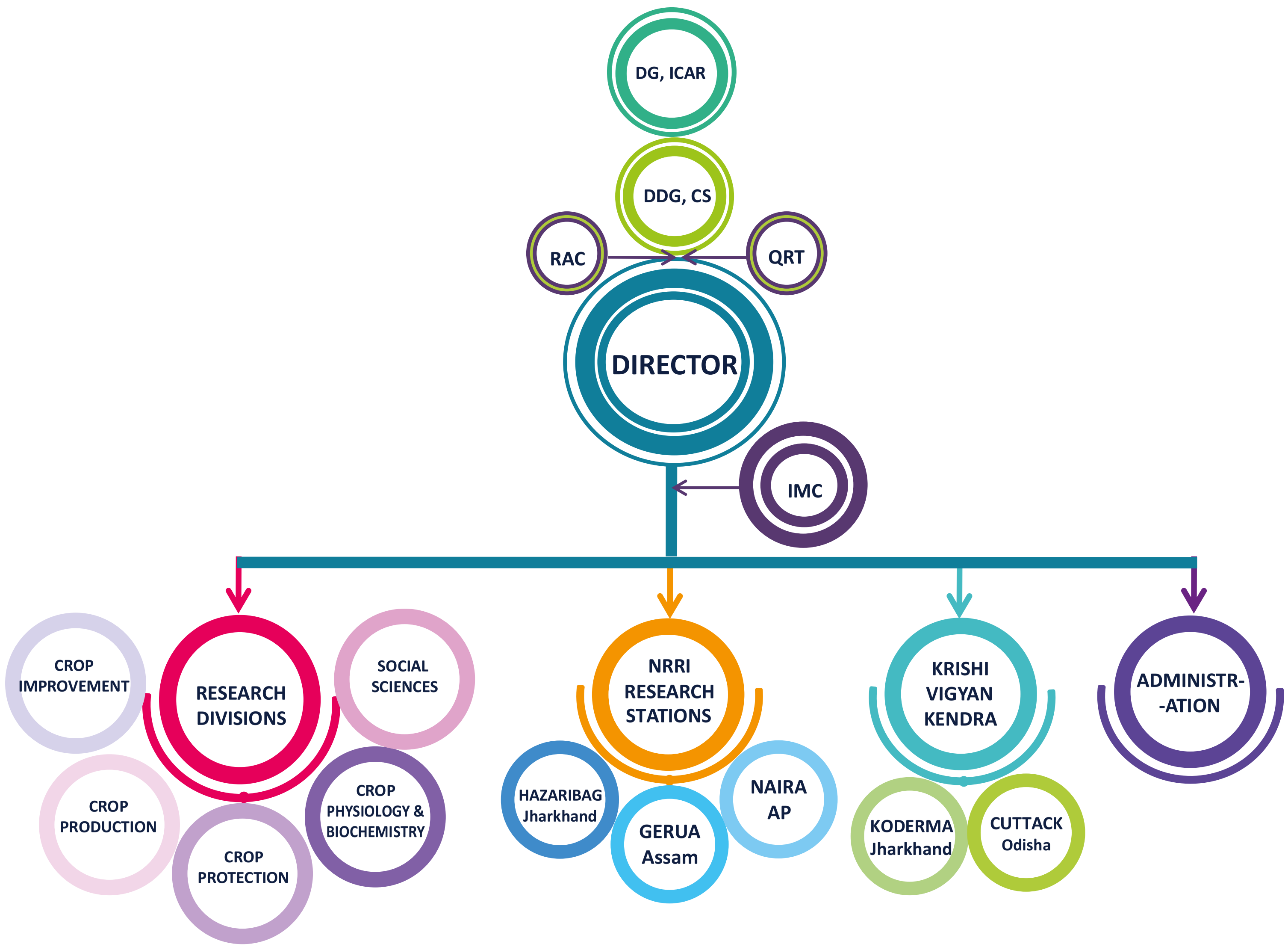
CONTENTS

ORGANOGRAM



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PREFACE

The role of ICAR-National Rice Research Institute (NRRI) in boosting the overall rural economy in the pandemic-hit year of 2021 is evident with an all-time record food grains' production of 316 million tons in the Country during 2021-22 crop year with a rice production of 127.9 million tons. ICAR-NRRI started its journey 75 years ago with the back drop of Bengal famine. During its long journey, the institute significantly contributed to famous Green Revolution and helped make India self-sufficient in food grain production. The institute is working with different rice stakeholders in India and abroad. The institute addresses all Sustainable Development Goals (SDGs) through its current research programmes and activities having multi-dimensional approaches benefitting the stakeholders of India as well as the world. In its 75 years of journey, the institute has released 154 high yielding rice varieties including five hybrids.

In spite of COVID 19 pandemic during the year 2021, the institute kept its journey in achieving new heights. The institute has developed twelve high yielding varieties, out of which three were released and notified by CVRC and nine by SVRC for cultivation in farmers' field. During the year, the institute was granted two patents those are Solar based "Alternate Energy Light Trap (AELT) with patent No. 357993 and "A Multi-use composition for bio control of plant pathogen infestation, and growth enhancement" with patent No. 383679. The institute has registered ten unique rice germplasm with National Bureau of Plant Genetic Resources (NBPGR), New Delhi and nine rice varieties with Protection of Plant Varieties & Farmers' Rights Authority (PPV & FRA), New Delhi. During the year, the Institute worked on 35 research projects under seven research programmes, 130 externally-aided projects and one flagship project. The salient outputs of the projects are presented in the executive summary and details are presented under various programmes in the report.

During the year, the Institute hosted ARRW Diamond Jubilee National Symposium on "Gen-next Technologies for Enhancing Productivity, Profitability and Resilience of Rice Farming" (Organized by the Association of Rice Research Workers) through virtual mode. The Institute celebrated its Platinum Jubilee Year 2020-21 and also Platinum Jubilee Foundation Day on 23rd April 2021. On this occasion, a 500-seating capacity multifacility MKCG Platinum Jubilee Auditorium was inaugurated.

The Institute sincerely acknowledges the guidance and encouragements received from Dr. T. Mohapatra, Secretary, DARE and Director General, ICAR for carrying out various research and development programmes. Sincere thanks are due to Shri Sanjay Singh and Shri Sanjay Garg, Special Secretaries, DARE and Secretaries, ICAR; Shri Sanjeev Kumar, Additional Secretary, DARE and Financial Advisors, ICAR for their continuous support and guidance. Valuable suggestions, encouragement and support received from Dr. SK Sopory, Chairman and other esteemed members of Research Advisory Committee (RAC); Dr. TR Sharma, DDG (Crop Sciences), ICAR; esteemed members of Institute Management Committee and Institute Research Council (IRC) are sincerely acknowledged. Thanks are also due to Dr. DK Yadav, ADG (Seeds), Dr. RK Singh, ADG (CC & FFC), Dr. YP Singh, ADG (FFC) and other officials of the Council for their constant support and guidance.

I sincerely thank the Heads of the Divisions, Officers In-Charges of Regional Stations, Administration & Finance sections of the Institute for their whole-hearted support and dedication in carrying out the activities of the Institute. My sincere thanks are due to the Members of Publication Committee and Publication Unit for compiling and editing the Annual Report. I sincerely appreciate the efforts and commitment of all the staff to serve this premier Institute. I hope that the Annual Report will be useful for the researchers, policy makers, development functionaries, farmers, farmwomen and students in promoting rice research and development.

(Padmini Swain)
Director

EXECUTIVE SUMMARY

The 'Programme-1' aims to develop novel rice varieties, hybrids and other technologies to increase yield and nutritional quality, mitigate various biotic and abiotic stresses in rice to enhance socio-economic condition of the rice stakeholders. During the year 2021, twelve rice varieties including two hybrids were released and notified. A total of 2158 accessions of rice germplasm / elite lines / donors/ varieties were supplied to researchers from which 167 accessions were shared with different institutes/organizations throughout the country. As part of seed production, 57.91q nucleus seed of 91 varieties, and 427.64 q breeder seed of 56 varieties were produced during 2020-21. Besides, 34 QTLs for desirable traits were mapped and several donors for salinity, submergence, yield and dual stigma exsertion were identified. Using Doubled Haploid (DH) technology, genomic regions associated with drought tolerance at vegetative stage were identified. Also, morphological indicators for discrimination of DHs and haploids were developed. The developed androgenic protocol was successfully used in sugarcane for production of green regenerants with variable ploids. Utilization of *CRISPR/ Cas9* technology could enhance 23% spikelets per panicle in genome edited lines of Swarna.

The 'Programme-2' focuses on developing, validating and disseminating innovative cutting edge technologies to enhance productivity, ensure sustainability and improve resilience of rice based production system. Android based real time N application app "riceNxpert" was evaluated *vis-à-vis* SPAD meter and Customized Leaf Colour Chart (CLCC) and showed the potential of improving N recovery efficiency by 8-14%. Methodology for loading nano-clay-polymer composites (NCPC) with low molecular weight organic acids and P was standardized. The NCPC loaded with diammonium phosphate (DAP) and citric acid (CA) acted as a smart delivery system, which slowed down the P release compared to raw DAP. A simplified and farmers friendly tensiometer was developed and irrigation scheduling based on this tensiometer observed to mitigate methane emission by 51% and global warming potential by 21%. The NRRI – ARM (Aerobic Rice Moisture) sensor for real time soil moisture monitoring in rice fields was developed, which has potential to save irrigation water input by nearly 41%. Mass production of *Azotobacter chroococcum* Avi2, phosphate solubilizing bacteria (*Ensifer adhaerens* PSB 14) and exopolysaccharides producing bacteria (*Bacillus* spp. EPS-1) was standardized using Jensen's (JM), Pikovaskaya's (PM) and M1 (MM) media. Application of *Trichoderma* NRRI formulation @ 10 g kg^{-1} of seeds as seed treatment enhanced yield of CR Dhan 314 by 13.1 %. Agroecological intensification of rice-maize cropping system by introducing direct seeded rice of CR Dhan 314 followed by maize + groundnut resulted in higher system productivity as compared to rice - maize + cowpea cropping system and sole rice-maize cropping system. Study on effect of crop geometry and spacing on submergence tolerance of tolerant and susceptible cultivars indicated that hexagonal arrangement and wider spacing (20 x 15 cm) enabled better tolerance against the submergence stress. Land use and land cover change analysis for six coastal districts in Odisha (Balasore, Bhadrak, Kendrapada, Jagatsinghpur, Puri and Ganjam) at 5-year intervals since 1990 to 2018 indicated a steady decline in agricultural area dominated by rice-based cropping systems.

The 'Programme-3' includes applied as well as basic research aiming to develop integrated management system for rice pest and diseases. As a result, the division got two patents during 2021, one on development of 'Alternate Energy Light Trap (Patent No. 357993)' and another for 'A multi-use composition for biocontrol of plant pathogen infestation, and growth enhancement (Patent No. 383679)'. Division also made database on WBPH, brown spot disease and root knot nematode and all these are available in NRRI website. During 2021, around 550 germplasm including NRRI varieties and 700 AICRIP entries were screened for identification of resistant donors. Agro-ecological zone-based diversity study of false smut pathogen from north, east and north-eastern Indian states revealed three distinct groups of isolates. Different spectral bands were detected for elucidating yellow stem borer damage in rice through hyperspectral remote sensing techniques and a mobile app namely, 'Rice Pest Lab' was developed. Significant progresses were achieved in research of plant protection molecules that included identification of efficacious combination insecticides (Chlorantraniliprole + Cartap hydrochloride + Triflumezopyrim) for stem borer and leaf folder and fungicide (Difenoconazole 25EC) for controlling sheath blight pathogen and baseline sensitivity analysis study revealed that LD_{50} value of 88% false smut pathogen population of eastern and north-eastern India are highly sensitive to 0.05 ppm propiconazole. Method was standardised to find out residual toxicity of pesticides in rice grains and residue dynamics of Triflumezopyrim and its toxicity against *Nilaparvata lugens*. A viable dissemination strategy for IPM in farmer's fields under shallow lowland ecosystem was identified and validated.

Programme-4 focuses on rice grain quality, abiotic stress tolerance and improving photosynthetic efficiency. Towards achieving superior rice having C_3-C_4 intermediate pathway, rice transgenic (cv. Naveen) lines were developed by over-expression of *SiPPDK,* which showed increased plant height and per plant yield by 59.22% over wild type plants. Early and mid-early rice cultivars tend to respond more under elevated CO_2 conditions with increased yield, photosynthetic rate and harvest index (HI). Two genotypes, HT-20 (AC-34975) and HT-18 (AC-34973) were found to be heat tolerant by phenotyping a set of diverse rice genotypes using a novel approach of Tolerance at Cellular Level (TCL). Out of 68 genotypes, 11 were found to be tolerant to both vegetative stage drought and submergence stress and one genotype IC-516149 was identified to possess high anaerobic germination potential as well. Out of 40 *O. nivara* accessions, two salt-tolerant lines were identified, which showed a salt-susceptibility score of 3-5. Besides, five unique rice germplasm were registered as stress tolerant accessions. The parboiling process was found to improve the cooking quality of rice grains and reduced the glycaemic index (GI) and glycaemic load (GL) of brown and milled rice. Cooking rice in excess water was found to reduce the level of total antioxidants and total soluble sugar content significantly in pigmented and non- pigmented rice. Rice bran cake was developed as a novel value-added product having higher antioxidant activity (DPPH) than the cakes available in markets. Increased activities of glutamine synthetase and glutamine-oxoglutarate aminotransferase at flowering stage was found to be associated with high grain protein content.

Under Programme-5, two models INSPIRE – 1.0 (INnovative extension model for fast SPread of varieties In Rice Ecosystems) and INSPIRE – 2.0 were developed and validated for rapid dissemination of recent technologies to the end users and provided feedback to the technologists. During 2021, on-farm demonstrations of 28 rice varieties were conducted in 355 farmer's fields covering about 205-acre area in 19 districts of nine states and INSPIRE 2.0 covered three districts of Odisha using 11 rice varieties and 130 participating farmers, and grain yield advantage of about 10-20 per cent over local check was noticed. About 17 rice varieties have been identified for estimating economic contribution of NRRI rice varieties through economic surplus approach and 11 varieties were chosen to evaluate them through willingness-to-pay (WTP) by farmers for premium seed varieties and consumers for specialty rice. Estimation of growth trend in domestic consumption of rice in India showed a four-fold increase, though no definite growth pattern was observed. In quest for nexus between rice consumption, population and GDP of the country, it was noticed that domestic consumption of rice move more with the population growth and less likely to relate with the GDP of the country. Since last one decade, rice export from India flourished well, and during the year 2020-21, export of Non-Basmati rice remarkably enhanced and earned more foreign exchequer than the Basmati rice.

Programme-6 targets to develop stress tolerant varieties, and improved integrated crop production and protection packages for the small and marginal farmers of rainfed drought-prone environments. During 2021, CR Dhan 320 (IET 27914) was released in CVRC for irrigated areas in the states of Jharkhand, Bihar and West Bengal (yield of 5.35 t ha^{-1}). Four traits-specific genetic stocks, INGR 21114, INGR 21177, INGR 21178, and INGR 21179 were registered under PGRC, ICAR for drought and multiple abiotic stress tolerance. In total 516 accessions were characterized and promising entries such as IC 0640862, IC 0640865, IC 0640869, IC0640873, IC0640879 and IC0640880 were identified for multiple stress tolerance. Sixty diverse rice germplasm of eastern India were evaluated for reproductive stage drought tolerance using *QTL*-linked markers and presence of *DTY QTLs* was predicted in a considerable number of genotypes. Developed and standardized recombinase polymerase amplification assay-based detection of *BADH2* and false smut in rice. Demonstrated the effectiveness of integrated nutrient management options in rice based cropping system. Improved management options [RDF (N in three splits) + application of Zn as $ZnSO_4$ (25 kg ha^{-1})] provided significant improvement in grain yield under drought-prone shallow lowland. It focused on developing resilient technologies for coastal rice ecology, survey was conducted in three coastal districts of Andhra Pradesh and the insect pest incidence in rice crop (*var.* MTU 1061) was recorded.

The focus is also on genetic improvement and management of rice for rainfed lowland. During 2021, 766 accessions of rice germplasm were maintained and recorded data on days to 50% flowering, plant height, number of effective tillers and grain yield. Efficacy of fungicide against rice bakanae disease was tested and observed that spraying of propiconazole at the rate of 2 ml l^{-1} of water at 15 days after transplanting recorded the lowest incidence of bakanae disease and recorded higher yield. Crop transplanted in first fortnight of February recorded lowest incidence of rice stem borer (0.76%) and highest yield as compared to late planting.

कार्यकारी सारांश

चावल की फसल से जुड़े हितधारकों की सामाजिक–आर्थिक स्थिति में सुधार हेतु चावल की उपज और पोषण की गुणवत्ता बढ़ाने, चावल में विभिन्न जैविक और अजैविक तनावों को कम करने, चावल की नई किस्मों, संकर किस्मों और अन्य प्रौद्योगिकियां विकसित करने पर 'कार्यक्रम–1' की कार्यकलापें केंद्रित है। वर्ष 2021 के दौरान, दो संकर सहित चावल की बारह किस्में विमोचित एवं अधिसूचित की गईं। शोधकर्ताओं को चावल के जननद्रव्य/श्रेष्ठ/दाताओं/किस्मों के कुल 2158 प्रविष्टियों की आपूर्ति की गई, जिसमें से 167 प्रविष्टियां पूरे देश में विभिन्न संस्थानों/संगठनों को वितरित किए गए। वर्ष 2020–21 के दौरान बीज उत्पादन के रूप में, 91 किस्मों के 57.91 क्विंटल नाभिक बीज और 56 किस्मों के 427.64 क्विंटल प्रजनक बीजों का उत्पादन किया गया। इसके अलावा, वांछित लक्षणों के लिए 34 क्यूटीएल की मैपिंग की गई और लवणता, जलमग्नता उपज और दोहरे स्टीग्मा एक्सजर्सन के लिए कई दाताओं की पहचान की गई। दोहरी अगुणित तकनीक का उपयोग करते हुए वानस्पतिक स्तर पर सूखा सहिष्णुता से जुड़े जीनोमिक क्षेत्रों की पहचान की गई। इसके अलावा, दोहरी अगुणित और हाप्लाइड के भेदों के लिए रूपात्मक संकेतक विकसित किए गए। विकसित एंड्रोजेनिक प्रोटोकॉल का गन्ने में परिवर्तनशील प्लोइड के साथ हरे रंग के पुनर्योजी के उत्पादन के लिए सफलतापूर्वक उपयोग किया गया। *CRISPR/ Cas9* तकनीक के उपयोग से स्वर्णा की जीनोम संपादित वंशों में प्रति बाली 23% स्पाइकलेट बढ़ सकते हैं।

'कार्यक्रम–2' की कार्यकलापें उत्पादकता बढ़ाने, स्थिरता सुनिश्चित करने और चावल आधारित उत्पादन प्रणाली के अनुकूलनीयता में सुधार के लिए नवीन अत्याधुनिक तकनीकों के विकास, सत्यापन और प्रसार पर केंद्रित है। एंड्रॉइड आधारित डिजिटल रीयल टाइम नाइट्रोजन एप्लिकेशन ऐप ''राइसएनएक्सपर्ट'' का मूल्यांकन एसपीएडी मीटर और कस्टमाइज्ड लीफ कलर चार्ट (सीएलसीसी) की तुलना में किया गया और नाइट्रोजन की प्राप्ति दक्षता में 8–14% तक सुधार करने की क्षमता देखी गई। कम आणविक भार वाले कार्बनिक अम्लों और फॉस्फोरस के साथ नैनो–क्ले–पॉलीमर कंपोजिट लोड करने की पद्धति को मानकीकृत किया गया। डायमोनियम फॉस्फेट और साइट्रिक एसिड से भरी एनसीपीसी ने एक स्मार्ट डिलीवरी सिस्टम के रूप में काम किया जिसने कच्चे डायमोनियम फॉस्फेट की तुलना में फॉस्फोरस विमोचन को धीमा कर दिया। एक सरल और किसान अनुकूल टेन्सियोमीटर विकसित किया गया और इस टेन्सियोमीटर के आधार पर सिंचाई की सूची का अपनाने से देखा गया कि मीथेन उत्सर्जन में 51% और वैश्विक ताप क्षमता में 21% तक कम हुआहै। एनआरआरआई–एआरएम (एरोबिक चावल नमी) सेंसर चावल के खेतों में वास्तविक समय में मिट्टी की नमी की निगरानी के लिए विकसित किया गया जिसमें लगभग 41% तक सिंचाई जल प्रयोग बचाने की क्षमता है। जेन्सेन (जेएम), पिकोवास्काया (पीएम) और एम1 (एमएम) मीडिया का उपयोग करके *एजोटोबैक्टर क्रोकोकम* एवी2, फॉस्फेट घुलनशील बैक्टीरिया (*एन्सिफेराडेरेन्स* पीएसबी 14) और एक्सोपॉलीसेकेराइड पैदा करने वाले बैक्टीरिया (*बैसिलस* एसपीपी ईपीएस–1) के बड़े पैमाने पर उत्पादन को मानकीकृत किया गया। ट्राइकोडर्मा एनआरआरआई सूत्रीकरण 10 ग्राम/किलोग्राम बीज दर से उपचार करने से सीआर धान 314 की उपज में 13.1% की वृद्धि हुई। चावल–मक्का फसल प्रणाली के तहत सीआर धान 314 के सीधी बुआई चावल की खेती के बाद मक्का+मूंगफली से चावल–मक्का+लोबिया फसल प्रणाली और एकल चावल–मक्का फसल प्रणाली की तुलना में उच्च उत्पादकता मिली। सहिष्णु और ग्राह्यशील किस्मों की जलमग्न सष्णुिशीलता की फसल ज्यामिति और दूरी के प्रभाव पर अध्ययन से पता चला कि हेक्सागोनल व्यवस्था और अधिक दूरी (20 X 15 सेमी) ने जलमग्न तनाव के विरुद्व बेहतर सहिष्णुता प्राप्त हुआ। ओडिशा में छह तटीय जिलों बालेश्वर, भद्रक, केंद्रापड़ा, जगतसिंहपुर, पुरी और गंजाम में वर्ष 1990 से 2018 तक 5 साल के अंतराल पर भूमि उपयोग और भूमि क्षेत्र परिवर्तन विश्लेषण से पता चला कि चावल आधारित फसल प्रणालियों के प्रभुत्व वाले कृषि क्षेत्र में लगातार गिरावट हुई है।

'कार्यक्रम–3' की कार्यकलापें चावल फसल की कीटों और रोगों के लिए एकीकृत प्रबंधन प्रणाली विकसित करने के उद्देश्य से प्रायोगिक एवं मौलिक अनुसंधान पर केंद्रित है। परिणामस्वरूप, प्रभाग को 2021 के दौरान दो पेटेंट, एक 'वैकल्पिक ऊर्जा प्रकाश जाल (पेटेंट संख्या 357993) और दूसरा 'पौधा रोगजनक संक्रमण के जैव नियंत्रण के लिए एक बहु–उपयोग संरचना और वृद्धि (पेटेंट संख्या 383679) विकास करने पर प्राप्त हुए। प्रभाग ने सफेदपीठवाला पौध माहू, भूरा पौध माहू, भूरा धब्बा रोग और जड़गांठ सूत्रकृमि पर डेटाबेस भी बनाया और ये सभी एनआरआरआई वेबसाइट पर उपलब्ध हैं। वर्ष 2021 के दौरान प्रतिरोधी दाताओं की पहचान के लिए एनआरआरआई किस्मों और 700 एआईसीआरआईपी प्रविष्टियों सहित लगभग 550 जननद्रव्यों का परीक्षण की गई। उत्तर, पूर्व और उत्तर–पूर्वी भारतीय राज्यों के आभासी कंड रोगजनकों के कृषि–पारिस्थितिक क्षेत्र–आधारित विविधता अध्ययन से वियुक्तों के तीन अलग–अलग समूहों की पहचान हुई। हाइपरस्पेक्ट्रल रिमोट सेंसिंग तकनीकों के माध्यम से चावल में पीला तना छेदक क्षति को स्पष्ट करने के लिए विभिन्न वर्णक्रमीय बैंड का पता लगाया गया और 'राइस पेस्ट लैब' नामक एक मोबाइल ऐप विकसित किया गया। पादप संरक्षण अणुओं के अनुसंधान में महत्वपूर्ण प्रगति हासिल की गई जिसमें तना छेदक और पत्ता मोड़क के लिए (क्लोरेंट्रानिलिप्रोल+करताप हाइड्रोक्लोराइड+ट्राइफ्लुमेजोप्रिरिम) और आच्छद अंगमारी रोगजनक को नियंत्रित करने के लिए कवकनाशी (डिफेनोकोनाजोल 25ईसी) प्रभावोत्पादक कीटनौंाक मिश्रण की पहचान की गई तथा बेसलाइन संवेदनशीलता विश्लेषण अध्ययन से पता चला कि पूर्वी और उत्तर–पूर्वी भारत की 88% आभासी कंड रोगजनक संख्या का एलडी$_{50}$ मान 0.05 पीपीएम प्रोपिकोनाजोल के प्रति अत्यधिक संवेदनशील है। चावल के दानों में कीटनाशकों की अवशिष्ट विषाक्तता और ट्राइफ्लुमेजोपाइरिम के अवशेषों की गतिशीलता और *नीलपर्वत लुगेंस* के विरुद्व इसकी विषाक्तता का

पता लगाने के लिए विधि का मानकीकरण किया गया। उथले निचलीभूमि पारितंत्र के तहत किसान के खेतों में आईपीएम के लिए एक व्यवहार्य प्रचार रणनीति की पहचान की गई और उसे मान्य किया गया।

कार्यक्रम–4 की कार्यकलापें चावल दाना की गुणवत्ता, अजैविक तनाव सहिष्णुता और प्रकाश संश्लेषक दक्षता में सुधार पर केंद्रित है। C_3-C_4 मध्यवर्ती मार्ग वाले बेहतर चावल प्राप्त करने के लिए, *SiPPDK* के अतिप्रकटीकरण द्वारा चावल ट्रांसजेनिक (नवीन) वंश विकसित की गई जो जंगली प्रकार के पौधों की तुलना में पौधे की ऊंचाई और प्रति पौधे की उपज में 59.22% वृद्धि हुई। शीघ्र और मध्य–शीघ्र चावल की किस्में अधिक उपज, प्रकाश संश्लेषक दर और फसल सूचकांक सहित बढ़ी हुई कार्बन डायक्साइड स्थितियों के तहत अधिक प्रतिक्रिया देती हैं। दो जीनप्ररूप, एचटी–20 (एसी–34975) और एचटी–18 (एसी–34973) को सेल्युलर स्तर पर सहिष्णुता के एक नए उपाय का उपयोग करते हुए विभिन्न चावल जीनप्ररूप के एक सेट को फेनोटाइपिंग करके ताप सहिष्णु पाया गया। अड़सठ जीनप्ररूप के एक पैनल से, 11 को वृद्धि चरण के सूखे और जलमग्न तनाव दोनों के लिए सहिष्णु पाया गया और एक जीनप्ररूप आईसी–516149 को उच्च अवायवीय अंकुरण क्षमता के लिए भी पहचाना गया। चालीस *ओ. निवारा* प्रविष्टियों के एक पैनल से, दो लवण सहिष्णु वंशों की पहचान की गई जिसने 3–5 स्कोर सहित लवण–ग्राह्यशीलता दिखाया। इसके अलावा, पांच विशिष्ट चावल जननद्रव्यों को तनाव सहिष्णु प्रविष्टियों के रूप में पहचान की गई। उसनाने की प्रक्रिया चावल के दानों की पकाने की गुणवत्ता में सुधार करने और भूरा चावल और कुटाई की गई चावल के ग्लाइसेमिक इंडेक्स और ग्लाइसेमिक लोड को कम करने के लिए पाई गई। चावल को अधिक पानी में पकाने से रंजित और गैर–रंजित चावल में कुल एंटीऑक्सिडेंट और कुल घुलनशील चीनी मात्रा का स्तर काफी कम हो जाता है। राइस ब्रान केक को एक नए मूल्य वर्धित उत्पाद के रूप में विकसित किया गया जिसमें बाजारों में उपलब्ध केक की तुलना में उच्च एंटीऑक्सीडेंट गतिविधि होती है। फसल में फूल लगने की अवस्था में ग्लूटामाइन सिंथेटेज और ग्लूटामाइन–ऑक्सोग्लूटारेट एमिनोट्रांस्फरेज की बढ़ी हुई गतिविधियाँ उच्च प्रोटीन मात्रा से जुड़ी पाई गईं।

कार्यक्रम–5 के तहत, दो मॉडल इंस्पायर–1.0 (चावल पारितंत्र में किस्मों के तेजी से प्रसार के लिए अभिनव विस्तार मॉडल) और इंस्पायर–2.0 को उपयोगकर्ताओं के लिए हाल में विकसित प्रौद्योगिकियों के तेजी से प्रसार के लिए विकसित और मान्य किया गया तथा प्रौद्योगिकीविदों को इसकी प्रतिपुष्टि प्रदान की गई। वर्ष 2021 के दौरान, नौ राज्यों के 19 जिलों में लगभग 205 एकड़ क्षेत्र को शामिल करते हुए 355 किसानों के खेतों में 28 चावल की किस्मों का प्रदर्शन किया गया और इंस्पायर 2.0 में ओडिशा के तीन जिलों में 11 चावल की किस्मों और 130 भाग लेने वाले किसानों को शामिल किया गया तथा यह देखा गया कि स्थानीय तुलनीय की अपेक्षा लगभग 10–20% अधिक उपज मिली है। आर्थिक अधिशेष दृष्टिकोण के माध्यम से एनआरआरआई चावल की किस्मों के आर्थिक योगदान का आकलन करने के लिए लगभग 17 चावल किस्मों की पहचान की गई है और 11 किस्मों को प्रीमियम बीज किस्मों और विशिष्ट चावल के लिए उपभोक्ताओं द्वारा भुगतान करने की इच्छा द्वारा उनका मूल्यांकन करने के लिए चुना गया। भारत में घरेलू चावल की खपत वृद्धि की प्रवृत्ति का अनुमान से चला पता कि इसमें चार गुना वृद्धि हुई है लेकिन कोई निश्चित विकास पैटर्न नहीं देखा गया। चावल की खपत, जनसंख्या और देश के सकल घरेलू उत्पाद के बीच संबंध की खोज में यह देखा गया कि चावल की घरेलू खपत जनसंख्या वृद्धि के साथ अधिक चलती है और देश के सकल घरेलू उत्पाद से संबंधित होने की संभावना कम होती है। पिछले एक दशक से, भारत से चावल की निर्यात में अच्छी वृद्धि हुई और वर्ष 2020–21 के दौरान गैर–बासमती चावल के निर्यात में उल्लेखनीय रूप से वृद्धि हुई और इसने बासमती चावल की तुलना में अधिक विदेशी राजकोष अर्जित किया।

कार्यक्रम–6 की कार्यकलापें चावल की तनाव सहिष्णु किस्मों का विकास पर केंद्रित है और वर्षाश्रित सूखा–प्रवण क्षेत्र के छोटे और सीमांत किसानों के लिए एकीकृत फसल उत्पादन और सुरक्षा पद्वतियों सुधार किया गया है। केंद्रीय किस्म विमोचन समिति ने झारखंड, बिहार और पश्चिम बंगाल राज्यों में सिंचित क्षेत्रों के लिए वर्ष 2021 के दौरान सीआर धान 320 (आईईटी 27914) किस्म का विमोचन किया। इसकी उपज क्षमता 5.35 टन/हेक्टेयर है। चार लक्षण–विशिष्ट आनुवंशिक सामग्री, आईएनजीआर 21114, आईएनजीआर 21177, आईएनजीआर 21178, और आईएनजीआर 21179 को सूखे और कई अजैविक तनाव सहिष्णुता के लिए आईसीएआर के तहत पीजीआरसी में पंजीकृत किया गया। कुल 516 प्रविष्टियों का लक्षणवर्णन किया गया और आईसी 0640862, आईसी 0640865, आईसी 0640869, आईसी0640873, आईसी0640879 और आईसी0640880 जैसी आशाजनक प्रविष्टियों को बहु–तनाव सहिष्णुता के लिए पहचाना गया। पूर्वी भारत के साठ विविध चावल जननद्रव्यों का क्यूटीएल–लिंक्ड मार्करों का उपयोग करके प्रजनन चरण सूखा सहिष्णुता के लिए मूल्यांकन किया गया और जीनप्ररूप में काफी संख्या में डीटीई क्यूटीएल की उपस्थिति का अनुमान लगाया गया। चावल में आभासी कंड और *BADH2* का रीकॉम्बिनेज पोलीमरेज एम्प्लीफिकेशन आधारित परीक्षण विकसित और मानकीकृत किया गया। चावल आधारित फसल प्रणाली में एकीकृत पोषक तत्व प्रबंधन विकल्पों की प्रभावशीलता का प्रदर्शन किया गया। बेहतर प्रबंधन विकल्प के रूप में उवर्रकों का अनुशंसित मात्रा का प्रयोग नत्रजन (तीन भागों में). जस्ता (25 किग्रा/हेक्टेयर), से सूखा प्रवण उथली निचलीभूमि की उपज में महत्वपूर्ण सुधार हुआ है। यह कार्यकलापें तटीय चावल पारिस्थितिकी के लिए अनुकूल प्रौद्योगिकियों के विकास पर केंद्रित है एवं इसके लिए आंध्र प्रदेश के तीन तटीय जिलों में सर्वेक्षण किया गया और चावल की फसल (एमटीयू 1061) में कीट एवं रोग प्रकोप दर्ज की गई।

यह भी कार्यकलापें वर्षाश्रित निचलीभूमि के लिए चावल के आनुवंशिक सुधार और प्रबंधन पर केंद्रित है। वर्ष 2021 के दौरान चावल के जननद्रव्य के 766 प्रविष्टियों को बनाए रखा गया और 50% फूल आने के दिन, पौधे की ऊंचाई, दौजी की संख्या और अनाज की उपज का आंकड़े दर्ज किए गए। चावल में बकाने रोग के विरुद्व कवकनाशी की प्रभावशीलता का परीक्षण किया गया और देखा गया कि रोपाई के 15 दिनों के बाद प्रोपीकोनाजोल 2 मिली/लीटर पानी की दर से छिड़काव करने से बकाने रोग की सबसे कम घटना दर्ज की गई और उच्च उपज मिली। देरी से बुवाई की तुलना में फरवरी के पहले पखवाड़े में रोपित फसल में धान के तना छेदक (0.76:) का प्रकोप सबसे कम हुआ और उच्चतम उपज दर्ज की गई।

NATIONAL RICE RESEARCH INSTITUTE

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

NRRI & SUSTAINABLE DEVELOPMENT GOALS

1 NO POVERTY | 2 ZERO HUNGER | 3 GOOD HEALTH AND WELL-BEING | 4 QUALITY EDUCATION | 5 GENDER EQUALITY | 6 CLEAN WATER AND SANITATION | 7 AFFORDABLE AND CLEAN ENERGY

AT A GLANCE : YEAR 2021

NRRI IN NUMBERS

1. 12 New Rice Varieties including two hybrids Released
2. 10 Unique Rice Germplasm Registered with ICAR-NBPGR
3. 9 New Rice Varieties Registered with PPV & FRA
4. 11 Technologies Commercialized and 2 Patents Granted
5. 159 Peer Reviewed Research Papers Published
6. 9 States Covered through Extension Activities
7. 28 New Rice Varieties Demonstrated in Farmers Field
8. 620 Personnels including Farmers Visited the Institute
9. 87 Training Programs Attended by 3577 Persons Conducted
10. 57 Agromet Advisory Bulletins Released
11. 25 Agro Advisory Services & 19 Video Barta Released
12. 1215 Field Demonstrations Conducted

INTRODUCTION

Introduction

ICAR-National Rice Research Institute (ICAR-NRRI), formerly known as Central Rice Research Institute (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 NRRI regional station, Hazaribag was established to tackle the problems of rainfed uplands, the NRRI regional station, Gerua for problems in rainfed lowlands and floodprone ecologies and NRRI regional station, Naira for coastal saline ecologies. Two Krishi Vigyan Kendras (KVKs) also function under NRRI, 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 NRRI 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 NRRI 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 Group 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 Cuttack railway station on the Cuttack-Paradeep State Highway. The institute lies approximately between 85° 55'48" E to 85° 56'48" longitudes and 20° 26'35" N to 20° 27'35" N latitudes with the general elevation of the farm being 24m above the MSL. The annual rainfall is 1200 mm to 1500 mm, received 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-1

Genetic Improvement of Rice

The Crop Improvement Division of the Institute is involved in developing novel rice varieties, hybrids, and other technologies so as to increase yield, improve nutritional quality, mitigate various biotic and abiotic stresses to enhance socio-economic condition of the rice stakeholders. The division with its cadre strength of 25 scientists and 24 technical staff operates 11 institute research projects and 25 externally aided projects. During the year 2021, 12 rice varieties including two hybrids were released and notified. Thirty-three new wild rice germplasm accessions were collected from Nabarangpur and Nuapada districts of Odisha and Gariaband district of Chhattisgarh. A total of 2158 accessions of rice germplasm / elite lines / donors/ varieties were supplied to researchers out of which 167 accession were shared with different institutes/organizations throughout the country. As a part of seed production, 57.91q nucleus seed of 91 varieties, and 427.64 q breeder seed of 56 varieties were produced during rabi 2020-21. Besides, 34 QTLs were mapped for various desirable traits, several donors for salinity, submergence, yield, and dual stigma exsertion were identified. Utilization of DH technology could identify genomic regions associated with drought tolerance at vegetative stage. Besides, morphological indicators for discrimination of DHs and haploids were developed. The developed androgenic protocol for rice was successfully used in sugarcane for production of green regenerants with variable ploids. The genome edited rice line Swarna developed using CRISPR/ Cas9 technology showed 23% increase in number of spikelets per panicle. The subsequent section discusses the salient achievements of the programme for the year 2021.

Exploration and collection of wild rice

An exploration and collection for wild rice in collaboration with ICAR-NBPGR Base Centre, Cuttack Odisha was undertaken at Nabarangpur and Nuapada districts of Odisha and Gariaband district of Chhattisgarh during 25 November to 4 December 2021. During the visit, 22 blocks of three districts were covered. A total of 33 samples were collected from which four species were wild rice consisting of *O. nivara* (10 samples), *O. rufipogon* (7 samples), *O. officinalis* (2 samples) (Fig. 1.1 & Fig. 1.2) and *O. sativa* var. *spontanea* (14 samples). The passport information, collection list and GPS data were recorded and deposited in the Institute's Gene bank.

Fig. 1.1. *O. officinalis* from forest, Gariaband forest, Chhattisgarh.

Fig. 1.2. *O. rufipogon* from pond in Nabarangpur, Odisha.

Conservation of germplasm and supply of seeds

Altogether 2957 rice germplasm accessions were characterized for agro-morphological traits as per the descriptors. The same set was conserved in MTS of NRRI Gene bank. These materials include 2808 accessions of rice germplasm received from ICAR-NBPGR, New Delhi, DUS testing materials, newly collected cultivated and wild rice germplasm. A total of 2630 accessions of rice germplasm / elite lines / donors/ varieties were supplied to researchers for their utilization in research programmes. Out of 2630 accessions, 338 accessions were shared with different institutes/ organizations throughout the country with signing of proper MTA.

Characterization and documentation of pigmented rice germplasm

A set of 262 pigmented rice germplasm *were phenotyped based on various qualitative and quantitative characters. In case of qualitative traits, maximum variability (5) was observed for awn type, leaf blade and apiculus colour. No variability for panicle type (Int) and ligule shape (cleft)* was observed (Fig. 1.3). Wide range of variation among the accessions for effective tillers (33.45%) was observed (Table 1.1).

Molecular characterization of rice germplasm for industrial traits using novel genic markers

Rice Bran Oil

Allelic diversity at the gene locus OsPLD1 (*LOC Os01g07760*), influencing rice bran oil stability, was investigated in 120 varieties released by ICAR-NRRI and 96 weedy rice accessions using the novel cgSSR marker (F: 5'-TTGCTTCTTCTCCGCTCAGA-3'; R: 5'-CCATGGCTGCTGATTTGGAT-3'). The gene was found to be highly conserved in the genotypes.

Fig. 1.3. Variation in qualitative traits.

Table 1.1. Variability observed for quantitative traits.

Characteristic	Mean	Range	CV (%)
Plant height (cm)	113.62	54.00-178.33 (Naardi – Goindi)	21.07
Leaf Length (cm)	34.35	16.33-53.0 (Lohandishan-kar – Bharati)	22.12
Leaf width (cm)	0.84	0.30- 1.70 (Khama – Hariyapauni)	26.89
Panicle length (cm)	21.67	11.00-29.00 (Gopal – Mariadhan)	14.26
Tillers	5.82	1.66-12.00 (Gariba – Saharabhojni)	33.45
Fertility (%)	75.75	18.75-100 (Gopal – Niwariprem)	20.86
HGW (g)	2.31	1.06-3.23 (Dhanigoda – Gandhibiroin)	15.83

However, in the variety Nua-Chinikamini, a sequence length polymorphism in the 5'-UTR region of the OsPLD1 gene was observed (Fig. 1.4). Further research on the influence of this rare allele on gene expression and bran oil stability in the Nua-Chinikamini cultivar is needed.

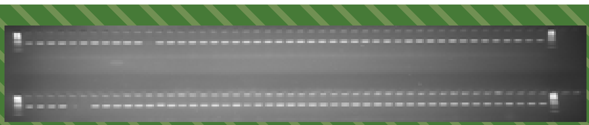


Fig. 1.4. A rare allele of the gene *OsPLD1*, which influences rice bran oil stability, was observed in the variety Nua Chinikamini.

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

Nucleus seed and breeder seed production

Panicle progeny rows of 91 rice varieties were grown for maintenance breeding. After thorough rouging and rejection of probable variant in progeny lines, true to the type panicles were collected for next generation nucleus seed production. The remaining lines were harvested, threshed separately and after table top examination pure lines were bulked as nucleus seed. In 2020-21, altogether of 57.91 q of nucleus seed of 91 varieties were produced. The bulk nucleus seeds are being used to produce breeder seed of the same variety. Breeder seed was produced as per DAC indent. Altogether 427.64 q of breeder seed, consisting of 56 varieties were produced.

Participatory Seed Production

The seeds of four popular rice varieties (Pooja, Swarna *Sub1*, CR Dhan 800 and CR Dhan 409) were produced in two villages i.e. Baripada in Jagatsinghpur district and Bhandilo in Kendrapara district. A total of 631.58 q seed qualified as per TL seed standard. The seed was procured by the Institute and sold to other farmers as TL Seed.

Optimization of PCR multiplexing protocol for gene-based markers for varietal characterization in rice

One hundred and forty novel gene-based SSR markers were designed based on the gene loci data available in the rice genome annotation project database. The markers were used for genotyping 124 rice varieties released from the ICAR-NRRI, Cuttack. Four highly polymorphic markers were selected and employed to develop a DNA fingerprint of 24 rice varieties which are currently in the seed chain (Fig. 1.5).

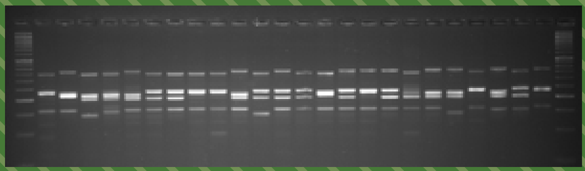


Fig. 1.5. Lane 1: 50 bp ladder, 2: Annada, 3: CR Dhan 101, 4: CR Dhan 102, 5: CR Dhan 201, 6: CR Dhan 202, 7: CR Dhan 203, 8: CR Dhan 210, 9: Khitish, 10: Shatabdi, 11: Naveen, 12: CR Dhan 300, 13: CR Dhan 303, 14: CR Dhan 304, 15: CR Dhan 305, 16: CR Dhan 306, 17: CR Dhan 307, 18: CR Dhan 308, 19: CR Dhan 309, 20: CR Dhan 310, 21: CR Dhan 311, 22: CR Dhan 312, 23: CR Dhan 315, 24: Savitri, 25: Pooja, Lane 26: 50 bp ladder.

Optimization of DNA extraction protocol from rice seeds and detection of *Fusarium fujikuroi* causing bakanae disease using Loop-mediated Isothermal Amplification (LAMP) technique

Fusarium fujikuroi is one of the fungal pathogens which cause bakanae disease in rice. In the present investigation, a rapid and efficient method of genomic DNA extraction from stored seeds, overnight soaked seeds, germinated seeds and symptomatic seedlings are reported. The modified method yielded abundant, high quality DNA (100-200 ng DNA/mg). Further, the attempt was made to detect *Fusarium fujikuroi* from above rice samples using LAMP technique (Fig. 1.6). The specific primers were designed using TEF-1α gene sequences and loop-mediated isothermal amplification procedure was used to detect genomic DNA of *Fusarium fujikuroi* in samples. The positive reaction was observed through color change and agarose gel electrophoresis. The detection limit using this technique was 10fg of genomic DNA. LAMP is very sensitive, simple, rapid and specific for the detection of *F. fujikuroi*. The protocol takes approximately one hour to prepare high quality DNA which in combination with LAMP is a fast and cost-effective alternative to traditional diagnostic methods for early detection of species of *Fusarium* in rice seeds.

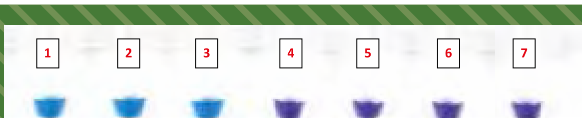


Fig. 1.6. The specific loop-mediated isothermal amplification of *Fusarium fujikuroi* by the primers 1-6 assessm ent based on HNB visualization of colour change of the LAMP products; 1. *F. fujikuroi*; (infected seeds); 2. *F. fujikuroi (infected seedlings)*; 3. *F. fujikuroi (rhizosphere soil)*; 4. *R. solani*; 5. *Magnoporthe oryzae*; 6. *Helminthosporium oryzae*; 7. Nuclease-free water.

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

Identification of donor sources from wild rice accessions for biotic and abiotic stresses

Collectively, 101 accessions from 14 wild rice species were evaluated for brown plant hopper (BPH) *Nilaparvata lugens* (stal.) resistance against local populations of biotype 4 and anaerobic germination tolerance (Table 1.2).

Wide hybridization for developing pre-breeding lines

Multiple accessions from all the six wild species of AA genome, besides *O. glaberrima* were crossed with CR Dhan 307 and F_1 seeds were produced. BC_1F_1 populations were developed from the crosses involving CR Dhan 307 with *O. nivara, O. meridionalis, O. glumaepatula* and *O. glaberrima*. Previously developed populations of *O. sativa* (varieties Swarna, Annapurna, Naveen, and CR Dhan 307) and three accessions of *O. rufipogon* (AC 100005, AC 100015 and AC 100444) were advanced further through selfing.

Development of chromosome segment substitution lines (CSSLs)

The cross involving high yielding *indica* rice genotype CR Dhan 307 (Maudamani) and wild rice *O. rufipogon* (AC 100444) was chosen for development of CSSLs. From the polymorphic cross transferable molecular markers identified, the CSSL set in heterozygous condition was identified from BC_2F_1 lines (Fig. 1.7). Further, homozygous plants for the targeted segments have been identified from BC_2F_2 populations. The population size of >2500 BC_3F_1 lines have been advanced till BC_3F_2 generation. The population will serve as valuable resource to map novel genes/QTLs for yield related traits, dormancy, and seed longevity.

Table 1.2. Identification of novel wild rice donor lines.

Germplasm Id/ Accession Number	Species	Trait	Resistance/ tolerance level as per SES score
EC946906/IRGC 105690	*O. punctata*	BPH resistance	Resistant (The accession has been earlier reported as resistant against Laguna BPH colony of Philippines)
W118 (PAU) / AC100042	*O. nivara*	Anaerobic germination	Moderately tolerant
W1125 (PAU)/ IR 99574	*O. punctata*	Anaerobic germination	Moderately tolerant

Fig. 1.7. Identification of chromosome segment substitution lines (CSSLs) from the cross of CR Dhan 307/ *O. rufipogon* (AC 100444).

Identification and notification of BPH resistant variety CR Dhan 317 (CR 2711-76, IET 24409)

CR Dhan 317 was notified for release in the BPH endemic irrigated areas of Odisha in the 87th meeting of Central Sub-Committee on Crop Standards. It is a semi-dwarf variety (130-140 days), non-lodging with 5.0 t ha^{-1} yield potential in BPH endemic areas of Odisha. It possesses good grain quality along with *BPH 31* resistant gene (Fig. 1.8 & 1.9).

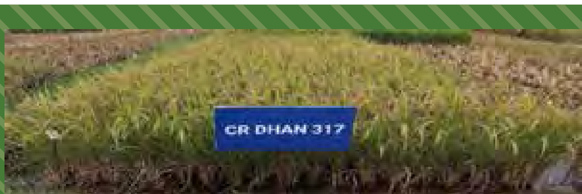


Fig. 1.8. Field view of CR Dhan 317 (CR 2711-76, IET 24409).

Fig. 1.9. Reaction of CR Dhan 317 (CR2711-76) along with parents (Tapaswini & Dhobanumberi) and resistant check varieties against BPH.

Developing multiple stress-tolerant Lalat MAS for drought, submergence, low P, and bacterial leaf blight with eight QTLs/genes by introgressing DTY 1.1, DTY 2.1, DTY 3.1, Sub1, and PSTOL1 with xa5, xa13 and Xa21

Multiple stress-tolerant medium duration genotypes are required for the present climate-changing scenario that suits to grow in both *rabi* and *kharif* season. Therefore, a region-specific rice variety Lalat having three bacterial leaf blight (*xa5, xa13, and Xa21*) genes has been selected to introgress with multiple QTLs/genes responsible for abiotic stresses such as drought, submergence, and low phosphorus tolerance from donor CR Dhan 801. CR Dhan 801 is the first multiple abiotic stress tolerant rice variety released from the Institute having tolerance against drought and submergence with inherent low P tolerance. In each back-cross population, genotypes were screened with respective foreground markers of *DTY1.1, DTY 2.1, DTY 3.1, Sub1*, and *PSTOL1* (K46-1, K29-1&K29-3). In BC_2F_2, 2205 lines and in BC_3F_2, 3395 lines were genotyped with foreground markers. Among the 2205 lines of BC_2F_2, three lines that carried all desired QTLs were backcrossed with the recurrent parent to generate 3395 BC_3F_2 lines. Besides, 213 lines of BC_2F_4 and BC_3F_2 were selected based on foreground markers as well as genotyped with respective SNP markers of *DTY1.1, DTY 2.1, DTY 3.1, Sub1, xa5, xa13* and *Xa21.* The SNP markers could classify the 213 genotypes into four major clusters (1 to 4). Cluster 1 was further sub-clustered into two groups, red and green colour (Fig. 1.10). The recurrent parent (Lalat MAS, brown circled) and their close resemblance with different gene combinations were grouped

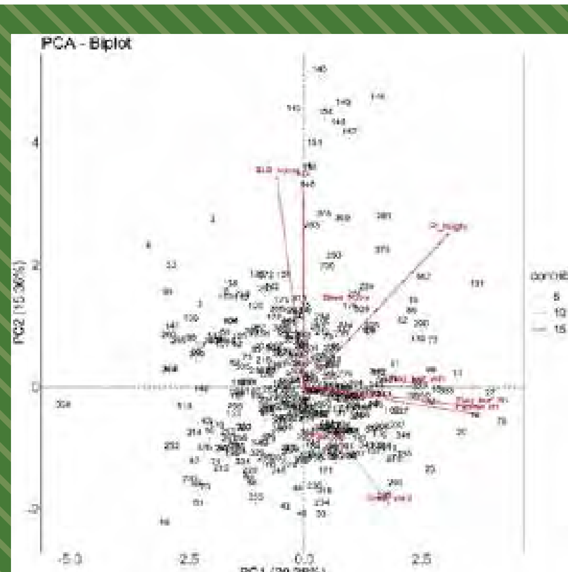


Fig. 1.10. PCA biplot of the 376-panel population based on the variance in yield and yield component traits, biotic traits under normal and stress reaction explained by two axes.

under red colour clade. The donor CR Dhan 801 (red circled) is grouped under red clade. Among all the lines genotyped with SNP, line number 48 (BC_3F_2) and 155 (BC_2F_4) (black circled) had all desired QTLs seven in number except *qDTY3.1*. Lines with different combination of genes for drought, submergence, low P and bacterial blight were grouped in red clade with donor CR Dhan 801. Similarly, line number 194, 180, 27, 204, and 146 (black circled) were grouped with six QTLs such as *DTY 1.1, DTY 2.1, sub1, xa5, xa13,* and *Xa21*. The selected advanced breeding lines will be tested for drought, submergence tolerance, PUE and resistance against bacterial leaf blight in *rabi* 2022.

Identification of superior haplotype for root vigour under low input dry direct-seeded condition

Two candidate genes *GLPT2* (*LOC_Os06g08170*), a Glycerol-3-phosphate transporter 2 and *OsEXPA12 (LOC_Os03g06000*) were identified with repose to crown root number and root dry weight, respectively, at 28 days after sowing. *GLPT2*, centered on 4.02 Mb was selected as the candidate gene for the haplotype study. The gene harboured a total of 85 SNPs, of these nine SNPs were in the exon region of the gene. The nonsynonymous SNPs were positioned in the following order; at 3,948,822 bp (T/C polymorphism), 3,950,213 bp (C/T polymorphism), 3,960,275 (A/G polymorphism) and 3,962,787 (A/T polymorphism) that resulted in the amino acid substitution from Arg (R) to Cys (C), Cys (C) to Arg (R), Gly (G) to Ser (S) and Ser (S) to Thr (T), respectively. Besides, five synonymous polymorphisms were also observed. The genotypes were grouped into three haplotypes: hap A (n=3), hap B (n=153) and hap C (n=43) for the above-mentioned SNPs (Fig. 1.11). The cultivars of haplotype A were significantly different from that of hap B and hap C with a higher number of crown roots.

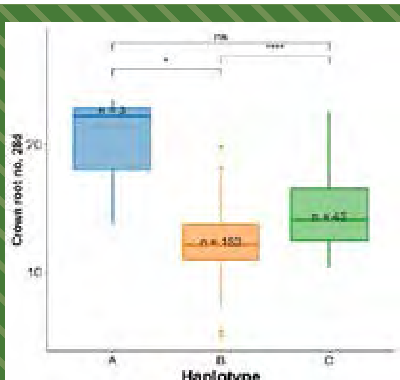


Fig. 1.11. Variation observed for the gene LOC_Os06g08170 responsible for Crown root number.

The gene *OsEXPA12 (LOC_Os03g06000)* coding for expansion protein was significantly associated with root weight at 28 days. This gene was reported to be root-specific and helps in the development of outer cell layers. A total of 225 SNPs highlighted from this region of which only 10 were in the exons region and among them three were non-synonymous SNPs. The cultivars used in this study were grouped into three haplotypes; hap A (n=13), hap B (n=169) and hap C (n=20). The hap A group was significantly different and superior to hap B and hap C.

Iron deficiency tolerance

In order to understand the genes involved in tolerance, the tolerant RA23 and susceptible Lalat-Mas (LMAS) were raised under 0% Fe and control with full Fe. The venn diagram (Fig. 1.12) depicts the differential expression of genes observed from the four transcriptomic data. Among them, *Os01g0647200* (expressed protein), *Os07g0142100* (Iron deficiency-inducible peptide, IMA/FEP peptide, regulation of a major pathway of iron uptake and translocation, Iron deficiency response) and *Os01g0952800* (helix-loop-helix DNA-binding domain-containing protein) genes that regulated under Fe deficiency were found to be up regulated in both susceptible (Lalat-MAS) and tolerant (RA23) lines.

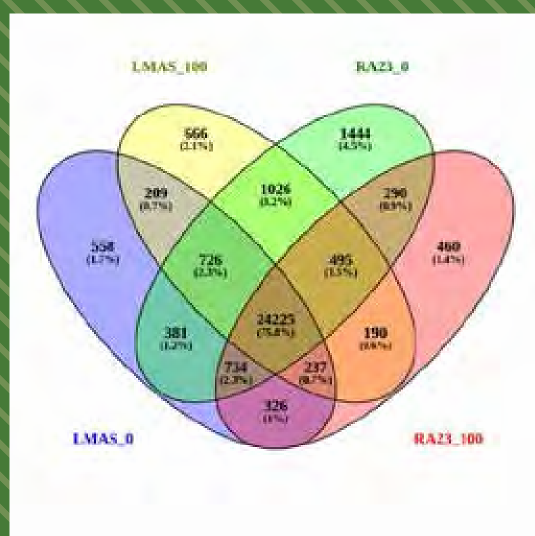


Fig. 1.12. Venn diagram of the cross-comparison of DGE based on RNA-seq data for Fe deficiency tolerance.

Identification of QTLs for Sheath blight (SB) resistance

In order to identify the QTLs for Sheath blight (ShB) resistance in rice, a core panel of 192 genotypes were selected from 330 rice accessions based on the disease reaction against ShB for association mapping studies. The study confirmed that the population had a significant amount of genetic variation for ShB related traits across seasons. Altogether total of 133 SSRs classified the genotypes into three major clusters. Employing both GLM and MLM (Q+K) models, 30 SSRs were associated with targeted traits across seasons. Five QTLs such as *qShB.4-1, qShB.4-2, qShB.8-2, qShB.10-1* and *qShB.10-2* were identified for sheath blight resistance (Fig. 1.13). Further, elite alleles associated with markers imparting resistance against sheath blight was identified in IC 283139, IC 277248, Sivappu Chithirai Kar and Bowalia, which would be useful in developing rice varieties with durable disease resistance.

Fig. 1.13. QTLs for sheath blight resistance identified in chromosome 4, 8 and 10 of rice using linkage disequilibrium.

Breeding for Aroma and Grain Quality in Rice

Biofortified variety released and notified

Biofortified rice variety CR Dhan 411 (Swarnanjali) in Swarna (MTU 7029) background was released by SVRC, Odisha and notified for cultivation in Odisha in 2021 (Fig. 1.14). Average grain yield of this variety is 5.62 t ha^{-1} with 140 days (138-148 days) maturity duration. The protein content and yield of Swarnanjali were 10.01% and 5.29 t ha^{-1}, respectively. The grain type is short bold and the husk colour is similar to Swarna. Another biofortified variety CR Dhan 315 with 25 ppm Zn in milled rice was notified for Gujarat and Maharashtra in irrigated condition.

Fig. 1.14. CR Dhan 411 (Swarnanjali) Morphology of grain, paddy, panicle and field view.

Improvement of biofortified variety for biotic stress resistance

A breeding program was undertaken to transfer the bacterial blight resistance genes, *Xa13*, *Xa5* and *xa21* to high protein Swarna background (Swarnanjali). CR 2830-PLS-17 was crossed with CR Dhan 800 carrying three bacterial blight (BB) resistance genes in Swarna background. Two hundred F_2 lines were screened for resistance in Swarnanjali background. Eight high protein lines with BB score less than five were identified. Four (P-22, P-33, P-72, P-166) out of the eight lines showed a disease score of three.

Detection of unique germplasm and improvement for multiple nutritional traits

ARC 10075 (IC 0597237) (INGR 21092) for high protein content (12%) in milled rice has been registered by the PGRC in 2021. After evaluation of 293 germplasm from Odisha (*kharif* 2018 and 2020), two germplasm such as Champeisiali (AC 43368) and Gedemalati (AC 34306) with highest Fe (44.1 ppm) and Zn (40.48 ppm) content in brown rice, respectively were detected. Twenty new crosses and eight backcross derived mapping populations have been generated using donors such as Bindli, ARC 10063, Edavankudi Pokkali, Pandari Gurmatiya, ARC 6027 and Kalobhat for high grain protein, zinc, anti-oxidant and low phytate for improvement of high yielding rice for multiple nutritional traits.

Pigmented Rice

Evaluation of germplasm for Identification of new donors

Twenty seven breeding lines and other germplasm were evaluated for identification of new donors for antioxidant and related traits. Highest Total Anthocyanin content (TAC) was observed in AC 44793. AD-18-6-7 and *Chakhao* Amubi-2 were found to have ϒ-oryzanols (131.75 mg 100 g^{-1}) and total phenolic content (374.43 mg catechol 100 g^{-1}). Kalabiroin and

AD-18-6-7 are reported higher TFC (73.78; 72.22 mg CEt 100 g^{-1}, respectively). The observed variation in the set of genotypes under study has been depicted in Fig. 1.15.

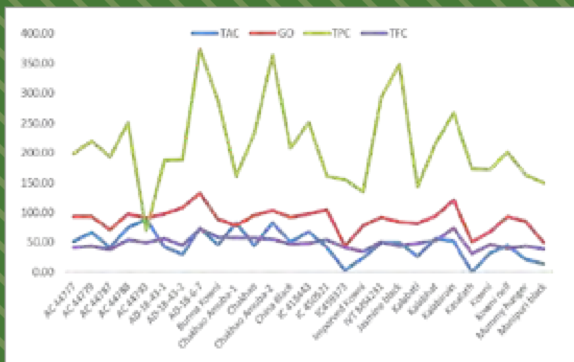


Fig. 1.15. Variation for antioxidant related traits in 27 genotypes.

Note: TAC: Total Anthocyanin content (mg/100 g); GO: gamma Oryzanol (mg/100 g); TPC-Total Phenol Content (mg CEt/100 g); TFC: Total Flavonoid Content (CE/100 g); CEt-catechol; CE-catechine.

Purification of landrace

Under collaborative programme with Green Foundation, Manipur on purification of aromatic black grain genotype from Manipur *Chakhao,* 26 lines with dark grain pigmentation, superior yield traits and grain types were identified after third cycle of selection during *kharif* 2021. The low phytate for improvement of high yielding rice with multiple nutritional traits lines displaying complete uniformity were selected for bulk multiplication.

Evaluation of breeding lines

A population consisting of 177 semi-dwarfs, non-lodging derivatives of *Chakhao* (Fig. 1.16) were characterized for antioxidant related traits. Highest variability was observed for anthocyanin content (76.40%) and lowest for gamma-oryzanols (21.30%). Highest TAC was observed in QCR-48-2-52; highest ϒ -oryzanols in QCR 48-2-85 (115.31 mg/100 g), Total phenolics content in QCR-48-2-65 and breeding line QCR-48-2-65 was identified with highest total flavonoids (282.26 mg CE /100 g). The genotypes with superior yield, plant type and antioxidant traits have been selected for further improvement.

Aromatic rice

Dwarf mutants of *Gobindbhog* type1 and *Gobindbhog* type2 were identified in M_1 generation during *kharif* 2020 (Fig. 1.17). *Banspatri*, an aromatic and *Sunakathi*, a fine-grained landrace from Odisha have been subjected to purification and improvement for disease resistance. Twenty new combinations of crosses have been generated under recombination breeding.

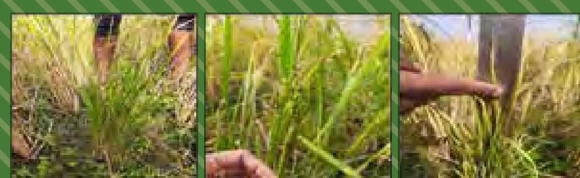


Fig. 1.17. Dwarf mutants of *Gobindbhog* identified in M_1 generation.

Fig. 1.16. Depicting the phenotype of the black pigmented derivative of *Chakhao*.

Characterization of germplasm for grain quality

Forty rice varieties were evaluated for superior quality to popularize and use as donor. Hulling per cent varied from 81.0 (Salivahan) to 74.5 (Prachi). The varieties *viz.,* Gurjari, Mahsuri, Sudhir, Jagannath, Golak, Utkalprava, Rajashree, Matangini, Sabita, Sonamani, Manik, Indravati, Shravani, Jagabandhu, Birupa, Surendra, Bhanja, Rajashree, Mahalaxmi are having HRR% > 60. Kernel length ranged from 5.02 mm (Bindli) to 6.55 mm (Sudhir). Long grain (>6.5 mm) was observed in Moti, Sudhir, Utkalprava, Matangini, Sabita and Sonamani. Elongation ratio is high (>2.0) in Sashi, Sudhir and Ramakrishna. Kernel length after cooking was highest in Sudhir (13.5) and lowest in Shravani (8.45). Purnendu (27.9%), Mandyavijay (25.8%), Matangini (25.96%) and Gurjari (26.0%) have high amylose content.

Glutinous Rice

Breeding and genetic characterization of glutinous rice was included in the program as per directives from the ICAR and PMO. Crossing has already been initiated using Aghanibora as one of the parents under breeding of glutinous rice.

Characterization of germplasm from Northeastern region of India for utilization in breeding for glutinous rice

Altogether, 145 rice accessions collected from Northeastern region of India (Majuli, 73; Nagaland, 72) were characterized for grain amylose content (AC) and alkali spreading value (ASV). Within Majuli germplasm AC varied from 5.02% (Ranga Sali) to 26.05% (Kunkunijoha), whereas AC in Nagaland germplasm varied from 2.15% (Tukhoburi) to 22.5% (Pawnhi). The grouping of rice germplasm into different AC classes is shown in Fig. 1.18. The waxy (AC=0-5%) rice accessions were Rulu, Kemenya, Chabatari, Tukhoburi, and Chaha Pota. Subsequently, a cross has been made with Rulu (IC-0635886) with Sahabhagidhan targeting development of high yielding waxy rice variety.

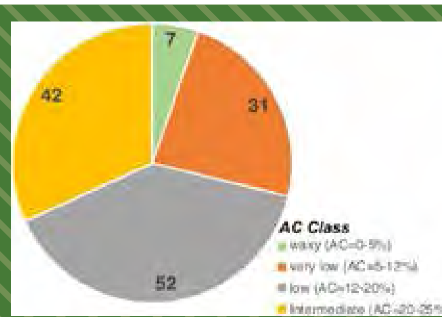


Fig. 1.18. Variation in amylose content (AC) in 145 rice accessions of Northeastern India.

Breeding towards climate resilient genotypes for rainfed shallow lowland

The new variety, CR Dhan 413 (Reeta-Panidhan) has been released by SVRC Odisha. The variety is a high yielding and late maturing with submergence tolerance (Fig. 1.19A, 1.19B, 1.19C). Maturity duration of the variety is 145-150 days with semi-dwarf plant type. It possesses short bold grain, more panicles per m^2 (281) with 120 days to 50% flowering, normal tillering (8-12), medium and dense panicle with moderate test weight (23.3 g). It is resistant to BPH, WBPH, stem borer (dead heart) and moderate resistant to white ear head, plant hopper, leaf folder and case worm.

Another variety Trilochan (CR Dhan 803) was released for shallow lowlands of Odisha developed from the popular variety, Pooja through marker-assisted backcrossing (Fig. 1.20A. 1.20B, 1.20C). The average yield of the variety in Odisha testing is 5043 and 3469 kg ha^{-1} under normal and submergence

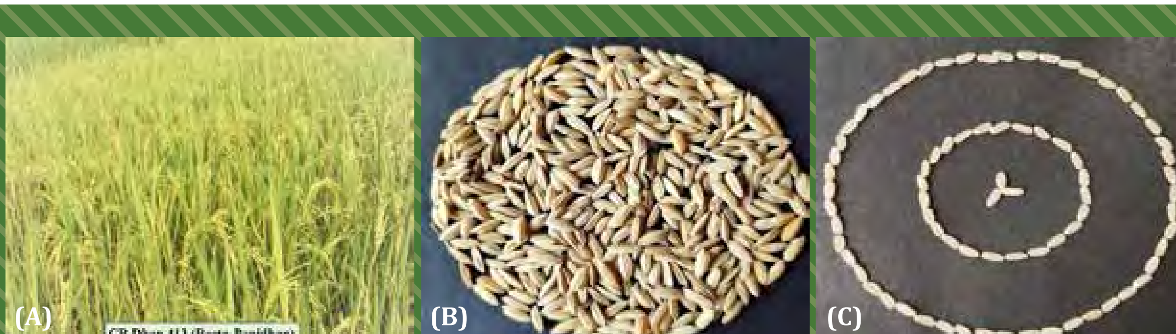


Fig. 1.19. Rice variety, CR Dhan 413 (Reeta-Panidhan) (A) At dough stage (B) Grains and (C) Kernels.

condition, respectively. The variety is photosensitive with average maturity duration of 150 days. It possesses short bold grain with a test weight of 19.95 g. It is resistant to stem borer (dead heart) and BPH and moderately resistant to white ear head attack, WBPH, leaf folder, plant hopper, and case worm. The variety moderately resistant to neck blast and rice tungro virus.

CR Dhan 512 (Satrughna) was developed from the breeding materials of the cross, Gayatri / AC 38599 with objective of high yield with water logging and tolerance to major diseases and insects. The mean yield of the variety was 3923 kg ha^{-1} in Odisha showing 32, 67, 67.8 and 28% higher yield over the national (CR Dhan 506), regional (Purnendu) and local checks, respectively**.** Duration of the variety is 155 days with semi-dwarf plant type. It possesses short bold grain, more panicles per m^2 with 125 days to 50% flowering, normal tillering, medium and dense panicle with moderate test weight (23.5 g). It is resistant to whorl maggot and rice thrips, while moderately resistant to stem borer (dead heart & white ear head). It possesses intermediate amylose content, short bold grain and other desirable grain quality traits (Fig. 1.21).

Isogenic lines carrying *Sub1* + *Xa21* + *xa13*+ *xa5* + *qDTY1.1* + *qDTY2.1* + *qDTY3.1* in the background of mega variety, Swarna was started during 2017-18. The BC_{1F1} plants carrying the desired gene combination of *Sub1*+*Xa21*+*xa13*+*xa5*+*qDTY1.1*+*qDTY2.1*+*qDTY3.1* were hybridized with variety Swarna during *kharif*, 2020 to produce BC_2F_1 seeds. A total of 750 BC_2F_1 seeds were produced. The candidate QTLs controlling superoxide dismutase, flavonoids, anthocyanins, carotenoids, γ-oryzanol and antioxidant activity in rice were detected from the association study. The QTLs *qSOD1.1*, *qSOD5.1* and *qSOD10.1* were detected to control Superoxide dismutase content while *qTAC1.1*, *qTAC3.1*, *qTAC5.1* and *qTAC6.1* controlled total anthocyanin content in rice grain. The QTLs *qTFC6.1*, *qTFC11.1* and *qTFC12.1* for total flavonoids; *qGO8.1* and *qGO11.1* for γ-oryzanol content, and *qABTS11.1* and *qABTS 12.1* for antioxidant activity were detected. Also, the candidate QTLs for four antioxidant enzymes namely *qACD2.2*, *qACD11.1* and *qACD12.2* for DPPH; *qCUPRAC3.1*, *qCUPRAC11.1* and *qCUPRAC12.1* for CUPRAC; *qCAT8.1* and *qCAT11.1* for Catalase, and *qFRAC11.1*; *qFRAC12.1* and *qFRAC12.2* were detected to regulate the FRAC enzyme in rice

Fig. 1.20. Rice variety, CR Dhan 803 (Trilochan) (A) At dough stage (B) Grains and (C) Kernels of the variety.

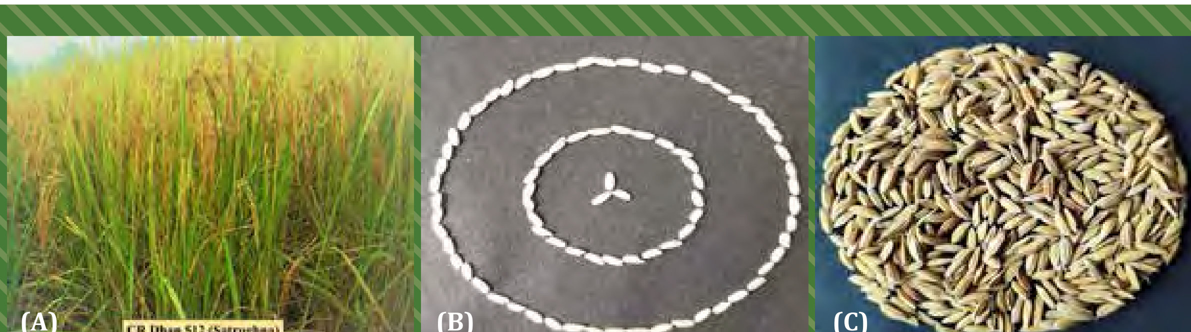


Fig. 1.21. (A) CR Dhan 512 (Satrughna), (B) Grains (C) Kernels.

grain. The entries like CR 3933-39-2-1-2-1, CR 4039-2-1-2-1-1, and CR 3145-4-1-3-2-1-2 were promoted to AVT2 SDW based on the performance in the AVT1 SDW trial during *kharif,* 2020. The entry CR 3987-3-1-1-1-1 in rainfed shallow lowland trial (AVT I RSL) of last year was promoted to AVT2 RSL. In addition, three Varshadhan near isogenic lines *viz.*, CR 2538-42-17-32-3-3, CR 2538-42-17-32-3-2, CR 2538-20-14-24-2 were also promoted to AVT2 NIL (Submergence) trial. Another 16 entries showing more than 6 t ha^{-1} under station trial were nominated to the 1st year AICRIP lowland trials.

Genetic Enhancement for Multiple Stress Tolerance in Rice for Coastal Ecosystem

Identification of unique donors for salinity tolerance and detection of QTLs for stagnant flooding tolerance

Remeni Pokkali (AC 41585) was registered by the Plant Germplasm Registration Committee as unique germplasm (INGR21117) for its tolerance to salinity at both seedling and reproductive stages. Rahaspunjar (IC575321) (INGR21116) with around 20% yield reduction as against 73% in Swarna under stagnant flooding condition with normal water was also registered. Seventeen putative additive QTLs for plant height, shoot elongation, panicle number and grain weight under control and stagnant flooding condition were identified using homo-polymorphic high-quality SNPs derived from genotyping by sequencing of 150 RILs derived from Swarna/ Rahaspunjar. Two major QTLs clusters were found on chromosome 1 and chromosome 3. Some of the associated SNPs with QTLs located on putative functional genes encoding sucrose transport protein *SUT1*, ethylene-induced calmodulin-binding protein, NADH dehydrogenase, etc. were reported to be directly or indirectly responsible for inducing tolerance to stagnant flooding. Some putative functional genes associated with QTLs were directly associated with ethylene biosynthesis and encoding auxin responsive factors for better adaptation under stagnant flooding.

Genomics assisted selection

F_5 breeding population with 60 lines from the three-way cross IR 64/AC 41585//Gangasiuli along with parents and tolerant and susceptible checks (IR 29, FL 478, Swarna *Sub1*, FR13A, Swarna) for salinity at seedling and submergence condition were taken for this study. Pokkali (AC 41585) was identified salinity tolerant at both seedling and reproductive stages and Gangasiuli was identified as tolerant germplasm to submergence and stagnant flooding. *Sub1* BC2 marker and the AEX1 marker, a functional single nucleotide polymorphism (SNP), for *Sub1A* were employed to differentiate submergence-tolerant and susceptible genotypes. High yielding breeding lines with high survival ability such as Su-15 (78.95%), Su-18 (68.42%), Su-47 (78.95%), Su-50 (73.68%), Su-9 (68.42%) and Su-58 (73.68%) contained all tolerant alleles of *Sub 1* QTL. Phenotypically moderately salinity tolerant (SES=5) lines, Su-1, Su-3, Su-4, Su-9, Su-12, Su-15 and Su-19 had all tolerant alleles (FL 478 alleles) in *Saltol* QTL region. Su-6, Su-8, Su-31 and Su-59 although found salinity tolerant (SES=5), but lacked tolerant alleles. Based on overall results Su-15 and Su-9 with tolerant alleles for *Saltol* and *Sub 1* and also with salinity tolerance at seedling stage as well as with high survivability under submergence stress could be considered as multiple stress tolerant lines.

Evaluation of breeding lines and introgression lines in simulation tank and at target site

Twenty-one genotypes including landraces, elite breeding lines, introgressed lines were evaluated for their performance under salinity stress (EC= 8 dSm^{-1}) at reproductive stage. RIL-SP-225 (0.691), Maula (0.629), RIL-SR-204 (0.626), RIL- SP-211 (0.596) and Pokkali (AC 41585) (0.576) were found tolerant or moderately tolerant genotypes over the susceptible genotypes Savitri (0.446) based on STI (stress tolerant index). RIL-SP and RIL-SR are RILs derived from Savitri/ Pokkali (AC 39416a) and Swarna/ Rahaspunjar crosses, respectively.

A set of 165 salt tolerant genotypes along with three checks (Pokkali: AC 41585, FL 478 and IR29) were planted for evaluation in simulation tank salinized for 30 days with water EC 6.5-14.2 dSm^{-1} at seedling stage and again 30 days at the time of flowering with water EC 6-8 dSm^{-1}. No grain yield was recorded for susceptible variety IR 29. One entry CR 3878-245-9-4-3 yielded highest with 4.92 g per plant and 15.49% spikelet sterility. Three entries, namely CR 3884-244-8-5-11-3-4 (11.8%), CR3908-187-1-1-5 (11.83%) and CR 3900-135-6-6-1 (13.88%) were detected with lower sterility than the tolerant variety Pokkali (19.61%).

Five elite high yielding lines were evaluated at coastal saline areas of West Bengal in *kharif* 2020. Under medium to low salinity condition in Sundarbans, IET 27852 at Bhangar block (EC= 2.1- 6.3 dSm^{-1}) and at Gosaba block (EC= 1.6-3.7 dSm^{-1}) was found highest yielder with 3860 kg ha^{-1} and 5454 kg ha^{-1} grain yield, respectively. Three saline tolerant elite lines i.e. IET 27852, IET 27865 and IET 27051 were evaluated in four coastal districts of Andhra Pradesh, namely, Srikakulam, East Godavari, Krishna and Guntur in *kharif* 2021. IET-27051 evaluated in Krishna district in Manimeswaram village, recorded 6180 kg ha^{-1} grain yield with tolerance to yellow stem borer.

Among 45 fertile disomic wide cross derivatives of *O. brachyantha*, *O. longistaminata* and *O. rufipogon,* few lines such as CR 3993-215-14-2, CR 4211-41-5-7, CR 4223-33-15-19-6, CR 4224-23-5-14-1, CR 4225-19-15-13-5 and CR 4229-22-1-7-3 were found promising based on survivability at seedling stage at farmer's field of Pokhariapada Village of Erasama block of Jagatsinghpur district under salinity and waterlogged conditions during *kharif* 2021.

Development and release of variety for coastal saline areas

CR Dhan 412 (NICRA Dhan: Luna Ambiki) was released and notified for Odisha in 2021 for cultivation in coastal saline areas (Fig. 1.22). It was derived from Gayatri/ SR 26B cross. SR 26B is tolerant to both salinity and stagnant flooding. CR Dhan 412 was also found tolerant to moderate salinity stress (EC 4-7 dS m^{-1}) and also moderately tolerant to stagnant flooding. It has long maturity duration (142 days) with 118 cm plant height. The mean grain yield was found around 4.4 t ha^{-1} (Fig. 1.22).

Fig. 1.22. Field view of CR Dhan 412 (NICRA Dhan: Luna Ambiki).

Harnessing heterosis for enhancing yield and quality of rice

Development of CMS, restorer and hybrid combinations

Collectively, 1158 test crosses involving nine CMS and 125 pollen parents (with high GEBVs) were evaluated and 26 heterotic hybrids (>15% heterosis over respective duration hybrid checks), 12 promising maintainers and 63 good restorers (> 85% fertility restoration) were identified. Besides, 38 mid-early to medium duration hybrids with >15% yield superiority over respective duration checks, US 314 and Rajalaxmi were re-evaluated under station trials. Mid-early duration CMS, CRMS 57A (WA) (CRMS31B/25B) possessing 34% outcrossing and >60% dual stigma exertion was utilized in crossing program. Medium duration CMS, CRMS58A (WA) under genetic background of INH1001 possessing MS grains and > 30% out crossing was developed. In addition, 73 sterile crosses (BC_3-BC_8) with sustainability (BLB, BPH resistance traits) and seed producibility were advanced.

Hybrid release / New promising hybrid combinations

Long duration hybrids, CR Dhan 702 (IET25231) and CR Dhan 703 (IET25278) were released and notified for cultivation under irrigated shallow-lowland and rainfed shallow lowland and *boro* ecosystem, respectively of Odisha (Fig. 1.23). Both the hybrids are also being tested under adoptive trials in Bihar for state notification.

Fig. 1.23. Field view of rice hybrid CR Dhan 703 notified for Odisha.

Trait development/genetic diversification of parents and hybrids

Pyramiding of four BB resistant genes (*Xa4*, *xa5*, *xa13* and *Xa21*) in CRL 22R and Pusa 33-30-3R were advanced to BC_2F_5; salinity and submergence tolerance in IR42266-29-3R (restorer line) were advanced to BC_3F_2. Introgression of BPH resistant/ tolerant in improved-IR42266-29-3R and improved CRMS 32A were advanced to BC_2F_3. Pyramiding of long stigma trait in CRMS 31A and CRMS 32A from wild donor *O. longistaminata* was advanced to BC_3F_6. Genetically fixed lines with long stigma were started conversion into new CMS, population was advanced to BC_3F_1 which recorded ~60% outcrossing. Introgression of *Rf* genes (*Rf3* and *Rf4*) was advanced to backcross generation in partial restorers Akshaydhan, Azucena (BC_3F_5), INH 10001 and NP 801(BC_2F_5). Introgression of WC genes in partial restorer but good combiner inter-sub specific line SR 11-3-1 (*ixj*) from Khawo Hawm (donor) was advanced to BC_2F_2 generation.

Seed production of parents/hybrids

Altogether 632.0 kg truthful labeled (TL) seeds of 32 hybrids including three released, Rajalaxmi (138.0 kg), Ajay (102.0 kg) and CR Dhan 701 (164.0 kg) were produced. Besides, 145.0 kg breeder seeds of 13 CMS, CRMS 31A (36.0 kg) and CRMS 32A (62.0 kg) and nucleus seeds of released hybrids were produced. Agro-practices for seed production of six new combinations were refined.

Identification of novel transcript from RNA-Seq data in rice hybrids and parental lines and validation using Real Time PCR analysis

A number of novel transcripts of two popular rice hybrids, Ajay and Rajalaxmi along with their parental lines were identified using RNA-Seq data of two developmental stages (panicle initiation and grain filling stages) and validated through expression analysis using qRT PCR. High quality reads of all tested rice genotypes were mapped with *Oryza sativa* spp. *japonica* reference genome sequence using *Oryza sativa* GFF file with Tophat v1.3.3 software and also assembled with reference based transcript followed by expression analysis using cufflinks v1.3.0 software. Gene feature GFF file contains gene based mRNA and exon information of *Oryza sativa* spp. *japonica.* Some of them were partially or fully mapped to gene models in the form of GFF file. However, some novel exons were identified, which are not present in gene models *i.e.* in reference GFF file. The gene names "CUFF" were prefixed where *O. sativa* annotations does not match to the predicted gene models. The identified novel transcripts were searched for the similarity against other eukaryotes using Swiss Prot-Uniprot database and BLASTX programme at E-value cut-off 1e-05. The details of novel transcripts are presented in Table 1.3.

Table 1.3. Details of novel transcripts identified using RNA-Seq data in two rice hybrids and their parental lines at two developmental stage.

Sample Name	No. of Novel Transcript	No. of Annotated Transcript
CRMS 31A-S1	5486	3919
CRMS 31A-S2	6103	4238
CRMS 32A-S1	3998	2882
CRMS 32A-S2	6738	4733
CRMS 31B-S1	3437	2455
CRMS 31B-S2	6921	4776
CRMS 32B-S1	1714	1241
CRMS 32B-S2	5830	4134
IR 42266-29-3R-S1	4766	3386
IR 42266-29-3R-S2	6439	4467
Ajay-S1	3135	2207
Ajay-S2	5285	3633
Rajalaxmi-S1	5636	3925
Rajalaxmi-S2	6874	4818

S1: Panicle initiation stage, S2: Grain filling stage

The novel transcript, CUFF.10120.2 showed 7.48 folds higher expression level as compared to other identified transcripts. Simultaneously, the novel transcripts, CUFF.14964.1, CUFF.861.2, CUFF.8384.2 and CUFF.1417.3 were found to be up-regulated in Ajay than other parental lines at grain filling stage (Fig. 1.24). Similarly, up-regulation of CUFF.7824.1 was noticed in Rajalaxmi at grain filling stage. In case of panicle initiation stage, restorer line showed higher expression of 10 tested transcripts as compared to other genotypes used.

Development of new generation rice (NGR) for breaking yield ceiling

The Variety CR Dhan 316 has been identified during 2021 by Odisha State Seed Sub-Committee for Agricultural Crops for Irrigated Medium of Odisha state (Fig. 1.25). It shows the yield potential of 9.6 t ha^{-1}.

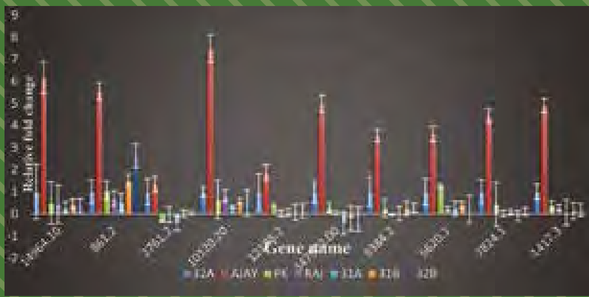


Fig. 1.24. **Relative fold change (FC) (qRT-PCR) of selected novel transcripts of rice hybrids Ajay and Rajalaxmi and their parental lines at grain filling stage.**

Fig. 1.25. CR Dhan 316 in dough stage.

Development of elite cultures for NGR traits related to grain yields

New Generation Rice (NGR) is high-yielding rice conceptualized for breaking yield ceiling under favourable conditions based on the ideotype concept. Very high yielding lines embodied with traits defined under NGR were selected (CR 3856-44-22-2-1-11-4-1-10 (SRB1-10), which performed best with 8.37 t ha^{-1}, followed by CR 3967-40-3-1-1-1-2 (SR 15-2-1) with 7.67 t ha^{-1} and CR 4212-12-17-1-1-2-1-1 (C 824-1-2-1) with 7.54 t ha^{-1}. Similarly other two genotypes CR 3856-44-22-2-1-11-4-5-5 (SRB 5-5) and CR 3856-44-22-2-1-11-4-1-6 (SRB 1-6) could perform modestly with 6.64 t ha^{-1} and 6.63 t ha^{-1} yield, respectively. Most importantantly, these genotypes recorded yield increment of 60.9, 47.5, 45, 27.7 and 27.5 percentage, respectively compared to popular check variety Swarna (5.2 t ha^{-1}). In 2021, twenty-nine entries were nominated to AICRIP testing (IVT), whereas, one was promoted to AVT2 late (CR 3969-17-2-2-1-1-1-1) and four were promoted to AVT1 *viz.*, one in RSL (CR 3967-8-3-2-2-1-1); one in SDW (CR 3936-11-1-1-1-1-1) and two in *Boro* (CR 4212-12-17-1-1-2-1-1, CR 4312-5-1-1-3). The genotypes *viz.*, CR 3938-2-2-1-1-1-4, CR 4121-36-21-1-1-4-2, CR 4121-36-21-1-1-4-9, CR 3856-44-22-2-1-11-4-6-2-1 and CR 3969-24-1-2-1-10-1-5 performed superior with moderate resistance of score of 1-3, whereas CR 3938-2-2-1-1-1-4 was found to be highly resistant with high yield and BLB score of 1. This is a significant lead for further work (Fig. 1.26).

Fig. 1.26. **Susceptible culture (CR 409-15-2-1) (Left), Resistant culture (CR 3938-2-2-1-1-1-4) (Right).**

SRA 170 (*xa5, Sub1*) was found to be highest yielder with 7.28 t ha^{-1} followed by SRA 2-19 (*xa5, Xa21, Sub1)* with 6.77 t ha^{-1} and SRA 142-1 *(Xa21, xa13, Sub1*) with 6.38 t ha^{-1}, respectively with yield increment of 30.5%, 21.3% and 13.1%, over recurrent parent (5.58 t ha^{-1}), whereas, SRA-2-101 (*Xa21*, *xa13* and *xa5*) recorded 5.9 t ha^{-1} with 5.7% yield advantage over recurrent parent without BLB resistance genes (Table 1.4). Earlier 30 novel QTLs were identified in NGR cultures. Twenty SSRs were co-localized with more than two traits. It was tried to validate the SSRs and it was found that four SSRs, *viz.*, RM 1132, RM 19, RM 204 and RM 297 could validate the QTLs in NGRs, hence could be utilised further in NGRs in molecular studies.

Validation of *IPA1*

Forty-eight genotypes were used for clustering NGR and check genotypes using functional *IPA1* markers (Fig. 1.27). Very high yielding NGRs and checks were clustered into three groups, where five NGR genotypes including Swarna (circled in red) were found in one cluster having high yield stability.

Identification of micro-RNAs for grain sterility/ fertility

In a study for miRNA regulation of spikelet specific grain development is low against high sterile recombinant inbred lines of NGRs, namely CR 3856-62-11-3-1-1-1-1-1-1 (SR 157) and CR 3856-63-1-1-1-1-1-1-1 (SR 159), respectively, and inferior verses superior spikelets were compared during first 10

Table 1.4. Targeted trait improvement in available NGR cultures.

Sl	NGR	Genes	Plot. Yield (t ha^{-1})	% incr Ch.	PH	TL	PL	FLL	FLW	FG	TG	TGW
S 1	SRA-170	*xa5, Sub-1*	**7.28**	**30.5**	112.6	7	26.6	33.6	1.86	180	195	22.3
S2	SRA 2-19	*xa5, Xa21,*	**6.77**	**21.3**	122.6	7.6	6.8	32	194	172	200	18.7
S 3	SRA 142-1	*Xa21, xa13, Sub-1*	**6.31**	**13.1**	117.8	7.6	29.6	30	1.74	196	226	22.3
S4	SRA 3-41	*xa5, Xa21, Sub-1*	6.21	11.3	127.0	6.8	23.8	36.2	2.04	181.8	213.4	21.66
S5	SRA-148-99	*xa5, xa13, Sub-1*	6.13	**9.9**	110.4	7.4	26	33	2.08	169	188	21.4
S6	SRA-2-101	*Xa21, xa13* and *xa5*	5.90	5.73	115.4	6.8	26.6	37.6	2.04	160.4	184.3	20.56
RC	SR 1-3-1 (RP)	Nil	5.58	-	120.9	5.7	27.9	31.6	2.04	164.8	188.6	23.75

Fig. 1.27. Clustering of NGRs (Dendogram) using SPL14-P-Indel, SPL14-12-SNP, SPL14-04-SNP primers.

days after anthesis (Fig. 1.28). Grain filling was poorer in SR159 than SR157 and inferior spikelets in the former were most vulnerable. Between the cultivars, overall expression of unique miRNAs with targets on ethylene pathway genes was higher in SR159 than SR157 and the situation was opposite for auxin pathway genes. Precision analysis in psTarget server database identified up-regulation of MIR2877 and MIR530-5p having *Os11t0141000-02* and *Os07t0239400-01* (*PP2A* regulatory subunit-like protein and ethylene-responsive small GTP-binding proteins) and MIR396h having *Os01t0643300-02* (an auxin efflux carrier protein) and *Os01t0643300-01* (a PIN1-likeauxin transport protein), as targets with highest probability at anthesis and five days after anthesis, respectively, in the inferior spikelet and the fold change values of DGE matched with pattern of gene expression (relative transcript level) in the qRT-PCR studies conducted for relevant miRNAs and protein factors for ethylene and auxin signaling.

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

Editing stomatal density gene, EPFL9 for improving drought tolerance through CRISPR/Cas EPIDERMAL

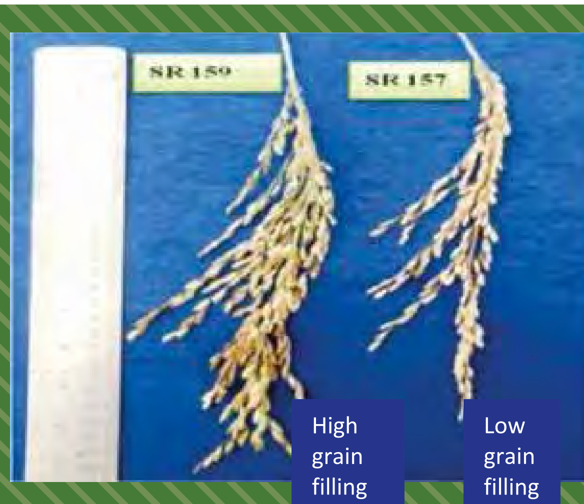


Fig. 1.28. Panicles of RILs SR 159 and SR 157.

PATTERNING FACTOR (EPF) and EPF-LIKE (EPFL) signaling peptides maintain the correct density and spacing of stomatal precursor cells through binding ERECTA-family receptors. The sgRNA oligos were taken up for cloning into shuttle vector- pYL sgRNA containing the guide RNA cassette under the control of rice codon optimized OsU6q promoter. Two complementary oligo nucleotides of sgRNAs were annealed and cloned into the BsaI sites of pYL*CRISPR*/*Cas9* pubi-H (Fig. 1.32). Further, the vector - pYL*CRISPR*/*Cas9* pubi-H harboring sgRNA for target gene was transformed into *DH5α E. coli* competent cells and transformation was confirmed by colony PCR and plasmid sequencing.

Multiple SWEET genes for BB resistance in rice

The gene specific primers for *SWEET-11, 13* and *14* were designed for the amplification of promoter and genic regions. Amplified products were sequenced and the TAL effectors binding sites (EPE) were analysed. Accordingly, gRNAs were designed for these three genes for development of *CRISPR*/*Cas-9* construct and subsequent rice transformation for editing.

In vitro mutation for trait improvement in rice

A protocol was established for *in vitro* mutation in *indica* rice varieties (Shaktiman and Kalajeera) using EMS mutagen. Totally, 167 mutants developed from Shaktiman, were evaluated to check the stability out of which, 47 mutants were found homozygous in M_3 generation. Simultaneously, 16 plants of Kalajeera were generated with the target of height reduction, which are under phenotypic evaluation.

Identification of Morphological indicators for discrimination of Haploids from Diploids

A set of 46 putative haploid plants (on the basis of plant height) derived from the F_1s of IR20 x Mahulata along with its two parents were evaluated. The study also highlights the smaller size floret and anther and small desiccated microspores as other morphological markers (Fig. 1.29) for distinguishing the haploids from DHs/diploids.

Identification of QTLs for vegetative stage drought tolerance in rice

A total of 118 DHs derived from IR20 (Susceptible) x Mahulata (Tolerant) along with the two parents were screened under protected net house condition (Fig. 1.30) and a total of 416 STMS and SNP markers were used for genotyping. Based on the result, a total of 13 QTLs for eight traits were identified (Table 1.5).

Table 1.5. Details of QTLs identified during drought screening.

Trait Name	Chromo-some	QTL name	Position (cM)	Left Marker	Right Marker	LOD	PVE (%)	Add
PH	3	*qPH-3.1*	37	chr03_6283461	chr03_3657643	6.4	13.1	9.8
	9	*qPH-9.1*	34	chr09_2298381	chr09_17707080	3.1	13.1	-15.5
TN	4	*qTN-4.1*	71	chr04_30174083	chr04_23046635	2.9	3.3	-1.2
LR	2	*qLR-2.1*	57	RM110	chr02_22340836	3.1	10.0	-1.6
LA	5	*qLA-5.1*	199	IRGSP1_ C05_13854594	chr05_6129755	6.5	23.5	-6.1
RWC	1	*qRWC-1.1*	77	SCT1_4	chr01_42425574	4.9	3.0	-14.2
	2	*qRWC-2.1*	7	chr02_35818319	chr02_21060669	2.7	8.4	19.3
	8	*qRWC-8.1*	61	chr08_20053642	chr08_2208785	3.6	7.6	20.8
LCT	2	*qLCT-2.1*	301	RM207	RM482	3.4	10.0	0.3
	2	*qLCT-2.2*	625	RM6374	RM250	2.6	12.5	0.3
CCI	5	*qCCI-5.1*	203	chr05_6833061	chr05_7195992	4.4	13.1	8.6
	12	*qCCI-12.1*	100	chr12_14060565	chr12_14936674	3.2	8.8	3.9
LN	5	*qLN-5.1*	190	chr05_22295097	chr05_23661597	2.7	10.6	2.3

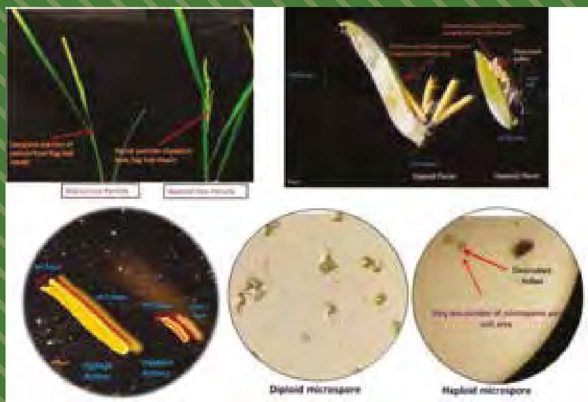


Fig. 1.29. Morphological indicator for discrimination of Haploids from Diploids.

DHs in final artificial drought stress condition

Fig. 1.30. Phenotyping of DHs mapping population of IR 20 x Mahulata for vegetative drought stress in Net house.

Evaluation of doubled haploid population for grain morphological traits

The doubled haploid (DH) lines derived from the cross between Pokkali and Savitri were evaluated for grain length, grain width and L/B ratio. PCA analysis revealed one major principal components (eigen value >1) which contributed to 75.45% of the total variation observed in the DH lines studied (Table 1.6). The first Principal Component (PC1) had an eigen value of 2.27 and was strongly associated with L/B ratio (0.66) followed by grain length (0.49), while grain width (-0.57) contributed negatively to the total variation.

Efficiency of developed androgenic protocol for generation of DHs in other crops

Androgenic protocol developed at the Institute was successfully implemented in sugarcane which proved its efficiency by producing microspore derived green plants at ICAR-Sugarcane Breeding Institute, Coimbatore.

Table 1.6. Principal Component Analysis in doubled haploid population.

Characters	PC 1	PC 2	PC 3
Grain length	0.49	0.80	-0.35
Grain breadth	-0.57	0.60	0.56
L/B ratio	0.66	-0.08	0.75
Eigen values	2.27	0.70	0.04
% variance	75.48	23.21	1.30

Yield improvement of IPA1 edited rice varieties

The edited lines developed from Swarna, Naveen and HKR127 showed ~ 22.3% increase in yield/plant as compared to their respective parents. Besides, panicle architecture and grain morphology varied significantly among all the edited lines (Fig. 1.31).

Fig. 1.31. Panicle Architecture in *IPA1* edited T_1 lines.

Development of Novel Genomic Resources for Rice

Identification and mapping of QTLs/ genes associated with resistance/ tolerance to biotic and abiotic stresses and straw quality.

Based on 22,214 high-quality SNPs (generated by GBS), an association mapping panel of 180 genotypes was constituted for the identification of QTLs for abiotic and biotic stresses.

Two mapping populations containing >200 RILs ($F_{5:6}$) of the cross Pooja (S)/ Thavalakannan (R), and >300 F_2 of the cross Tapaswini (S)/ Thavalakannan (R) were developed for the identification of QTLs/ genes associated with resistance to bakane disease. A total of 116 (12.0%) out of 967 and 100 (17.86%) out of 560 microsatellite markers showed polymorphism between Pooja & Thavalakannan, and Tapaswini & Thavalakannan, respectively. Genotyping of RILs is in progress (Fig. 1.32).

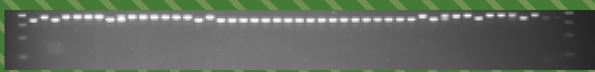


Fig. 1.32. Genotyping of RILs of the cross Pooja and Thavalakannan with polymorphic marker *OsbHLH107*. Lane 1 and 52: 50 bp marker; lane 2: Thavalakannan; lane 3: Pooja; lane 4 to 51: RILs.

An association panel of 133 rice genotypes was evaluated for straw digestibility in collaboration with International Livestock Research Institute (ILRI). A significant phenotypic variation of straw was observed for digestibility (In-Vitro Organic Matter Digestibility, IVOMD). The IVOMD ranged from 41.75% to 46.39% with a mean of 44.38%. The highest digestibility exhibited in the rice genotypes Kalburi, Jagle Boro, IC282518 and IC277274. The association mapping panel was genotyped with 133 SSR markers. Marker-trait association identified three novel QTLs, one each on chromosome 1, 4, and 5. Individual QTL explained 5.4% to 17.8% of phenotypic variations. The QTL, *qDI5.1* explained 17.8% of phenotypic variation for IVOMD of rice straw, and the marker RM334 was found to be linked to the QTL, *qDI5.1*. Structure analysis showed two sub-populations among 133 rice genotypes (Fig. 1.33).

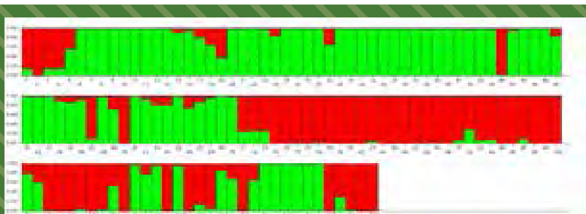


Fig. 1.33. Structure analysis shows two sub-populations among 133 rice genotypes based on the genotype data of 133 SSR markers.

Gene prospecting and epigenetics for tolerance to abiotic stresses

Analysis transcriptome data of N22 subjected to heat stress and control (non-stress) conditions downloaded from the database identified 1877 genes down-regulated, while 590 genes up-regulated (Fig. 1.34). Few major genes would be used for allele mining.

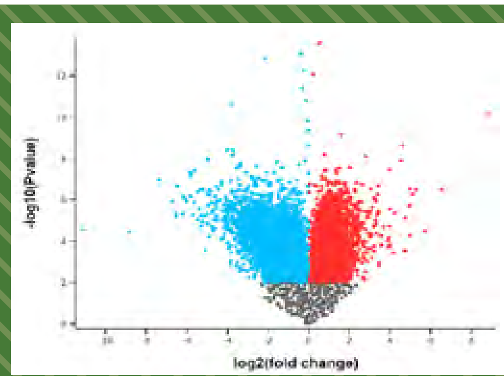


Fig. 1.34. Transcriptome data of N22 subjected to heat stress and control (non-stress) conditions downloaded from database, which identified 1877 and 590 genes down-regulated and up-regulated, respectively.

Functional validation of putative candidate genes for resistance to biotic stresses

Expression analysis of 15 putative genes in resistant parents (Salkathi and CR3006-8-2) and susceptible parents (TN1 and Naveen) identified 10 genes (LOC_Os04g02040, LOC_Os04g02510, *LOC_Os04g02520, LOC_Os04g02860, LOC_Os04g02920, LOC_Os04g21890, LOC_Os04g22900, LOC_Os04g32940, LOC_Os04g34250 and LOC_Os04g34330*) associated with BPH resistance QTLs in Salkathi (Fig. 1.35). These genes will be validated in BILs of the cross CR3006-8-2 (Pusa44/Salkathi) and Naveen.

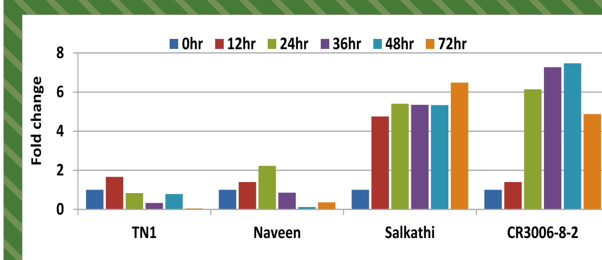


Fig. 1.35. Expression analysis of candidate gene (*LOC_Os04g02040*) in treated (12 hr, 24 hr, 36 hr, 48 hr and 72 hr) and non-treated (0 hr) samples of tolerant (Salkathi and CR3006-8-2) and susceptible (TN1 and Naveen) parents with BPH. Susceptible parents showed lower expressions, while tolerant parents showed enhanced and higher expressions.

Different activities undertaken at this division through 11 projects are imperative to focus on rice improvement for tackling the changing climatic scenarios along with the emerging socio-economic ambitions of the rice stakeholders. These activities also helped to achieve novel breakthroughs in the field of rice cultivation. The various technologies developed, including the varieties, and hybrids would enable the rural rice farmers to be self-sustainable in rice cultivation and production. Besides, nutrient rich rice will provide nutritional security. The division is also entrusted to produce and supply quality seeds to meet the increasing demand of the farmers, so that farmers can cultivate ecology based varieties to harvest the bounty of yield. The results of these projects may also enable the policy makers at regional and national levels towards making necessary amendments in the future agricultural policies for addressing the emerging challenges related to rice.

PROGRAMME-2

Enhancing Productivity, Sustainability and Resilience of Rice Based Production System

Productivity, Profitability, resource use efficiency and climate change resilience are major goals of sustainable rice production. The strategy to realize these goals should include a holistic approach encompassing technical, allocative and environmental aspects of resource use efficiency. Based on this principle the programme was planned to develop, validate and disseminate innovative cutting edge technologies that apart from enhancing productivity and profitability will also ensure environmental sustainability. The main objectives of the programme are (i) developing precision nutrient and water management framework using advanced digital, sensor based and nano technology (ii) site specific planning and development of cropping and farming system models and strategy of weed management for enhanced productivity, the profitability, (iii) economic and environmental friendly utilization of rice residues by resource conservation technologies and microbial intervention, (iv) customize new prototypes and improvement of identified machineries for small farm mechanization, (v) development and evaluation of rice-specific microbial formulation for nutrient, pest and residue management (vi) impact assessment of land use and land cover change on ecosystem services from rice based cropping systems and (vii) vulnerability analysis and prioritization of climate smart agricultural technologies for enhancing resilience in stress prone rice ecologies.

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

Evaluation of riceNxpert for real time N application

Field experiment was conducted during *kharif* 2020 with variety Swarna *Sub1* and Naveen under five different N management options T_1-Zero nitrogen application; T_2- Conventional recommended dose of N application (RDN); T_3-CLCC based N application; T_4-riceNxpert based N application and T5-SPAD meter based N application. All the treatments were replicated thrice in random block design. Results revealed that performance of real time N management using riceNxpert, CLCC and SPAD meter were at par. Overall 8.5-12.7% increase in yield in riceNxpert based N application could be achieved over conventional RDN. The riceNxpert based N application could enhance agronomic N use efficiency and N recovery efficiency by 30-40% and 8.6-14.7%, respectively as compared to RDN.

Smart delivery of phosphate fertilizers through nanoclay polymer composites loaded with low molecular weight organic acids and phosphorus

Nanoclay polymer composites (NCPC) was synthesized by copolymerization of partially neutralized acrylic acid, acrylamide and nanoclay (kaoline) using ammonium per-sulphate as radical initiator and N, N'-methylene bis-acrylamide as cross linker. Conventionally, nutrient is loaded into it by dissolving the nutrient in water, followed by adsorption, drying and grinding. We used three low molecular weight organic acids (LMWOA) (citric, malic and tartaric acids) and three sources of P (DAP, SSP and rock phosphate) making nine combinations. Uniform method of loading of these LMWOAs and P sources into NCPC was a challenge due to variable solubility of P sources. The procedure was modified to add DAP and citric acid in between the process of polymer formation. Thus, we got five variants NCPC (pure NCPC), NDR (DAP added after synthesis of NCPC), NDCAR (DAP and citric acid added after synthesis of NCPC), ND (DAP added in between the process of polymer formation), NDCA (DAP and citric acid added in between the process of polymer formation). P release from the above material was almost similar to that from the NCPC loaded P developed conventionally. Addition of DAP and CA during the process and conventional method of loading through water provided almost similar pattern and quantity of P release in water. Application of DAP using NCPC as smart delivery system to soil slowed their release compared to raw DAP. Simultaneous application of DAP and CA maintained higher concentration of P probably due to chelation of reactive sites of Fe and Al by CA. Water absorbency measured by the weight of water absorbed per unit weight of NCPC was 83-88. The X-ray diffraction analysis of polymer structure revealed a hump at lower angle (<3°2Θ) indicating an increase in the interlayer distance due to the nanoclay intercalation (Fig. 2.1).

Diazotrophic bacterial community under influence of 51 years old fertilizer applied paddy soil

nifH-targeted Illumina HiSeq sequencing was analyzed for assessment of diazotrophic bacterial community under 51 years old long-term fertilizer applied paddy soil. The results revealed that continuous application of N-alone suppressed *Bradyrhizobium japonicum*, uncultured N-fixing bacteria and many other N-fixing bacteria, while application of FYM with or without NPK encouraged most of N-fixing bacteria (Fig. 2.2). Interestingly, operational taxonomic unit of *Geobacter pickeringii* was lower in N-alone treatments and negligible in FYM+NPK treatment.

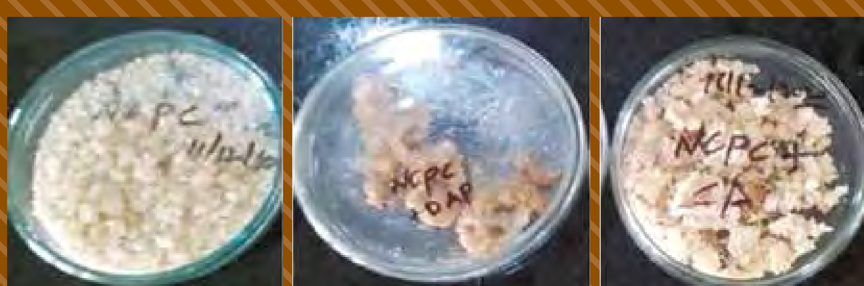


Fig. 2.1. Pure NCPC, NCPC+DAP, NCPC+ DAP+ CA

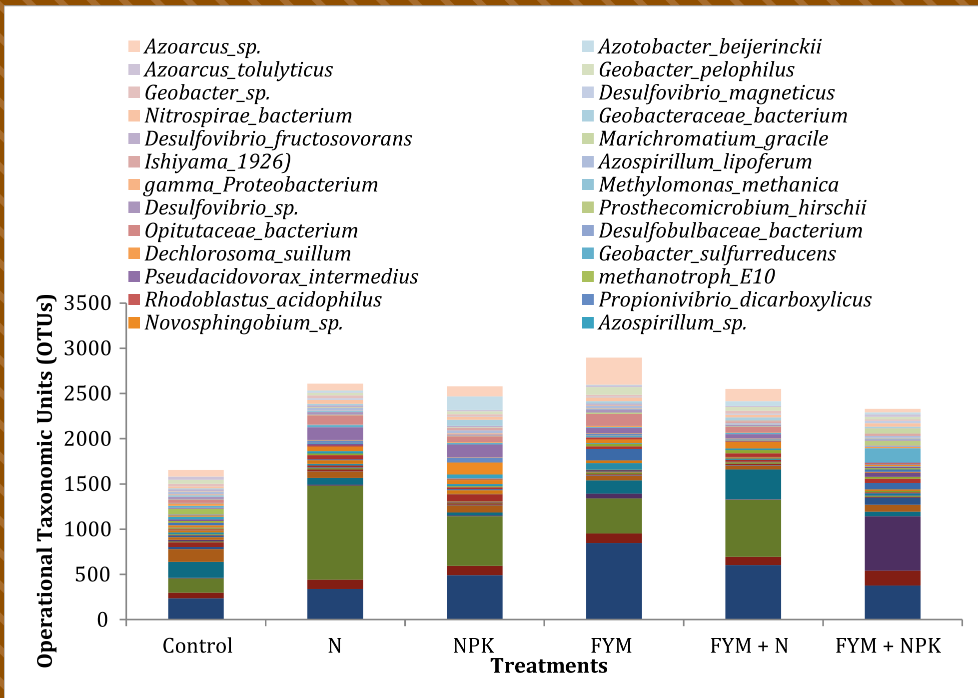


Fig. 2.2. Abundance of diazotrophs OTUs under influence of 51 years old LTFE paddy soil.

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

Capacity building and upscaling of rice based integrated farming system.

Seven trainings of four days duration were conducted on rice based integrated farming system for 188 farmers. Twenty-two rice based integrated farming system models developed at NRRI were replicated at farmers field of Tirtol, Ersama, Kujang, Nuagaon and Balikuda blocks of Jagatsinghpur district and Bramhagiri, Pipli, Nimapada and Puri Sadar blocks of Puri district. Land shaping was done in the farmers field and inputs were supplied (Fig. 2.3).

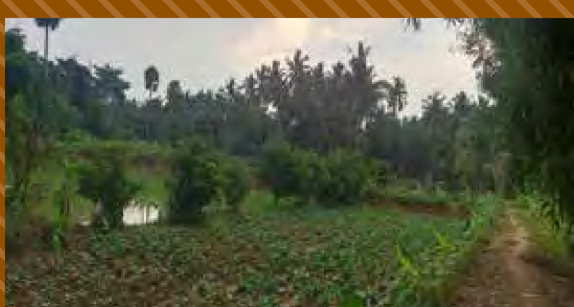


Fig. 2.3. IFS model demonstration at Pipli block of Puri District.

Elucidation of factors affecting the adoption of farming system models by use of expert system/ models

The prioritization matrix was prepared for components of farming system model (FSM) using expert opinion. Several indicators were used by consulting literatures, (Fig. 2.4). Weightage was given in such a way that the total weightage amounted to 100. Then the experts score in 1-10 scale to each of the components of farming system were obtained. Scores were based on weighted average. Information on various drivers controlling adoption of FSM were collected, such as, family factor (education, total number of members, number of earning family members), social factor (social affiliation, farming experience), land factor (land holding, leased in land, leased out land, share cropping, fallow land) and financial factor (annual income, share of farm income in annual income, access to credit facility, availability of off farm job).

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

Rainfall variability and extreme rainfall events in different blocks of Dhenkanal District

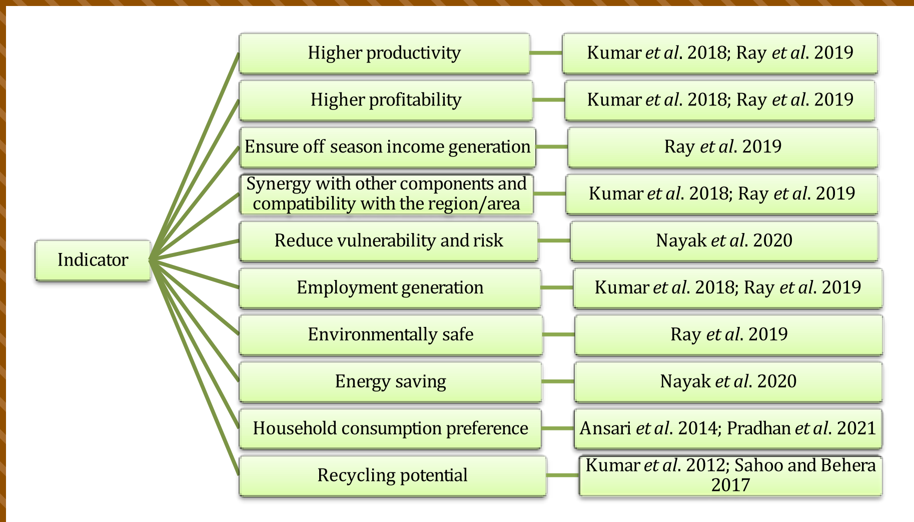


Fig. 2.4. Prioritization of components of FSM using expert opinion.

In order to assess the drought vulnerability index, certain weather parameters such as total annual rainfall, consecutive wet days (CWD; maximum number of days with RR ≥ 1 mm) and consecutive dry days (CDD; maximum number of consecutive days with RR ≥ 1 mm) were analyzed for different blocks of the Dhenkanal district. The daily meteorological data from 1988 to 2021 of each block i.e. Dhenkanal, Gondia, Odapada, Hindol, Kamakhyanagar, Bhuban, Parjang, Kankadahad were collected from Odisha rainfall monitoring system, Government of Odisha. Weather data were analyzed using RClimDex software. It was observed that total annual precipitation (PRCPTOT) of Dhenkanal district varied from 629.5 – 2762.0 mm during the study period of 34 years, while the maximum PRCPTOT was observed in Kamakhyanagar block (2762.0 mm) and the lowest in Odapada block (629.5). A significant ($p<0.05$) decreasing trend in total annual rainfall was observed for Gondia, Odapada and Kamakyanagar blocks, while for other blocks no significant trend was observed. Similarly, for consecutive wet days (CWD) the variability among all the blocks of Dhenkanal district varied from 1 to 27 days. A significant ($p<0.05$) increasing trend was observed for Dhenkanal Sadar block, while for other blocks no significant trend was observed. The values for consecutive dry days varied from 29 to 291 days and there was no significant trend observed for all the blocks.

Standardization of agronomic practices for double zero tillage rice-rice system

Prospects of moving from conventional tilled transplanted rice to zero tilled direct seeded rice (ZT-DSR) has been widely researched and discussed. However, double zero tillage rice (combinations of ZT-TPR and ZT-DSR) is a relatively new concept. Therefore, an experiment was conducted to study the effect of rice-rice system in ZT under DSR and TPR and to decipher their similarity/ dissimilarity, thereof. The main plot consisted of rice- rice system with (1) direct seeded rice (DSR) (2) puddle transplanted rice (TPR). The treatment combinations were: ZT-DSR, ZT-TPR, conventional-DSR, conventional-TPR. The data reveals that TPR- TPR system recorded higher grain yields compared to DSR-DSR cropping system both under ZT and conventional systems. Overall, *rabi* season yields were >20% higher than *kharif* season yield in zero tillage. This establishes that under zero tillage, *rabi* rice can be recommended. The soil parameters SOC (%) and available N were relatively higher in ZT (both DSR and TPR) while SOC (%) was highest in ZT- TPR. Available P and K were relatively higher in conventional system.

Evaluation of Arsenic partitioning in rice

Fifteen rice cultivars were screened and evaluated for their arsenic (As) loading in different plant parts. Local aromatic rice (LAR) varieties *viz.,* Badshabhog, Gobindbhog, Geetanjali, Pusa Sugandha-2 contain less As in the consumable part (polished rice). The As concentration in polished rice of LARs varied from 0.16 to 0.25 mg kg^{-1}, whereas the range was higher for HYVs/hybrid varieties which varied from 0.22 to 0.36 mg kg^{-1}. However, among HYVs, Shatabdi had the lower As in polished rice. The As accumulation in rice grain is significantly negatively correlated with Fe plaque formation on rice root (r^2=0.728, p<0.01). Irrespective of cultivars As accumulation in different grain parts followed the sequence of Husk > Bran > Polished rice.

Assessment of mined areas (reclaimed and non-reclaimed) of Odisha with special reference to heavy metals for sustainable production

In order to study the degree of contamination at mined and dumping sites and its peripheral areas along with control zones, soil and water samples were collected from the chromite mined areas in Sukinda valley of Odisha. The three sites are designated as mined and dumping site (S1); periphery areas (within 5 km; S2) and control zones (5 km away from the mine; S3). The samples were analyzed for various soil and water properties and it was observed that considerable degree of contamination was observed at mined and dumping sites while in peripheral areas moderate degree of contamination was reported. The mining site is highly contaminated with Cr (11.9 ± 9.68 mg kg^{-1}), Fe (101.3 ± 32.03 mg kg^{-1}), Cu (0.9 ± 0.12 mg kg^{-1}), Pb (0.9 ± 0.12 mg kg^{-1}), Zn (0.9 ± 0.12 mg kg^{-1}) and Mn (6.2 ± 2.84 mg kg^{-1}). Chromium content was found very high (11.9 ± 9.68 mg kg^{-1}) in mined and dumping site (S1), whereas the concentration was low for control zones (0.74 ± 0.83 mg kg^{-1}). The peripheral areas showed moderate degree of contamination for Cr and Fe and low contamination for Mn and no contamination for Pb and Zn.

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

Land use/land cover change in coastal districts of Odisha in last three decades

Land use, land cover change analysis was done for six coastal districts of Odisha (Balasore, Bhadrak, Kendrapada, Jagatsinghpur, Puri and Ganjam) at 5-years interval from 1990 to 2018. A steady decline in agricultural area dominated by rice-based cropping systems was seen in all districts from 1990 to 2018. However, the highest reduction in agricultural area was recorded in Balasore (17.6%), followed by Jagatsinghpur (12.9%), Puri (9.9%), Kendrapada (6.9%), Bhadrak (6.6%) and Ganjam (5.8%) in last three decades. The rate of loss of agricultural land has been steadily increasing. Between 1990 and 2018, forest cover decreased by 2.6%, 3.1%, and 7.8% in Ganjam, Kendrapada, and Puri, respectively, whereas it increased in Balasore (5%), Bhadrak (35%), and Jagatsinghpur (11.3%). For all districts, there has been a consistent upward trend in built-up area during last three decades. Balasore had the largest growth in built-up area (114.8%), while Bhadrak had the smallest (80.7%). Starting from 1990 to 2018, roughly 504.4 km^2 of agricultural land in Balasore was changed to other land uses, including built-up land (466.9 km^2) and forest (17.8 km^2).

Developing agronomy for new generation rice and rice based cropping system

Harnessing the agronomic potential of new generation rice through exploitation of seedling vigor and crop geometry

Effect of age of seedlings, seed treatment and seeding density in nursery on yield and yield attributes of new generation rice (CR Dhan 314) was studied. The experiment was laid out in split-split plot design and replicated thrice. The treatments consist of age of seedlings in main plot (30 and 45 days old seedlings), seed treatment in sub plots (*Pseudomonas* @ 10 g kg^{-1} of seeds, *Trichoderma* NRRI formulation @ 10 g kg^{-1} of seeds and control) and seeding density in nursery in sub-sub plots (40, 50 and 60 g m^{-2}). Experimental findings revealed that age of seedlings has significant effect on yield and yield attributes of CR Dhan 314. Older seedlings of 45 days resulted decrease in grain, straw and biological yield by 9.0, 8.2 and 7.5%, respectively over 30 days old seedlings. Seed treatment with biocontrol agents significantly increased the grain, straw and total biological yield. Application of *Trichoderma* NRRI formulation @ 10 g kg^{-1} of seeds as seed treatment significantly increased the grain, straw and total biological yield by 13.1, 12.2 and 12.6%, respectively which was at par with the *Pseudomonas* treatment. The increase in grain yield was mainly due to increase in number of panicles per unit area. Similarly, seeding density on rice nursery have also influenced the yield and yield attributes of new generation rice. Seeding density of 50 g m^{-2} recorded highest grain yield of 7.03 t ha^{-1} and it was at par with seed density of 40 g m^{-2}.

Agroecological intensification of rice-maize cropping system through introduction of new generation rice and conservation agriculture

Effect of stand establishment methods, varieties and agroecological intensification on productivity of rice -

maize cropping system was studied. The experiment was laid out in a split plot design with two production systems i.e. conventional and conservation agriculture in main plots, two varieties i.e. CR Dhan 314 (NGR) and Swarna in sub plot and three agro-ecological intensifications in dry season i.e. Maize + Groundnut, Maize + Cowpea and Maize in sub-sub plots replicated thrice. In *kharif*, the grain and straw yields of rice were significantly higher with DSR (conventional agriculture) compared to ZTR (conservation agriculture). Although lower grain yield was recorded in ZTR with both the varieties compared to DSR, the yield reduction was lower in CR Dhan 314. CR Dhan 314 registered significantly higher (8.03%) grain yield compared to Swarna. DSR was economical and profitable compared to ZTR. CR Dhan 314 recorded higher net return ha^{-1} (Rs. 6640/-) compared to Swarna with B:C ratio of 1.52. In *rabi*, highest REY was recorded with maize + groundnut intercropping compared to cowpea intercropping or sole cropping of maize. The highest system productivity was recorded with rice-maize + groundnut cropping system which was significantly higher than rice - maize + cowpea cropping system and sole rice-maize cropping system. The system productivity of conservation agriculture was at par with conventional agriculture.

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

In-situ rice straw decomposition

Field experiment was conducted with variety CR Dhan 310 during *rabi* season 2021 to evaluate different *in situ* rice straw decomposition methods with respect to yield and GHG emissions. Treatments (T1: Immediate Incorporation of Straw T2: Straw Retention + Zero Till (ZT) T3: Spreading of Straw + Happy-seeder seed sowing T4: Straw Retention + ZT (Happy-seeder seed sowing- Simulation; HS-s) were replicated five times in randomized block design. The results revealed that the crop yield was higher in spreading of rice straw (4.46 t ha^{-1}) followed by immediate incorporation of straw treatment (4.40 t ha^{-1}) as compared to other two treatments. The seasonal methane emission was higher in immediate incorporation of straw treatment (49.14 kg ha^{-1}) as compared to other treatments. However, the seasonal nitrous oxide emission was higher in both zero tillage treatments. The GWP was higher in immediate incorporation of straw treatment (1584.9 kg CO_2eq. ha^{-1}) than other treatments.

Harnessing microbiome for enhancing rice productivity and improving soil health

Standardization of mass production of bio-inoculants

Standardized mass production of *Azotobacter chroococcum* Avi2, phosphate solubilizing bacteria (*Ensifer adhaerens* PSB 14) and exopolysaccharides producing bacteria (*Bacillus* spp. EPS-1) using Jensen's (JM), Pikovaskaya's (PM) and M1 (MM) media, respectively. The shelf life of liquid formulations of these cultures after 6 months were in the range of $1.54 \pm 0.34 \times 10^9$, $1.35 \pm 0.21 \times 10^9$ and $1.27 \pm 0.15 \times 10^9$, respectively. Following three microbial strains *Aspergillus awamori* (NRRI-CPD-COMF5), *Trichoderma viridi* (NRRI-CPD-COMF6) and *Streptomyces sp* (NRRI-CPD-COMA4) were used for preparation of bio-encapsulation and compared the shelf life with solid and liquid formulations. Among different carrier formulations, bio-encapsulation recorded significantly higher population (9.3-10.2 log_{10} CFU per g ml^{-1}) followed by solid (8.8-9.1 log_{10} CFU per g ml^{-1}) based formulation after six months of storage.

Presumptive classification key of *Azolla* strains based on phenotypic traits

Diverse phenotypic traits were studied to uncover markers to differentiate 102 *Azolla* strains (Fig. 2.5). Presence of rounded leaf lobe in *A. caroliniana* made it a unique identity among Euzolla sub-section. Sporulation, star-shaped and medium-imbricated leaves and root architecture of GSMI 1 resembled with *A. microphylla.* Thick root hairs were present in Rhizosperma, whereas thin root hairs were in Euzolla sub-section. Similar morphology of cyanobacteria was observed in all strains of *Azolla*, mostly resembling *Nostocaceae* family.

Fig. 2.5. Phenotype used to differentiate *Azolla* strains.

Ascorbic acid-based formulation of endophytic N-fixing Azotobacter chroococcum Avi2 enhanced plant-growth promoting efficacy under moisture deficit stress

Combined application of ascorbic acid (AA) and *Azotobacter chroococcum* Avi2 was used to determine photosynthetic efficacy (chlorophyll fluorescence-imaging), antioxidants, and plant growth-promotion (PGP) under moisture deficit stress (MDS, -60 kPa) in drought-susceptible (IR64 and Naveen) and drought-tolerant (Ankit and Satyabhama) rice cultivars. Combined application of AA and Avi2 also significantly increased photosynthetic efficiency, antioxidant enzymes and grain yield (p<0.05) by 7.09% and 3.92% in drought-tolerant varieties Ankit and Satyabhama, respectively and 31.70% and 34.19% in drought-susceptible varieties IR 64 and Naveen, respectively compared to MDS treatment. Overall, the present study indicated that AA along with Avi2 could be an effective formulation to alleviate MS *vis à vis* enhances PGP traits in rice.

Validation of capsule based decomposing consortium for *ex-situ* decomposition of paddy straw

In order to standardize the optimum dose for decomposition of paddy straw with capsule based formulation of decomposing consortium, the capsule 5, 10, 15 and 20 numbers per tonne of paddy straw was evaluated and it was found that 10 capsules (with secondary level multiplication with 2.0% jaggery solution (100 lit) for 4-5 days) are needed for decomposition of paddy straw under *ex-situ* condition within 45 days. The capsule formulation was also validated under *ex-situ* decomposition of paddy straw with already standardized solid formulation of NRRI decomposing consortium (1.0 kg per tonne of straw), there was no significant variation in decomposition in terms of CN ratio reduction between capsule (18:1) and solid (17:1) based formulation after 45 days.

Field evaluation of entomopathogens against rice leaf folder

Solid based formulations of following entomopathogens *viz., B.thuringiensis* (BT1- NRRI-CPD-BIOCB7, BT2-NRRI-CPD-BIOCB8, BT3-NRRI-CPD-BIOCB9) and *Skermanella* sp (SK1-NRRI-CPD-BIOCB11) were evaluated against leaf folder, *C. medinalis* under field condition during *kharif* 2021. After 15 days of spray, the *C. medinalis* damage percentage was significantly lower in chemical spray (2.2 %) followed by BT3 (3.2%) and *SK1*(3.6%) compared to control (16.2%). Similar kind of trend was observed after second spray. This finding indicates that SK1 and BT3 strains biocontrol potential were equivalent to chemical spray for management of leaf folder under field condition.

Studies on AM fungal diversity in rice soil to identify suitable species for rice cultivation

Eighteen AM fungal species belonging to nine genera *viz*., *Acaulospora*, *Claroideoglomus*, *Rhizoglomus*, *Glomus*, *Paraglomus*, *Entrophospora*, *Funneliformis*, *Gigaspora* and *Scutellospora* were recorded in aerobic/upland rice soils from twenty different locations from five different states. The following genera *Claroideoglomus*, *Glomus* and *Acaulospora* were commonly abundant in aerobic/ upland rice soils (Fig. 2.6). More anastomosis formations observed in aerobic rice soils compared to wetland rice soil were responsible for higher diversity in aerobic soil. The above wet lab results were further confirmed with Illumina Miseq based targeted metagenomic analysis of AM fungal diversity in rice soils which revealed higher Shannon and Simpson index associated with aerobic rice ecosystem compared to wetland rice, recording a total of 101 OTUs from both aerobic and wetland rice fields. The co-occurrence network analysis using AM fungal metagenomics data processed using machine learning approaches such as random forest model indicated that *Paraglomus* was one of the keystone genera present in both wetland and aerobic rice ecosystems and this genus has more interactions with different AM genus in rice soils.

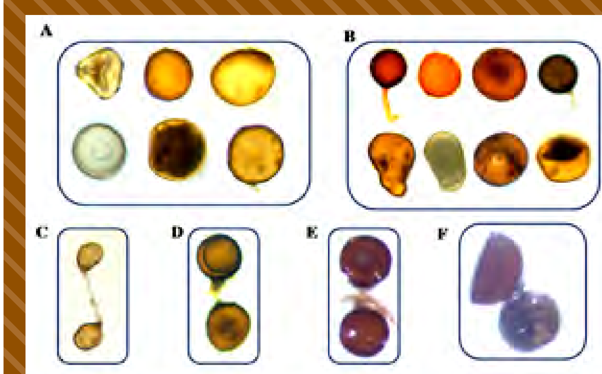


Fig. 2.6. **Distribution of different AM fungal spores in wetland (A) and aerobic (B, C, D, E and F) rice soils.**

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

Impact of rice-maize, rice-toria and rice-groundnut cropping sequences on weed dynamics, shifting of weed flora and development of management practices under direct sown rice

The experiment was laid out in split plot design and replicated thrice. The treatments consist of three cropping sequences in main plots (C_1: Rice-maize; C_2: Rice- groundnut and C_3: Rice-toria) and four weed control methods in sub plots (W_1: Rice (Pendimethalin*fb*1 hand weeding), Maize (Tembotrione), Toria (Quizalofop-ethyl), Grondnut (Imazethapyr); W_2: Rice (Bispyribac sodium *fb* 1 mechanical weeding), Maize (Tembotrione), Toria (Quizalofop-ethyl), Grondnut (Imazethapyr); W_3: two hand weeding; and W_4: Weedy check). Results of the experiment reveal the dominance of grasses in rice (42%), maize (72%) and groundnut (69%) while toria plots were dominated by broadleaved weeds (49%) followed by grasses (40%). Rice-maize cropping sequence registered higher system yield and it was at par with rice-groundnut. Early post emergence application of bispyribac sodium @ 30 g ha^{-1} in rice and herbicide based weed control in succeeding maize crop (Tembotrione), toria (Quizalofop-ethyl) and groundnut (Imazethapyr) recorded system yield of 10.66 t ha^{-1} rice equivalent yield (REY), highest net return (Rs. 108500/-) and benefit: cost ratio (2.08). Integration of herbicide and mechanical weeding in rice followed by herbicidal weed control in non-rice crop resulted increase in 43.2% REY.

Evaluation of different herbicide combination for broad spectrum weed control in Dry direct-seeded rice (D-DSR)

A field experiment was conducted to study the efficacy of herbicide mixtures and suitable weed control technology by integrating chemical and manual methods in dry direct seeded rice (D-DSR) during *kharif*, 2021 with cv. CR Dhan 312. The treatments included POST pre-mixTrifamone + Ethoxysulfuraon; POST Trifamone + ethoxysulfura on followed by (fb) one manual weeding (1MW); POST pre-mix Florpyrauxifen-benzyl + cyhalofopbutyl; POST Florpyrauxifen-benzyl + cyhalofopbutyl fb MW; PRE Oxadiargyl fb Trifamone + Ethoxysulfuraon; PRE Oxadiargyl fb Trifamone + Ethoxysulfuraon fb 1MW; PRE Oxadiargyl fb Florpyrauxifen-benzyl + cyhalofop-butyl; PRE Oxadiargyl fb Florpyrauxifen-benzyl + cyhalofop-butyl + 1MW; Oxadiargyl fb bispyribac-sodium with weed free and weedy check. Altogether eleven treatments were evaluated in randomized complete block design with three replications. Experimental results revealed that post application of herbicide mixtures *viz.*, Florpyrauxifen-benzyl + Cyhalofop-butyl or Trifamone + Ethoxysulfuraon at 12 DAE combining with one manual weeding found effective for controlling weeds in dry direct seeded rice. PRE application of herbicide (3 DAE) combining with POST application of herbicide mixture (21 DAE) combining with one manual weeding resulted in control of broad spectrum of weeds with weed control efficiency (WCE) of 89% but it showed phyto-toxicity at early vegetative stage that resulted in reduction in yield attributes and finally reflected in yield reduction of 2%.

Impact of different weed management techniques on early and medium duration rice varieties under dry direct-seeded rice

A field experiment was conducted during *kharif*, 2021 to study the weed spectrum and efficacy of sequential application of herbicide mixtures along with mechanical weed control by power weeder for broad spectrum weed control in dry direct seeded rice with cv. CR Dhan 206 (early duration, 110 days) and CR Dhan 602 (medium duration, 125 days). The treatments included two herbicide mixtures *viz.,* Florpyrauxifen-benzyl + Cyhalofop-butyl and Trifamone + Ethoxysulfuraon applied at 12 days after emergence (DAE) combining with mechanical weed control by power weeder at 35 DAE compared with recommended check herbicide mixture, bensulfuron methyl + pretilachlor (60+600 g ha^{-1} at 7 DAE) along with weed free and weedy check. Altogether ten treatment combinations were evaluated in split plot design with three replications in which two rice varieties were in main plot and five weed control treatments were in subplot. Results revealed that establishment of direct seeded rice crop by medium duration variety CR Dhan 602 (125 days) increased yield by 12% under favourable shallow lowlands than early medium duration variety CR Dhan 206 (110 days). POST application of herbicide mixtures *viz.,* Florpyrauxifen-benzyl + Cyhalofop-butyl or Trifamone + Ethoxysulfuraon at 12 DAE combining with mechanical weed control by power weeder found effective over the recommended practice of early POST application of Bensulfuron methyl +

pretilachlor followed by mechanical weed control by power weeder at 35 DAE for controlling broad spectrum of weeds in dry direct seeded rice during *kharif*.

Development and Refinement of Farm implements, post-harvest and value addition technologies for small farm mechanization

Optimizing the formulation for development of Health Promoting Rice based Extruded Products

The extruded products were prepared using a blend of rice, maize, hydrocolloid and vegetable powder. Effects of different percentage of rice flour, maize flour, xanthan gum and vegetable powder on the quality characteristics were analysed using a D-optimal mixture design. Effect of different percentages of vegetable powders on the physico-chemical, cooking, biochemical, textural and sensory properties of the products were investigated. The product responses were significantly affected by varying the proportions of vegetable powder. The regression models for product responses like hardness were highly significant ($P \leq 0.0001$), whereas water absorption index (WAI) and water solubility index (WSI) were significant at a ($P \leq 0.001$). Desirable ready to cook extruded products were obtained at vegetable powder at 15%. It was revealed that carrots, beetroots and moringa leaves at optimized levels can be used to produce ready to cook extruded rice based products with desirable quality characteristics and improved nutritional profile. The optimum formulation was obtained.

Enhancing water use efficiency in rice based cropping system

Determination of threshold soil water potential for enhancing water productivity of rice varieties introgressed with drought QTLs

A field experiment was conducted during *rabi* 2021 in split plot design with four irrigation treatments as main plot and six rice varieties as sub plot treatment. The different irrigation treatments were (a) Fully irrigated condition as the control (b) Re- irrigation at -20 kPa soil water potential (SWP)(c) Re- irrigation at -30 kPa SWP (d) Re- irrigation at -40 kPaSWP (e) Re- irrigation at -60 kPa SWP and different varieties under examination were V1 = DRR Dhan 44, V2 = Swarna Shreya, V3 = IR 64, V4 = CR Dhan 801, V5 = CR Dhan 802, V6 = Swarna. The experimental data revealed that varieties introgressed with drought QTLs showed significantly higher grain yield as compared to susceptible varieties under different levels of water deficit stress. Under moderate water deficit stress (-40 kPa) the decline in grain yield varied from 21-35% in tolerant varieties but for susceptible varieties the yield decline was upto 60%. Enzyme activities such as catalase (CAT), superoxide dismutase (SOD) and peroxidase (POX) significantly increased with increasing level of water deficit stress. Varieties introgressed with drought QTLs had higher activity of antioxidant metabolites that scavenge reactive oxygen species (ROS) as compared to the susceptible varieties under water deficit stress. The quantum of increase in ROS scavenging enzyme activity was more in tolerant varieties as compared to susceptible varieties.

Soil Moisture Monitoring and Irrigation Alert System

i) *Tensiometer based soil moisture monitoring and irrigation alert system*

A simplified and farmers friendly tensiometer based soil moisture monitoring and alert system was developed. In this tensiometer based soil moisture monitoring and alert system, a non- contact sensor is attached to the tensiometer tube to sense the water level. The sensor is connected to a microcontroller and relay module (Fig. 2.7).

After the irrigation event in the field the water level in the tensiometer tube is at its maximum level. But after some days the soil in contact with the ceramic cup of the sensor starts drying, there is an outflow of

Fig. 2.7. Tensiometer based soil moisture monitoring and irrigation alert system.

tube water through the ceramic cup which results in decrease in the water level of the tensiometer tube. As soon as the water level in the tube enters the threshold limit the sensor attached to the tube communicates a signal to the inbuilt microcontroller and GSM modem and sends an alert message to the farmers' mobile number registered with the system. The alarm in the form of message on mobile phone alerts the farmer for immediate arrangement of irrigation.

It has the potential to increase water productivity by around 28% without any significant decrease in grain yield. It also increases net return for farmers by reducing pumping costs and fuel consumption. Field trials demonstrated that irrigation scheduling based on tensiometer based soil moisture monitoring and alert system mitigates methane emission by 51% and global warming potential by 21%.

ii) *NRRI – ARM (Aerobic Rice Moisture) sensor for real time soil moisture monitoring in rice fields*

NRRI-ARM sensor works on the principle that electrical conductivity of the soil depends on the moisture content of the soil between the rods. The electronic circuit is designed in such a way to display moisture levels by glow of one LED lamp out of three LED lamps at a time. By using this, real time moisture status of the soil can be assessed. The sensing rods of the NRRI-ARM sensor is inserted in the rice field upto the required depth (approximately 25-30 cm). The inbuilt electronic circuit in the device interprets resistance or conductance between the sensor rods and illuminates one of the LED bulbs out of the three, depending on the soil moisture content. The electronic circuit is designed in such a way that different colored LED bulb corresponds to different levels of soil moisture content. Blue light indicates abundant moisture, hence irrigation not required; yellow light indicates low moisture content, hence irrigation is recommended and red light indicates very low moisture content, hence immediate irrigation is required. Field trials demonstrated that irrigation scheduling based on NRRI-ARM sensor produced statistically at par yield as that of conventional practice of maintaining standing water in rice field, moreover, it also saved irrigation water input by nearly 41% (Fig. 2.8).

iii) *Eco-friendly Irrigation Alert System*

Eco-friendly Irrigation Alert System was developed for precise water management in rice fields. In this system, a sensor is attached with the perforated pipe

Fig. 2.8. NRRI-ARM sensor installed in the field.

installed in the rice field at 15 cm depth. The sensor is connected to a microcontroller and relay module. The whole system is powered by a 12V battery and the battery is charged by a solar panel installed at the top of the structure. This system provides real time monitoring and is automatically controlled. This system alerts the end user through SMS, light and sound alarm and thus it facilitates effective monitoring of real time water level in the field. It has the potential to save around 30% of irrigation water without having any negative impact on grain yield. Thus, it increases the water productivity by 40%. It also increases net return for farmers by reducing pumping costs and fuel consumption. It also curtails the methane emission from rice field by around 37%.

Effect of crop geometry and spacing on submergence tolerance of tolerant and susceptible cultivars

The present experiment included two cultivars such as Swarna (susceptible) and Swarna-*Sub1* (tolerant)while taking the treatments of three crop geometries such as: circle, square and hexagon, and two spacing treatments were: 20×15 and 15×10 cm (row-row × plant-plant). The experiment was laid out keeping area of each geometry same, and transplanted in both submerged (treatment) and control tanks at the similar time of *kharif* season. After initial establishment, submergence treatment was imposed for 13 days and periodic survival count of plants was recorded. The salient findings were: i. planting geometries and spacing treatments affect the submergence tolerance and yield in rice, ii. the plants situated in the periphery across the three geometries showed better submergence tolerance ability, over the plants situated in the core, iii. among the planting geometries, apparently hexagonal arrangement enabled better stress tolerance, and iv. the wider spaced (20×15 cm) plants are more tolerant to the submergence stress as compared to the closer spaced (15×10 cm) plants. This experiment summarized that hexagonal distribution of planting geometry had less depletion rate of starch and chlorophyll, delayed leaf senescence, and less oxidative damage under submergence, followed by better recovery leading to better stress tolerance, as compared to circle and square geometries (Fig. 2.9).

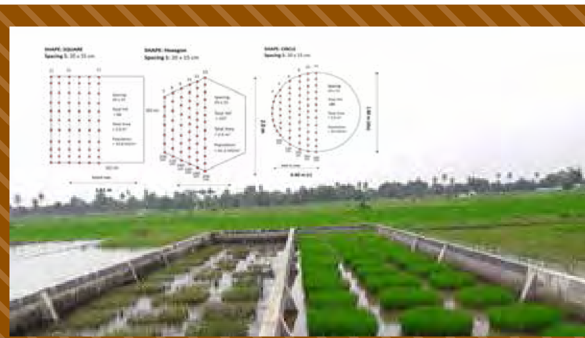


Fig. 2.9. Condition of treatment tank (submerged, in left) and control tank (in right) after withdrawal of submergence treatment with layout of crop geometry (square, hexagon, circle) replicated in the experiment.

Emerging challenges of intensive rice production in 21st century requires orientation of research goal towards enhancing productivity, ensuring sustainability and improving resilience of rice based production system. The research activities undertaken in the programme focused on harnessing cutting edge technology such as smart sensors, nano fertilizer, digital technology as well as fine tuning existing technology suiting to the specific agro ecosystem to improve resource use efficiency as well as enhancing system productivity in rice based production system. Attempt was made to utilize the agronomic potential of new generation rice through exploitation of seedling vigor and crop geometry. Mass production of bioinocuants was standardized for effective utilization of microbiome to enhance soil health. In addition to this work was initiated to analyze the climate change vulnerability of stress prone rice ecologies in eastern India and prioritize climate smart agricultural technologies for enhancing resilience in stress prone rice ecologies.

PROGRAMME-3

Biotic Stress Management in Rice

According to United Nations projections, the world's population is expected to grow from 7.8 billion in 2020 to 9.7 billion in 2050. Agricultural production still needs to be increased up to 70% to fulfill the food requirements of a steadily growing population. Obviously, increasing productivity is really challenging because there is steady degradation of cultivable land, natural resources and changing climate. Particularly, climate change may activate sleeper pathogens to become more aggressive. As a result, many minor pests are becoming major. In developing countries sustaining food securities are under enormous threat because of emerging new strain/races/biotype of virulent pathogens and insects. Future production has to be include more efficient and environment friendly production system. An efficient production system includes efficient management of rice pests and diseases, that cause losses both quantitatively and qualitatively. Crop protection division has taken holistic approaches on rice pest and disease management. The division is in continuous search for novel mediators in plant defense response to pathogenic infections in rice and are given efforts in identification of resistant donors, the resistant gene, and their mechanisms as well as multiple pest resistance genotypes. Recently we developed brown planthopper resistant variety Roshan (CR Dhan 317) and the responsible resistant gene *Bph31* was identified.

Identification and characterization of donors against biotic stresses

Identification of new source of resistant donor against BPH and WBPH

Out of 138 genotypes, only one genotype (Kharavela) recorded moderately resistant (score 3) and remaining genotypes were susceptible (score ≥ 5) against BPH, whereas two genotypes (Gajapati, Samantha) recorded moderate resistant (score 3) against WBPH.

AICRIP materials for planthopper special screening trial (PHSS) against brown planthopper (BPH), Cuttack *N. lugens* populations revealed that among the 17 gene differentials evaluated, only two *viz.,* PTB 33 (with *bph2*+*Bph3*+unknown factors) and RP 2068-18-3-5 (*Bph33* (t) gene) were found promising with score 1 (resistance).

Screening results revealed that the germplasm accessions *viz.,* IC 322922, IC 75881, IC 426149, IC 426139, IC 256515, IC 273558, IC 426148, IC 426126, IC 256545, IC 346890 showed resistant reaction with score 1 and IC 346237, IC 256547, IC 752742, IC 574971, IC 75883, IC 283249, IC 426092, IC 256849, IC 346892, IC 752742, IC 256545 and IC 7588 having resistant reaction with score 3.

Genetic dissection and identification of candidate genes for brown planthopper, *Nilaparvata lugens* resistance in Indian landraces

Among 268 rice genotypes, screened against *N. lugens*, 96 were selected for genotyping using 93 molecular markers linked to 26 different *N. lugens* resistant (R) genes. Genetic analysis revealed the mean genetic diversity of 0.275 and polymorphic information content of 0.240 for all 93 markers. Marker trait association via generalized linear model and multi linear model picked out three markers *viz.,* RM 19291 (*Bph30*), RM 28472 (*Bph18*) and RM 28449 (*Bph17*) for their significant association with different phenotypic parameters such as per cent damage, nymphal survival, feeding mark and honeydew excretion.

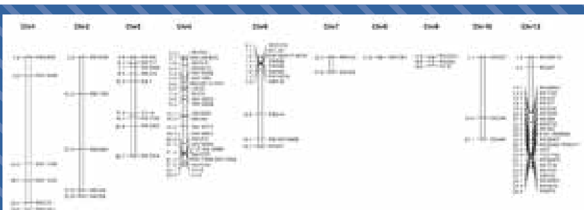


Fig. 3.1. Position of marker loci used in the study.

Evaluation, phenotyping and identification of genotypes for insect-pests and disease resistance

Asian gall midge

On completion of 2nd year phenotyping of 200 landraces of Assam, Nagaland and Karnataka for Asian Rice Gall midge resistance, 58 genotypes were found highly resistant.

Yellow Stem Borer (YSB)

Out of 50 NRRI varieties, four varieties namely, CR-801, Tara, Chandan and Ratna were found moderately resistant (damage score 11-20%) at vegetative stage against YSB under field condition.

Angoumois grain moth (*Sitotroga ceralella*)

A total of 80 rice germplasm accessions were evaluated for assessing the extent of damage caused by *S. cerealella* using the standard screening procedures. The weight loss ranged from 0.00 to 18.33 grams. Twenty-one varieties showed no weight loss even after the infestation, indicated that these are resistant to *S. ceralella*.

Sheath blight disease (*Rhizoctonia solani*)

Out of 72 NRRI released varieties, 45 OUAT released varieties, 82 Assam Rice Collections, 33 New Generation Rice lines and 11 doubled haploid lines screened for resistance against sheath blight disease, 8, 4, 4, 2 and 2 entries, respectively were found moderately resistant.

The internal transcribed spacer (ITS)-1 and ITS-4 region of the genome of 22 isolates of *R. solani* (AG1-IA) collected from different districts of Odisha were sequenced for genetic variability studies. The accession MK 478907, MK 478903, MK 480231, MK 480239, MK 480286 and MK 480289 have been submitted to NCBI.

Phenotyping and genotyping of WGR lines against bakanae and sheath blight resistance

Out of 184 WGR lines evaluated for bakanae and sheath blight resistance, 23 accessions were moderately resistant and 12 were resistant. These accessions were evaluated for their genetic diversity using 12 reported microsatellite (SSR) markers. Only one marker (RM 10153) produced monomorphic while, rest 11 markers produced polymorphic amplicons (2 -8 bands). A total of 37 alleles have been showed by polymorphism with a mean of 3.08 by RM-486 produced lowest amplicon size (104 bp) while

RM 3698 produced maximum amplicon size (900 bp). PIC values ranged from 0.031 (RM 10153) to 0.374 (RM 3698) with an average value of 0.264. Genetic diversity ranged from 0.032 (RM 10153) to 0.449 (RM 3698). All the twelve tested simple sequence repeat markers (SSR) were observed to be highly informative (PIC>0.5). Through AMOVA showed that 95% variation was observed among the individuals and 5% among the population. Based on Nei's genetic distance, the pair wise comparisons were made which reverted, more distance between the populations (Nei's genetic distance= 0.999).

Understanding the causal organism of rice grain discolouration

Grain discolouration of rice was reported to be caused by various pathogens and environmental factors. Rice grain showing typical brown or black spots was used for isolation of the pathogen and the mycelia were fast growing, brown to greyish black with radial growth of upto 8.2 cm after seven days of inoculation. The conidia were septate, brownish and 17-21 x 10-12 µm, curved (lunate), the sub terminal cell enlarged, pale brown at both ends with 3–5 septa. The DNA amplification of the ITS regions showed product size of ~600 bp. The ITS regions were sequenced and revealed 100% similarity with *Curvularia lunata*.

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

Agro-ecological zone based diversity of isolates of false smut pathogen *U. virens* in India

Genetic diversity of 112 *U. virens* isolates from India were done using 18 polymorphic Simple Sequence Repeat (SSR) markers. The highest major allele frequency was found in SSR 276 and lowest in SSR 79. Number of alleles was also varying from 1 to 6. The PIC value was highest in SSR79 and lowest in SSR276. Neighbor joining tree have been showing phylogenetic relationship among the *U. virens*. Similarity coefficient was ranged between 0.54 to 1.0. The dendogram showing three main clusters (Fig. 3.2).

Cluster I consisted of almost all isolates from Northern plains which are mostly from UP. But Cluster II was the highest group and consisted of isolates from Eastern Coastal plains, Eastern plateau and Eastern Ghats, Bengal and Assam zone, North eastern hills, Northern plains and central highlands. Thus cluster II has grouped isolates from almost all the eastern (WB, Odisha, few from eastern UP), north-eastern (Assam, Meghalaya) and central (MP). The cluster III were

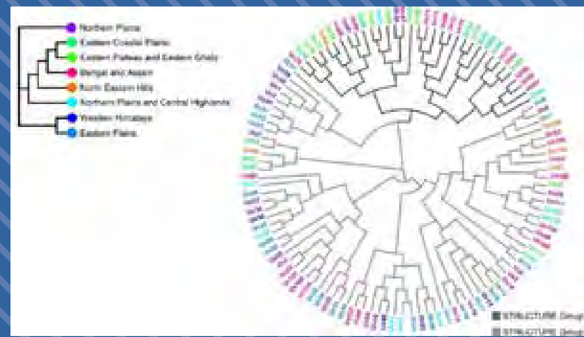


Fig. 3.2. Neighbor-joining tree constructed based on Rogers 1972 distance measures.

comprising of isolates mainly from western Himalaya region (HP, UK) and Eastern plain region (Parts of UP).

Effect of staggered sowing and flowering period on false smut of rice

In order to manage false smut disease, the effects of staggered sowing of rice on false smut incidence in two different seasons were studied. Six varieties namely, Pooja, Sarala, Anjali, Durga, Geetanjali and Naveen, were sown at 15-day intervals from 24th May to 20th August. Most varieties developed false smut when their flowering occurred during September and October in both years irrespective of their sowing dates. The relative humidity showed positive correlation with Pooja and Sarala but negatively correlated with Anjali, Durga, Geetanjali and Naveen.

Use of Precision Tools and Techniques in Rice Insect Pest and Disease Management

Detection of yellow stem borer damage in rice through hyperspectral remote sensing techniques

The field experiments were conducted to characterize the yellow stem borer (YSB) infestation at different damage levels on rice through hyperspectral remote sensing. Damages are categorized based on 50 and 100% damage severities.

The results revealed that the YSB damaged leaf had higher spectral reflectance in the visible region (400-700 nm) and in the SWIR region (1100-2500 nm) which decreases due to presence of stress. The spectra reach its peak value at 882 nm for both affected and heathy samples on the original spectra. There was a greater variation in the NIR region (700-1100 nm) which shows the healthy sample has more reflectance value than affected YSB samples. A sharp peak was seen at 550 nm indicating the presence of anthocyanin. Reduction of chlorophyll content occurs at 684 nm and at 691 nm the inclination in the spectra indicates the presence of red edge (Fig. 3.3a). Derivative analysis depicted sensitive bands such as 522, 569, 610, 721, 731, 764, 894 and 930 nm (Fig. 3.3b). The above nine spectral bands in the different spectral regions *viz.,* 482-560 nm, 558-746 nm, 700-750 nm, 785-795 nm, 796-806 nm, 808-846 nm, 885-906 nm, and 1255-1280 nm were also found as sensitive regions from which central wavelengths for eliminating continuum were identified (Fig. 3.4a-h). The bio-chemical analysis results showed that the value of phenol content of infested samples was more as compared to healthy samples but all other content such as chlorophyll, reducing sugar, non-reducing sugar and carbohydrate was more for healthy as compared to YSB samples.

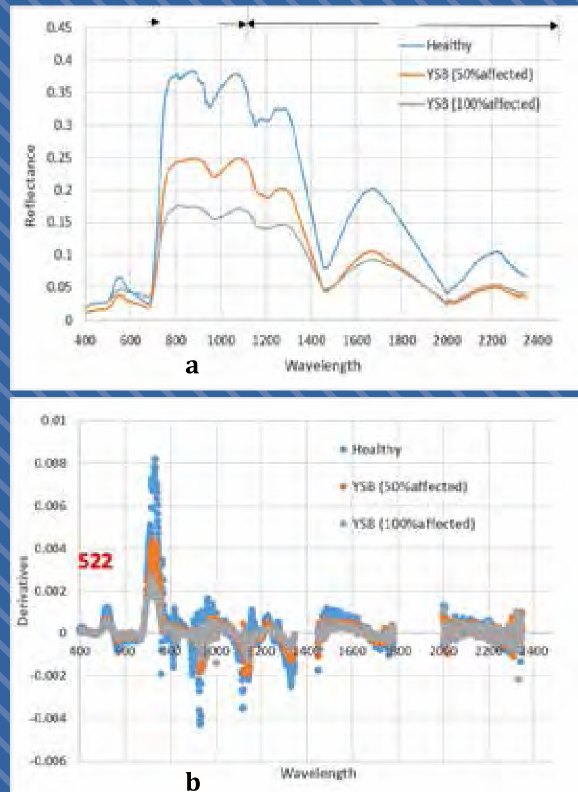


Fig. 3.3. (a) Spectral curve of Healthy vs YSB (at different damage level); (b) First derivative plot of Healthy vs YSB (at different damage level).

Development of smart digital biotic stress research tool

The evolution of Information Communication Technology (ICT) has led to the development of many smart phone-based applications. Rice Pest Lab, a mobile app was developed for biotic stress research in the lab as well as field. This app has three modules for Insect Pests, Diseases and Nematode. All the modules have the features like

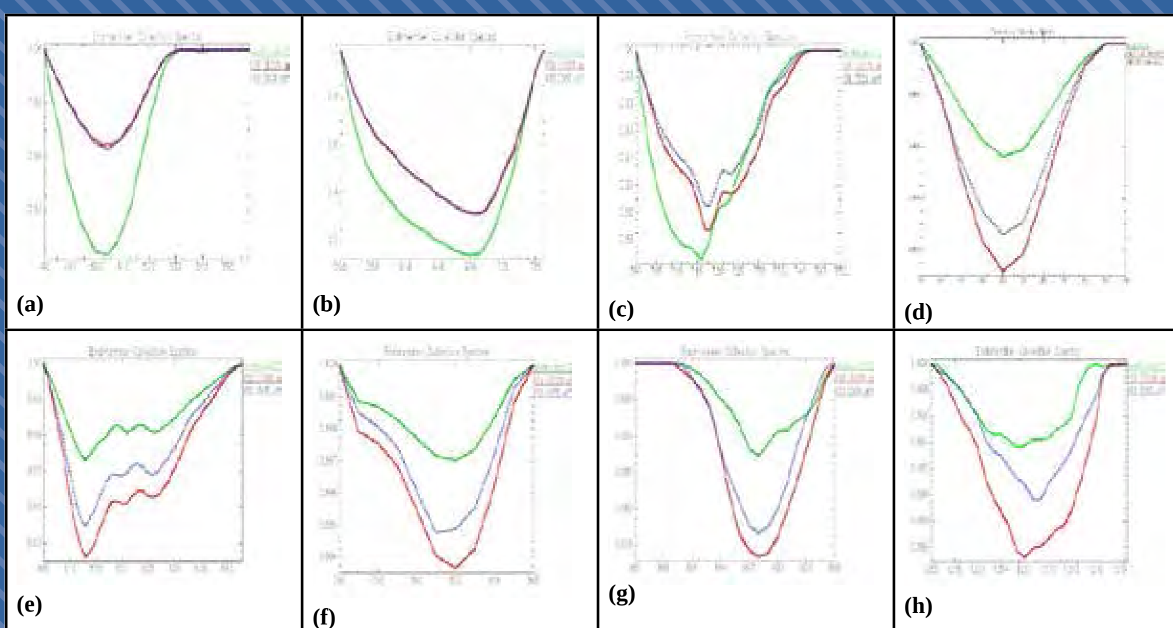


Fig.3.4. Spectral bands in the different spectral regions. (a) Absorption dips found in (482-560) nm; (b) Absorption dips found in (558-746) nm; (c) Absorption dips found in (700-750) nm; (d) Absorption dips found in (785-795) nm; (e) Absorption dips found in 808:846nm; (f) Absorption dips found in 796:806nm; (g) Absorption dips found in 885:906; (h) Absorption dips found in 1255:1280.

(i) Pest Screening (ii) Pest Monitoring (iii) Pest Diversity (iv) Pest Loss Assessment and (v) Pesticide Evaluation.

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

Differential response in tolerant and susceptible rice genotypes to sheath blight pathogen

CR 1014 has been identified as a tolerant rice genotype to sheath blight pathogen *Rhizoctonia solani*. Comparative transcriptomic analysis has been performed using Swana *Sub1* (susceptible) and CR 1014 (tolerant) under challenged condition. A total of 815 and 551 genes were observed (Fig. 3.5) to be differentially regulated in CR 1014 and Swarna *Sub1,* respectively in two different time points (3 days and 9 days after inoculation). The over expression of glycosyl hydrolase, secondary metabolite biosynthesis, cytoskeleton and membrane integrity during the glycolytic pathway, and maintaining photosynthesis rate made CR 1014 a superior performer against sheath blight pathogen. Venn diagrams showing unique and overlapping upregulated- and downregulated- genes in different 665 comparisons at P value cut off ≤ 0.05 666 SS-C-3, Swarna-*Sub1* control at 3 DPI; SS-C-9, Swarna-*Sub1* control at 9 DPI; SS-T-3, Swarna-*Sub1* treated at 667 3 DPI; SS-T-9, Swarna-*Sub1* treated at 9 DPI; CR-C-3, CR 1014 control at 3 DPI; CR-C-9, CR 1014 control at 668 9 DPI; CR-T-3, CR 1014 treated at 3 DPI; CR-T-9, CR 1014 treated at 9 DPI; DPI, Days post inoculation

Proteomic analysis of virulent and less virulent isolates of *Rhizoctonia solani*

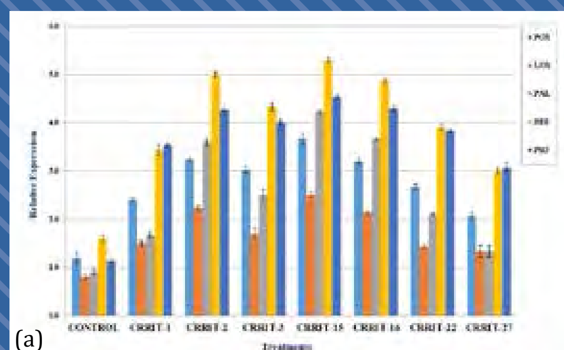
A comparative proteomic analysis was performed to identify the differentially expressed proteins between virulent (RS15) isolate and less virulent (RS22) isolates of *Rhizoctonia solani*. The virulence of RS15 and RS22 was further confirmed on other rice genotypes *viz.*, Pusa Basmati-1, Vanaprabha, Hazaridhan, Swarna, Lunishree, Savitri, Sadabahar and TN1. The proteomic information generated has been deposited in the PRIDE database with the identifier PXD023430. The virulent isolate consisted of 48 differentially abundant proteins; out of which 27 proteins had higher abundance while 21 proteins had lower abundance.

Fig. 3.5. Venn diagrams showing upregulated- and downregulated- genes.

Unravelling biocontrol mechanism and growth promotion of *Trichoderma* spp.

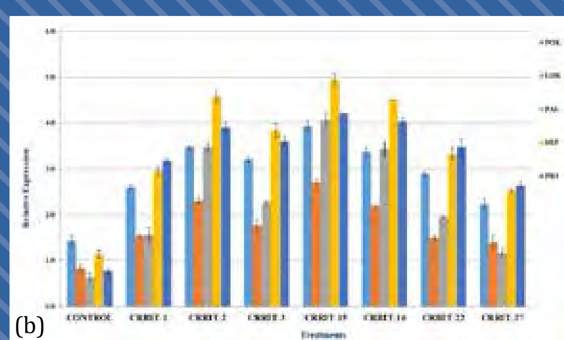
In order to understand the mechanism of biocontrol and growth promotion by *Trichoderma* spp. different defense enzyme expressions like lipoxygenase, peroxidase, phenylalanine ammonia lyase, defensin genes, and pathogenesis related three gene were studied in *Trichoderma* primed plants of two rice varieties (Annapurna and Shatabdi) using real time PCR (RT-PCR) and it was observed that the *Trichoderma* primed plants showed higher expression of all those genes in both the varieties (Fig. 3.6 a & b).

Variety: Annapurna



(a)

Variety: Shatabdi



(b)

Fig. 3.6.a & b: Effect of Trichoderma primed rice plants in (a) Annapurna and (b) Shatabdi as indicated by comparative expression of different defence enzymes using RT-PCR.

Plant protection molecules: efficacy, distribution, toxicity and remediation

Effectiveness of combination and new products in rice pest management

The insecticides combinations (Chlorantraniliprole 20% SC 0.3 ml l^{-1} + Cartap hydrochloride 50% SC 2 ml l^{-1}+ Triflumezopryrim 10% SC 0.48 ml l^{-1}) at 25, 50 and 65 days after tillering (DAT) recorded highest grain yield (3.2 t ha^{-1}) followed by Botanicals and Insecticides combination (Neemazal 1% EC 2 ml l^{-1}+ Dhanuvit 2 ml l^{-1}+ Cartap hydrochloride 50% SC 2 ml l^{-1}) (3.07 t ha^{-1}). In control, the grain yield was 2.5 t ha^{-1}. These pesticide combinations are found very effective against stem borer and leaffolder.

Seven new and commercially available fungicides namely, difenoconazole 25EC@ 0.5 ml l^{-1}, isoprothiolane 40 EC @1.5 ml l^{-1}, kasugamycin 3% SL @ 2.0 ml l^{-1}, kitazin 48 EC @ 1.0 ml l^{-1}, propineb 70 WP @ 3.0 g l^{-1}, tebuconazole 25.9 EC @1.5 ml l^{-1} and thifluzamide 24 SC @ 0.8g l^{-1} were evaluated against sheath blight disease caused by *Rhizoctonia solani*. Difenoconazole 25 EC was the best to control sheath blight with 17.8% disease severity (DS) followed by isoprothiolane 40 EC showing 18.4% DS.

Evaluated the toxicity of *Persicaria hydropiper* (L.) leaf extracts against *N. lugens* along with chemical insecticide, Imidacloprid. *P. hydropiper* leaf extracts produced significant mortality against *N. lugens* nymphal and adult stages in a dose dependent manner. Nine vital compounds were identified from the *P. hydropiper* extracts. Additionally, *P. hydropiper* extracts was found harmless to non-target organism, as they did not produce any toxicity on earthworm, *Eisenia foetida*.

Sensitivity study of false smut isolates collected from different eastern and north-eastern states of India to propiconazole fungicides

Sensitivity of 63 isolates of *U. virens* at five different concentrations (0.03, 0.04, 0.05, 0.06, 0.07 and control) based on the LD_{50} value (0.05) of Cuttack isolate to propiconazole standard was done. It was observed that 81.6% isolates were sensitive to near or below LD_{50} value (0.05), whereas 18.4% isolates were sensitive to above LD_{50} value. So, nearly 12 isolates were less sensitive to LD_{50} value of propiconazole standard (Fig. 3.7).

Fig. 3.7. Frequency distribution of sensitivity of *U. virens* isolates to Propiconazole standard.

In silico analysis of trehalase protein of *Rhizoctonia solani* and molecular docking studies for identification of potential bio-fungicide

Trehalase protein of *Rhizoctonia solani* is an enzyme which plays important role in the development of sheath blight disease of rice. In fungi, trehalase degrades trehalose, reduces its content which leads to scavenging of the reactive oxygen species (ROS). This excessive accumulation of ROS, induces differentiation of the fungi. Thus, structural analysis of the trehalase enzyme of *Rhizoctonia solani* is important for development of new fungicides. The complete cDNA sequence of acid trehalase (KC687092.1) was retrieved from the NCBI database and it was translated to the amino acid (AA) sequence and it was used to model the protein structure. The generated model was validated by the Ramachandran Plot which showed that 86% of AA were in the most favoured region and additionally 11.5% of AA in the allowed region. Further, molecular docking showed that the compounds like avenosterol, gedunin, stigmesterol had higher affinity for the enzyme in comparison to validamycin (a known trehalase inhibitor) (Fig. 3.8).

Development of a multi-residue method for pesticide quantification from rice grain

A multi-residue method for pesticide (>100) quantification from rice grain was established as per AOAC, SANTE and FSSAI guidelines. In brief, one kg rice sample was collected and ground. Rice sample (10 g) was taken in a 50 ml centrifuge tube and 12 ml of distilled water and 10 ml of ethyl acetate were added and vortexed for one min followed by addition

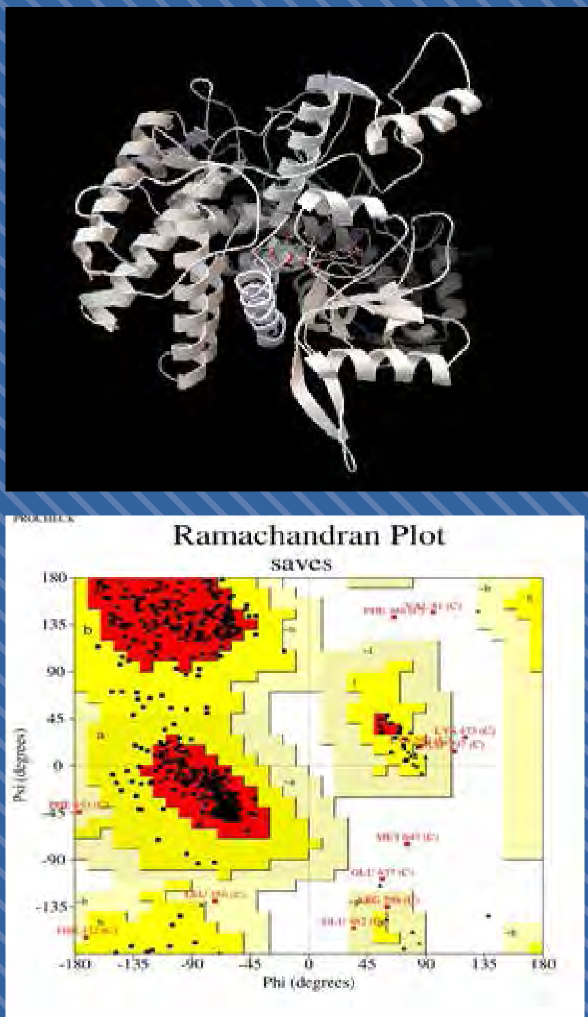


Fig. 3.8. The 3-D structure of modelled acid trehalase protein of *Rhizoctonia solani* and its validatation through Ramachandran plot.

of 4 g of anhydrous $MgSO_4$ and 1 g of anhydrous NaCl. The sample mixture was homogenized for three min and centrifuged at low temperature. Supernatant was transferred, added in centrifuge tube containing 50 mg ml^{-1} PSA and 150 mg ml^{-1} $MgSO_4$. The content was vortexed and centrifuged at 5000 rpm for five min at low temperature.

The supernatant was filtered through 0.2 micron PTFE membrane filter into sample vial for LCMSMS and GCMSMS injection. Detailed parameters were standardized as per the guidelines. In brief, the LOD of the method was < 10 ppb for most of the pesticides and LOQ was <10 ppb (for 60 pesticides). The recovery of different pesticides was within 80-120% of the fortified quantity with the precision of <20% R SD. We quantified the pesticide residues present in paddy as well as rice samples (300) collected from different districts of Odisha.

Residue Dynamics of Triflumezopyrim and its Toxicity against *Nilaparvata lugens* in Rice Ecosystem

Triflumezopyrim (TMP), a mesoionic insecticide, is commonly used for controlling plant hoppers in rice. First time, the dissipation of TMP from rice plant and soil under field conditions is being reported by NRRI. The median lethal dose and concentration were 0.036 per insect and 0.525 mg l^{-1}, respectively. TMP at recommended dose (25 g a.i. ha^{-1}) recorded 1.25 live BPH per hill as against 25.5 per hill in control at 14 days after treatment. The residue of TMP from rice plant and soil was estimated using three different doses (12.5, 25 and 50 g a.i. ha^{-1}). Maximum content of TMP in soil was <1% that of plant content on day-1. The dissipation pattern of TMP both from plant and soil was better explained by first-order double-exponential decay model (FODED) as compared to first-order kinetic model. Overall, the half-lives of TMP were ranged from 2.21-3.02 days in plant tissues and 3.78-4.79 days in soil as per the FODED model. Based on the persistence and toxicity of TMP, it can be concluded that TMP will be effective against BPH upto 7-10 days after application and could be recommended as an alternate pesticide in BPH management in rice (Fig. 3.9).

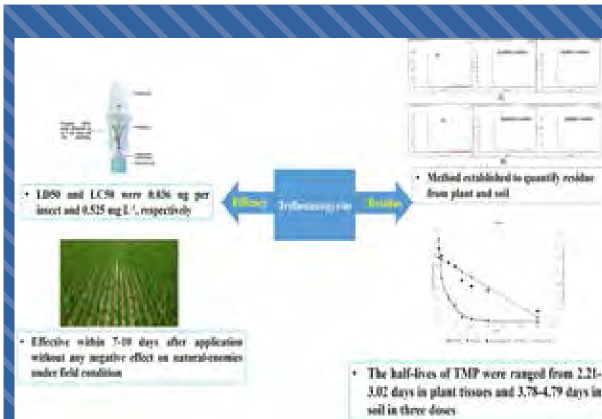


Fig.3.9. Graphical abstract of residue dynamics of Triflumezopyrim and its toxicity against *Nilaparvata lugens.*

Binary insecticide mixtures can improve the efficacy of individual insecticides against *Scripophaga incertulas* and *Nilaparvata lugens* in rice

Brown planthopper (BPH) and yellow stem borer (YSB) coexist in the late tillering stage of rice. Insecticide combinations are the most effective way to manage the pests having different feeding behaviour. This study investigated the toxicity of insecticides (chlorantraniliprole, triflumezopyrim, flonicamid and pymetrozine) in combination and alone against BPH and YSB under controlled and field conditions. The lethal doses (LD_{50}) were 17.215, 0.059, 0.180 and 0.036 ng per insect for chlorantraniliprole (CAP), flonicamid (FLO), pymetrozine (PYM) and triflumezopyrim (TMP) against BPH, respectively. Similarly, LD_{50} were 2.737, 0.073, 0.313 and 0.061 ng per larva against YSB, respectively. The combination of 17.215 ng chlorantraniliprole + 0.059 ng flonicamid per insect resulted in maximum mortality of BPH (86 %) while highest mortality (86.67%) of YSB was recorded at 2.737 ng CAP + 0.061 ng TMP per larva. Two mixtures of CAP+TMP (15 g + 18.75 g a.i ha^{-1} and 22.5 g + 12.5 g a.i ha^{-1}) were the most effective in managing BPH and YSB, respectively in field conditions (Table 3.1).

Effect of long-term pesticide application on rice yield

In long term pesticide trial, *kharif* 2020 (*kh,* 20) and *rabi* 2021(*r,* 21), the grain yield of insecticide Cartap were 5.25 t ha^{-1} (*kh,* 20) and 5.6 t ha^{-1} (*r,* 21) followed by Chlorpyriphos were 4.9 t ha^{-1} (*kh,* 20) and 5.4 t ha^{-1} (*r,* 21) and Carbendazim 4.10 t ha^{-1} (*kh,* 20) and 4.7 t ha^{-1} (*r,* 21), Pretilachlor 3.85 t ha^{-1} (*kh,* 20) and 4.5 t ha^{-1} (*r,* 21), whereas in control 3.4 t ha^{-1} (*kh,* 20) and 3.9 t ha^{-1} (*r,* 21), respectively.

nifH-targeted Illumina HiSeq sequencing was analyzed for nitrogen-fixing bacteria at species level under 11 years continuous pesticides applied paddy rice soil. Results revealed that continuous application of pesticides [Chlorpyriphos @ 500 g a.i ha^{-1}, Cartap @1 kg a.i ha^{-1}, Pretilachlor @ 750 kg a.i ha^{-1}, Carbendazim/Bavistin @ 0.1%) did not affect the *Bradyrhizobium japonicum*, uncultured N-fixing bacteria and most of the other N-fixing bacteria. While the abundance of Gallionellales bacteria drastically reduced in pesticide-treated paddy soil compared to control (Fig. 3.10).

Table 3.1. Susceptibility of BPH and YSB against different group of insecticides by topical application method.

Insecticides	No of insects tested	Lethal Dose (ng per insect)	95% Confidence Limits		Slope	Standard Error	χ^2 Calculated	df	$P>\chi^2$
			Lower	Upper					
BPH (24 HAT*)									
Chlorantraniliprole	250	17.215	14.746	19.660	2.83	0.505	4.618	4	0.328784
Flonicamid	300	0.059	0.009	0.167	0.33	0.112	0.992	5	0.963208
Pymetrozine	250	0.18	0.063	0.477	0.45	0.135	0.617	4	0.961156
Triflumezopyrim	400	0.036	0.023	0.054	0.734	0.078	8.9	7	0.259916
YSB (48 HAT*)									
Chlorantraniliprole	210	2.737	1.554	3.709	1.814	0.351	6.086	6	0.413626
Flonicamid	180	0.073	0.004	0.158	0.891	0.287	0.108	5	0.999804
Pymetrozine	210	0.313	0.186	0.418	1.741	0.336	1.358	6	0.968363
Triflumezopyrim	210	0.061	0.025	0.103	0.815	0.165	0.471	6	0.998174

HAT: Hours after treatment, BPH: Brown planthopper, YSB: Yellow stem borer

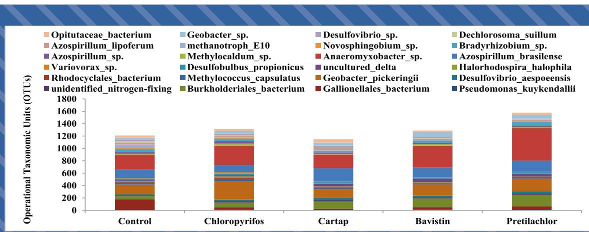


Fig. 3.10. Nitrogen-fixing bacterial OTUs under influence of 11 years old long-term pesticides applied paddy soil.

Host mediated insecticide hormesis in a gregarious ecto-parasitoid, *Habrobracon hebetor*

The stimulatory multigenerational effect of deltamethrin is being reported on *C. cephalonica*, laboratory host utilized for rearing many biological agents and subsequent performance of parasitoid, *Habrobracon hebetor* on it. Diet incorporated exposure with host larvae indicated that the lethal concentration (LC_{50}) was 281.13 mg l^{-1}. Further, effects of sub-lethal concentrations along with LC_{50} and control were ascertained by biological attributes and nutrient reserves of host consecutively for three generations. Most of the biological attributes tested were not significant in the foundress generation (G0), but significant in the successive generations (G1 and G2). The performance of parasitoid, *H. hebetor* on the multigenerational sublethal concentrations treated *C. cephalonica* revealed a significant increase in parasitoid fecundity by 65.33% when host larvae were exposed to LC_{15}. The emergence of both the sexes was significantly different; however, female longevity was significantly different but not the male. Hormesis phenomenon could be operating in host *C. cephalonica* especially at LC_{15} exposure that could be exploited in mass rearing of *H. hebetor* (Fig. 3.11).

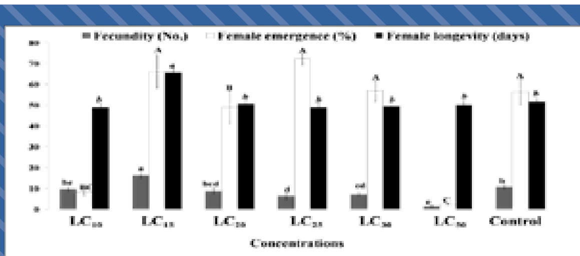


Fig. 3.11. Biological traits of the parasitoid *H. hebetor* following its development on a multi-generational sublethal concentration-exposed factitious host, *C. cephalonica*. The same letters above error bars in each generation indicate no significant difference according to one-way ANOVA (P < 0.05). LC: lethal concentration.

Effects of sub-lethal phosphine on factitious host, *Corcyra cephalonica* and behavioural response of it's ectoparasitoid, *Habrobracon hebetor*

The rice moth, *Corcyra cephalonica* is a destructive stored grain pest and also a factitious host for the mass production of several natural enemies. For *C. cephalonica*, the lethal (LC_{50}), low-lethal (LC_{25}) and sub-lethal (LC_5) concentrations of phosphine were found to be 67.975 ppm, 32.875 ppm and 11.893 ppm, respectively. The 5th instar larvae of *C. cephalonica* were exposed to these concentrations of phosphine and reared for two consecutive generations (G1 & G2). GC-MS analysis revealed eicosane and tetrapentacontane with higher peaks in the chromatogram. The adult female parasitoids spent significantly higher time in the treated arm than the control arm for C_7-C_{40} alkane chain (P=0.006), crude extracts LC_5(*P*=0.004), LC_{25} (*P*=0.008), LC_{50} (*P*=0.046) and untreated larvae (P=0.001) while for eicosane and tetrapentacontane the results were non-significant. The study concludes that sublethal phosphine-treated host may improve the behavioral response of the parasitoids and could be a possible case of behavioral hormesis.

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

Whole mitochondrial genome of brown planthopper, *Nilaparvata lugens* biotype 4

The mitogenomes of *N. lugens* are 16,072 bp long with 77.50% of A + T contents (Fig. 3.12). *N. lugens* mitochondrial genomes include the 37 genes *viz*., 13 PCGs (*cox1-3, atp6, atp8, nad1-6, nad4l* and *cob*), 22 tRNA genes, and 2 ribosomal RNA (*rrnS* and *rrnL*) subunits genes. However, *N. lugens* mitogenome in the present study retained one extra copy of the *trnC* gene. Additionally, also found 93 bp lengths for *atp8* gene in both the samples, which were 60-70 bp less than of other sequenced mitogenomes of hemipteran insects. Present study provides the reference mitogenome for *N. lugens* biotype 4 that may be utilized for biotype differentiation and molecular aspect based future studies of *N. lugens*.

Biosynthesis and evaluation of the efficacy of silver nanoparticles against sheath blight of rice caused by *Rhizoctonia solani*

The *Aspergillus* based synthesized nanoparticle was characterized and confirmed by a peak in the range of 420-430 nm (Fig. 3.13). The inhibitory effect of the

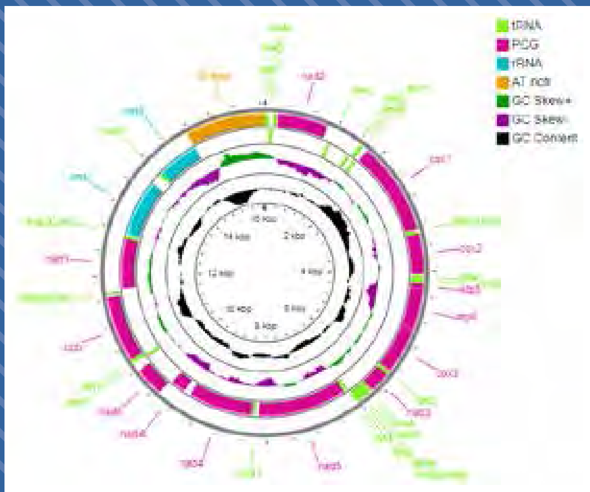


Fig. 3.12. ***Nilaparvata lugens*** **mitochondrial genome map (PCGs, RNA, tRNAs & CR) is indicated in the first outer circle. GC content and GC skew is represented in second and third circle, respectively.**

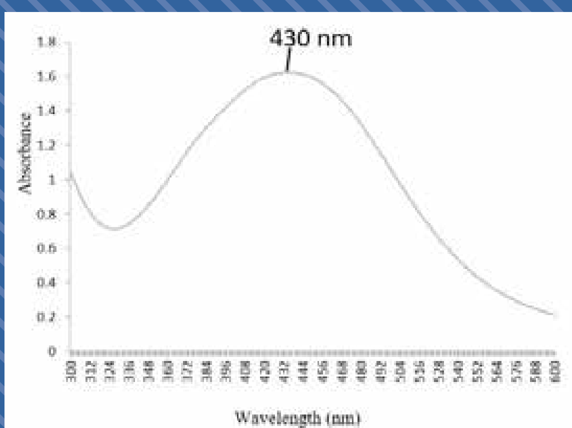


Fig. 3.13. UV-Vis spectrum of the synthesized AgNP.

synthesized AgNP was tested *in vitro* against *R. solani*, at different concentrations *viz.,* 5, 10, 15, 20, and 30 ppm. The AgNP was found to inhibit the growth of the pathogen by 13 to 28 % at different concentrations.

Validation and promotion of integrated pest management of rice module in farmer's fields under shallow lowland ecosystem

Validation and promotion of IPM module under shallow lowland ecosystem in the farmer's fields were undertaken in Haripur of Derabis Block (Dist. Kendrapara) with Swarna and Pooja (21 acres) involving 27 farmers. In IPM practice, seed treatment with *Trichoderma* @ 10 g kg^{-1} seed before sowing and need based application of pesticides were undertaken by the farmers in the affected areas only. Carbendazim 50 WP @1.0 g l^{-1} water against brown spot, sheath blight, sheath rot diseases; Cartap hydrochloride @ 1 kg ai ha^{-1} water against YSB, leaf folder, BPH and need based foliar application of Chloropyriphos 20% EC @ 0.5 kg ai ha^{-1} against gundhi bug were applied. Also, sex pheromone traps @ 8 nos. ha^{-1} with lure and bio-control agent (*T. viride* and *P. fluorescens*) formulations were provided to the farmers. Yield in need based IPM outperformed the farmer's practice with yield advantage of 1.92 t ha^{-1}.

Evaluation of bio-agents for management of false smut in rice

Experiments were conducted both *in vitro* and field conditions to evaluate and validate the bio-agents having best potential to manage the false smut pathogen, *U. virens*. The preliminary evaluation *in vitro* conditions revealed that *T. harzianum* showed the most promising as it indicated 66.88% inhibition percentage, followed by *T. atroviride* (51.16%), *Dendryphiella sp* (41.50%), *B. amyloliquefaciens* (36.56%) and *B. subtilis* (36.40%). All the bio-agents treated plants showed lesser disease severity than the control demonstrating their ability to suppress false smut incidence. Moreover, the chaffiness was much lower in *T. atroviride* and *B. subtilis* treated plants as compared to the control (Fig. 3.14).

Fig. 3.14. Beneficial effects of bio-agents on rice and their ability to reduce false smut under field. condition.

The crop protection division has given special emphasis in research of using modern tools like hyper-spectral, UAVs and development of smart digital biotic stress research tool and engaged in unravelling biocontrol mechanism and growth promotion of *Trichoderma* spp, Besides, the division is involved in finding baseline sensitivity of emerging disease like false smut and pests to the new molecules, and evaluation of new molecules as well as combination formulations for eco-friendly management of insect, disease and stored-grain pest. The division has also taken care for minimizing pesticide use and diminishing residual toxicity, thus doing work for viable dissemination of IPM strategies for pest-diseases and chemical residue analysis in grain as well as in rice eco-system and as a result developed a multi-residue method for pesticide quantification from rice grain, studied residue dynamics of triflumezopyrim and its toxicity against *Nilaparvata lugens* in rice ecosystem.

PROGRAMME-4

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

Enhancement of rice yield is one of the foremost targets of rice researchers across the globe. To sustain per capita rice consumption at present rate we would require to produce 50-55% more than the current production level that to in decreasing rice production area due to faster rate of urbanization. In order to achieve the target there is a need to improve the phosynthetic efficiency and yield potential of rice. In addition, rice is grown under diverse range of ecosystems and under changing climatic conditions where it gets exposed to different environmental stresses reducing grain yield. However, some germplasm lines or native landraces though poor yielder, have potential to tolerate the abiotic stresses with many mechanistic alterations. Besides, rice grain quality is the most important factor for evaluation of a variety as well as millers, consumers and farmer's point of view. It includes physico-chemical, nutritional and sensory qualities. Various biochemical factors (resistant starch, amylose, phytic acid) and heat processing (parboiling) affect starch digestibility and Glycemic index of rice based food or its products. These problems are being addressed by three different institutional projects and four externally funded projects by the active participation of nine scientific and eight technical staffs of this division.

Photosynthetic efficiency and productivity of rice under changing climate

Evaluation of rice germplasm for higher grain yield with higher biomass production ability

Six hundred and fifty rice genotypes/germplasm lines were screened under normal irrigated condition for their biomass production ability. Out of 650, 83 lines did not flower. Among rest of the lines, the grain yield varied from 0.50 to 5.20 t ha^{-1} and total biomass varied from 1.0 to 10.5 t ha^{-1}. The genotype IC-211535 recorded highest grain yield of 5.20 t ha^{-1} with high biomass of 10.37 t ha^{-1} and HI of 0.50. On the basis of high grain yield and biomass with high HI, 20 best genotypes were selected for further detailed study of photosynthetic efficiency (Fig. 4.1).

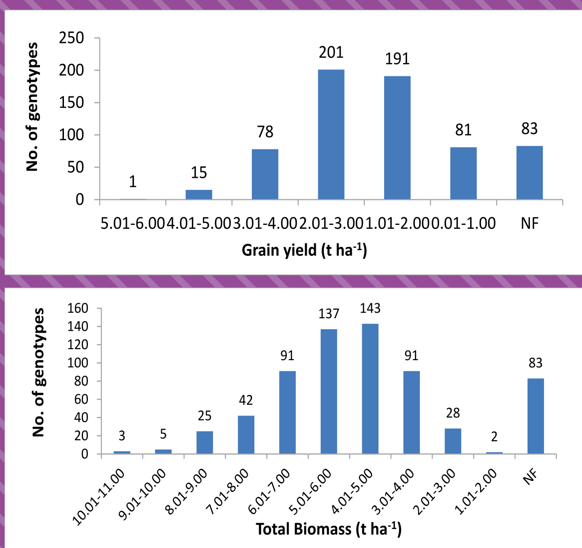


Fig. 4.1. Frequency distribution of genotypes for grain yield and total biomass.

Agronomical characterization of rice plants transformed with C_4 photosynthetic gene, *Setaria italica* PPDK (*SiPPDK*)

Rice transgenic (cv Naveen) lines were developed by individual over-expression of *Setaria italica PPDK (SiPPDK)* enzyme and characterized for agronomical performance of the transgenic lines. The lines with *SiPPDK* showed increased plant height (13.0%), increased tiller no. by 22.0% and increased per plant yield to the tune of 59.0% over the control i.e. wild type plants (Table 4.1).

Identification of CO_2 responsive rice genotypes

It is important to harness the beneficial effects of increased atmospheric CO_2 by identifying efficient CO_2 responsive rice genotypes and identifying the morpho-physiological markers for such hyper response. In order to identify CO_2-responsive rice cultivars we have screened 16 popular rice cultivars grown in different agro-ecologies and subjected them to e[CO_2] (elevated CO_2) treatment at 550 ppm in open-top chambers (OTCs) during *kharif* season. Sixteen cultivars broadly belonged to four different maturity groups i.e. early (90-110 days), mid-early (110-125 days), medium (135 days), and late (140 days and above). We observed significant yield enhancement, improvement in harvest index, photosynthetic rate, and leaf starch content under e[CO_2] treatment, while the number of days to attain 50% flowering reduced significantly. Interestingly, varieties having a crop duration between 100-125 days (early and mid-early) responded more than late and medium duration cultivars in terms of yield enhancement (over control) under elevated CO_2 treatment (Fig. 4.2).

Table 4.1. Agronomic traits of transgenic rice lines transformed with *SiPPDK* gene.

SiPPDK	Control	Vector Control	Transgenic	% Increase over control
Plant Height	82.25	53.53	93.08	13.00
Tiller No.	38.00	35.00	46.60	22.63
Panicle No.	34.00	33.66	39.80	17.06
1000 Grain wt.	20.80	20.01	21.23	2.07
Dry Biomass/plant	107.00	89.65	160.88	50.36
Yield (g)/plant	10.30	10.90	16.40	59.22

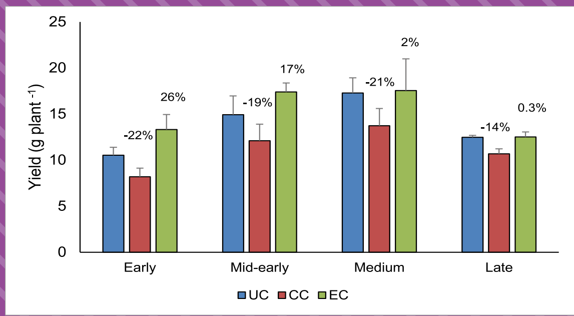


Fig. 4.2. **Yield enhancement under elevated CO_2 treatment (EC) in rice cultivars belonging to different maturity groups as compared to chambered (CC) and un-chambered controls (UC).**

Identification of rice genotypes with higher cellular level tolerance to heat stress by employing Temperature Induction Response (TIR) technique

The present study was aimed at identifying rice genotypes possessing higher heat stress tolerance at cellular level (TCL). Genotypic variation in seedling mortality during recovery from challenging temperature (54ºC) ranged from 46 to 76% in non-induced seedlings and 26 to 55% in induced seedlings. The present study could identify genotypes HT-20 (AC 34975) and HT-18 (AC 34973) as possessing tolerance to heat stress owing to their higher cellular level tolerance (Fig. 4.3).

Salicylic acid (SA) alleviates effect of heat stress by inhibiting tapetum cell apoptosis in rice

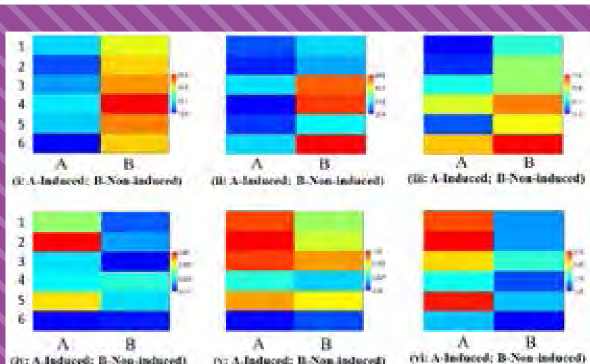


Fig. 4.3. **Matrix plots showing response of rice genotypes at cellular level to Temperature Induction Response (TIR) with regards to different physiological and biochemical parameters *viz.*, (i) MDA content; (ii) Reduction in root length; (iii) Reduction in shoot length; (iv) Seedling Mortality; (v) Catalase activity (g^{-1} min^{-1}); (vi) SOD activity (g^{-1} min^{-1}) and (vii) Peroxidase activity (g^{-1} min^{-1}).**

A susceptible variety for high temperature stress-Naveen was selected to study the effect of exogenous application of SA in combating heat stress. After panicle initiation, different concentrations of salicylic acid 0 (No-SA), 1, 2, 5 and 10 mM was sprayed to flag leaf and panicles. One set of sprayed pots were exposed to heat stress (40ºC) along with non-sprayed pots for seven days in polytunnel. A control set was also maintained under ambient temperature (32-34ºC). The spikelet fertility was ranged between 85-90% under control conditions, while it was decreased significantly under heat stress, particularly in the No-SA treatment as compared to the plants sprayed with SA. Among the SA treatments, 5 mM SA was found to be more effective in maintaining higher spikelet fertility under heat stress (Fig. 4.4). After heat stress, rice plants were transferred back to the natural conditions until full maturity. Under control conditions, no significant difference was found in pollen viability. However, an average decrease in pollen viability of 55.7% was observed under heat stress compared to the control. Rice plants sprayed with SA attained significantly higher pollen viability which ranged between 39.3- 41.5% than plants of the No-SA treatment (18 to 19%) under heat stress. Caspase 3 activity was noticeably increased in anthers of stressed plants compared to non-stressed plants indicating SA inhibits tapetum cell apoptosis and reduces pollen abortion under heat stress.

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

Identification of new source of germplasm for drought tolerance

One hundred nine genotypes from different sources (rainfed upland, high temperature stress, submergence tolerant, advanced breeding lines for early direct seeded rice, previously selected drought tolerant lines) with two tolerant and two susceptible checks were screened for vegetative stage drought tolerance during dry season 2021 under 10-12% soil moisture stress and -55 to -48 kPa soil metric potential. Out of 109 lines one-line AC 42997 was highly tolerant with SES ‘0’; 33 lines were tolerant with SES ‘1’; 35 lines moderately tolerant with SES ‘5’; 17 lines moderately susceptible with SES ‘7’.

Fig. 4.4. Effect of salicylic acid on Caspase 3 activity, pollen viability and spikelet fertility under high temperature stress.

Differential responses of root morphological traits associated with moisture stress condition

Twenty-five genotypes including six checks were evaluated for root trait studies in baskets under two different conditions (moisture stress and well-watered conditions) (Fig. 4.5). Sampling of roots and shoots were done at 15 days after stress when leaves began to completely roll and leaf tips dry (Fig. 4.6). Among 25 genotypes, TAGUR, AC 42997, KALABORA and SRILANKA recorded higher values for multiple root traits, under moisture stress condition (Table 4.2).

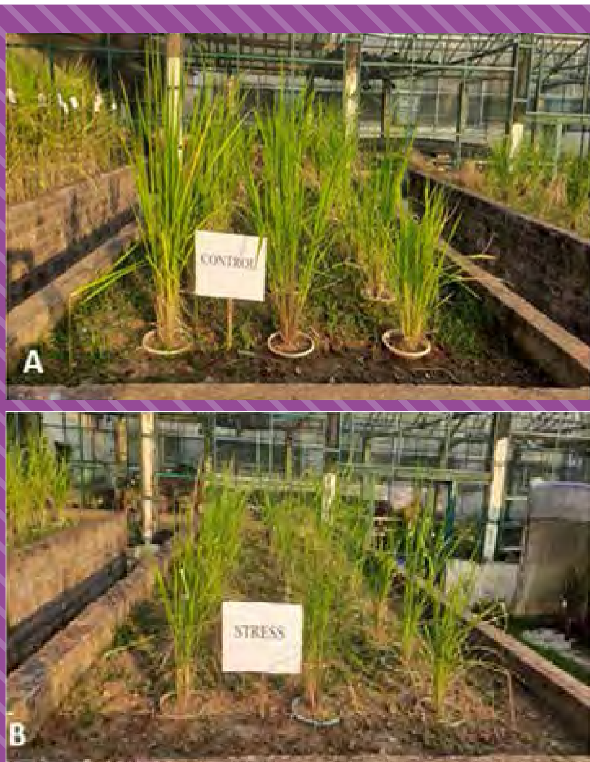


Fig. 4.5. Basket experiment conducted under well-watered (A) and moisture stress (B) conditions.

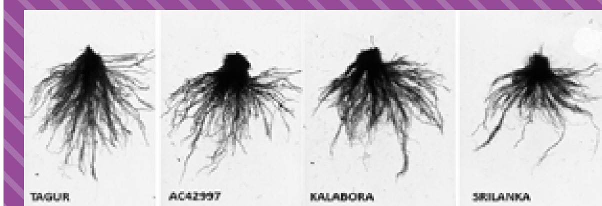


Fig. 4.6. Root images of best four rice genotypes captured in root scanner grown under moisture stress condition.

Differential role of *OsDREB* gene family members towards osmotic stress tolerance in *indica* and *japonica* ecotypes of rice

Different members of the *DREB* gene family are known to contribute towards osmotic stress tolerance. In this study, an attempt was made to work out their relative contribution towards osmotic stress tolerance in *indica* and *japonica* ecotypes of rice. Two genotypes (one tolerant and one susceptible) from each ecotype were grown hydroponically and the 21 days old seedlings were subjected to polyethylene glycol-induced osmotic stress (15% PEG-6000 equivalent to -3.0 bars osmotic potential). The tolerant genotypes CR143-2-2 and Moroberekan were found to have superior root traits (total root length, surface area, and volume), better plant water status, and increased total dry biomass as compared to their susceptible counterparts after 10-days of osmotic stress. We observed different members of *DREB* gene families having differentially induced in response to osmotic shock (1 h after stress) and osmotic stress (24 h after stress), which also differed between the two rice ecotypes. But among them only one member i.e. *OsDREB1B* showed significant correlation with drought tolerance indices in both *indica* and *japonica* ecotypes (Fig. 4.7).

Table 4.2. Summary of different root and shoot traits with best two lines having higher values evaluated under moisture stress condition.

Traits	Mean	Min.	Max.	Range	Two best lines
Root length density (RLD, cm cm^{-3})	1.44	0.73	1.96	1.23	BADAJANGIA (1.96), BEEK JER (1.93)
Maximum root length (MRL, cm)	44.68	33.7	51.9	18.2	AC-42997 (41.9), NASHKET BORA (51.3),
Shoot length (SL, cm)	76.73	51.4	100.5	49.1	TAGUR (100.5), SALKAIN (96.0),
Root volume (RV, cc)	6.70	4.28	13.15	8.95	TAGUR (13.15), GAMIRI (13.07),
Root dry weight (RDW, g)	5.44	1.161	13.47	12.309	KALA BORA (13.47), SRILANKA (10.024),
Root average diameter (RAD, mm)	0.88	0.65	1.21	0.56	KALABORA (1.21), KHESRE (1.04),
Shoot dry weight (SDW, g)	8.52	5.11	17.64	12.53	KALABORA (17.64), SRILANKA (13.65)
Total dry weight (TDW, g)	13.97	6.271	31.11	24.839	SRILANKA (31.11), BIROHI (23.676),
RDW/SDW (g)	0.62	0.23	0.78	0.55	AC-42997(0.78), LAL AIJUNG (0.78),
RDW/TDW (g)	0.38	0.185	0.438	0.253	AC-42997(0.438), LAL AIJUNG (0.437),
MRL/SL (cm)	0.60	0.52	0.66	0.14	BADAJANGIA (0.66) BIROHI (0.66),
Total root length (TRL, cm)	947.50	514.03	1948.13	1434.1	TAGUR (1948.13), GAMIRI (1772.12),

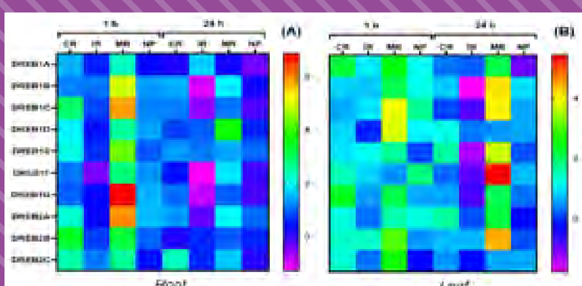


Fig. 4.7. Heat maps showing changes in expression of different *DREB* genes (n = 3) in root (A) and leaf (B) of four rice genotypes at two different time points (1 h and 24 h) since imposition of osmotic stress (15% PEG-6000).

Screening and identification of the *Oryza nivara* accessions tolerant to salinity stress

Screening for vegetative stage salinity tolerance was carried out with 40 different accessions of *Oryza nivara*. Hydroponically grown plants were subjected to 12 dS m^{-1} of salinity stress along with IR 29 (susceptible check) and FL478 (tolerant check) at seedling stage. From this panel, we identified two promising accessions of *Oryza nivara* (W118 – AC 100042/IC 336715 and W119 – AC 100042A) which showed an SES score of 3-5 after seven days of stress imposition when the susceptible check reached a score of 9 (Table 4.3). This suggests that the salt tolerance in wild *O. nivara* may not be achieved primarily by the salt-exclusion strategy, unlike what we observe in the case of salt tolerant cultivated *O. sativa* accessions.

Effect of lowlight stress on agronomic traits of rice

Light is a major constraint for the rice production. Forty rice genotypes were exposed to normal light and low light to study the grain yield and yield related traits. Present study revealed that rice plants grown under low light exhibit a 54.50% reduction in grain yield compared to normal light. Among the genotypes IR 72 recorded the highest grain yield (3.51 t ha^{-1}), highest harvest index (0.39) and minimal relative yield reduction (RYR) of 14.30% followed by Apo (2.65 t ha^{-1}) and Shatabdi (2.57 t ha^{-1}) under lowlight condition (Fig. 4.8). Harvest index (HI) was reduced by 28.94% over normal light condition. Under lowlight condition

Table 4.3. Characterization of promising *O. nivara* accessions for vegetative stage salt- tolerance (12 dS m^{-1}).

Name of rice genotype	SES score on VSI	Biomass, Shoot (mg, DW)	Chlorophyll content (mg g^{-1})	PS-II efficiency	Y(NO)	Na^+/K^+ ratio, Leaf
FL 478	3.0	65.70	2.69	0.792	0.207	0.34
W 118	3.0	56.30	1.83	0.757	0.242	1.02
W 119	5.0	54.73	2.08	0.794	0.205	1.23
IR 29	9.0	22.00	1.28	0.467	0.533	1.99

highest HI was recorded in IR 72 and Shatabdi (0.39) followed by Naveen (0.38) and Apo (0.37). Though Parijata recorded highest yield under normal light, it had low yield (1.6 t ha^{-1}) under low light may be due to high RYR (Fig. 4.8).

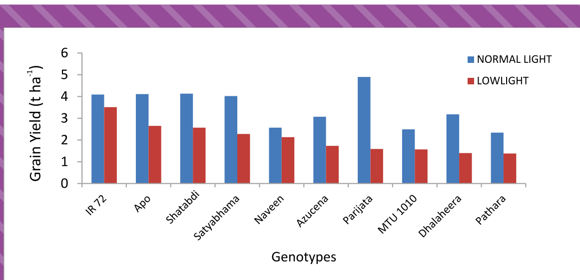


Fig. 4.8. Grain yield (t ha^{-1}) of ten best genotypes under lowlight condition.

Screening rice genotypes for multiple abiotic stress tolerance

a) Drought, submergence, anaerobic germination

Sixty-eight rice genotypes including a few selected germplasm from the ICAR-NRRI Gene Bank and some upland rice varieties were evaluated for multiple abiotic stress tolerance *viz.,* drought and submergence stress at early vegetative along with their anaerobic germination potential.

Among the studied genotypes, 49 were found to be highly drought tolerant characterized by drought score (DS) of 1, early vegetative vigour (EVV) score of 1-3 and recovery score (REC) of 1. Among these, we found 11 genotypes namely IC 516366, Gurjari, AC 38209, AC 35678, Khitish, Mahulata, IC 516008, IET 18727, EC 305939, IC 516149 and IET 18208 having >70% survival rate (SR) under two weeks of complete submergence. Besides, we found six genotypes i.e. IET 18716, PAU-9, Khandagiri, IC 516149, Annapurna and Sahbhagidhan showed high germination percentages (50-80%) under anaerobic conditions. The list of multiple abiotic stress tolerant promising genotypes is given in the Table 4.4.

Table 4.4. List of promising genotypes tolerant to multiple abiotic stresses. DS = Drought Stress, SUB = Submergence, AG = Anaerobic Germination.

Traits	Name of the tolerant genotypes
DS+SUB	IC 516 366, Gurjari, AC 38209, AC 35678, Khitish, Mahulata, IC 516 008, IET 18727, EC 305939, IC 516 149, IET 18208
DS+AG	IET 18716, PAU 9, Khandagiri, IC 516 149, Annapurna, Sahbhagidhan
SUB+AG	IC 516 149
DS+SUB+AG	IC 516 149

b) Effect of Low light stress on diverse set of Drought tolerant lines

Thirty-five diverse set of drought tolerant genotypes were exposed to 50% of Normal Light stress following standard protocol (50% LL stress imposed 15 days after transplanting till maturity). Grain yield reduced by 48.4% and total Biomass by 35.5% under low light. Relative yield reduction was lowest in check Swarnaprabha (19.2%), followed by Satyabhama (24.03%) and IR 72 (29.71%). However, another seven genotypes: Apo, MTU 101, Shatabdi, Brahman Nakhi, Naveen, Parijata and BVD 109 had RYR of 30-40% and eight genotypoes (Pathara, Black Gora, Khitish, Annada, Lalat, Rasi, Vandana, Kamesh) had RYR of 40—50%. These genotypes can be considered as lowlight tolerant genotypes having vegetative stage drought tolerance.

Elite unique genetic stocks tolerant to abiotic stresses registered

Five unique rice germplasm were registered by the Plant Germplasm Registration Committee (PGRC) of ICAR, New Delhi during 2021:

INGR21116: Rahaspunjar (IC 575321; AC 42128) – registered as a unique multiple abiotic stress tolerant genetic stock having tolerance to salinity and stagnant flooding (both fresh and saline water), and also possessing very high anaerobic germination potential. INGR21117: Remeni Pokkali (AC 41585) – registered as unique genetic stock possessing both vegetative and reproductive stage salinity tolerance. INGR20211: AC 42997 (IC 0576152) – registered as unique genetic stock possessing vegetative stage drought tolerance, prolific roots and high water use efficiency. INGR20212: *O. nivara* wild rice accession (IC 330611) – registered as unique genetic stock possessing vegetative stage drought tolerance. INGR20213: *O. nivara* wild rice accession (IC 330470) – registered as unique genetic stock possessing vegetative stage drought tolerance.

Standardization of screening protocol for vivipary/pre-harvest sprouting in rice genotypes

With the objective of standardization of an efficient evaluation method for identifying genotypic differences in viviparity, two screening protocols (i) field based and (ii) laboratory based were performed with 26 rice genotypes. In order to induce viviparity at the exact time after flowering, panicles of each variety were tagged according to the flowering date. So as to conduct field evaluation of viviparity at 20, 25, 30, 35, 40 days after flowering, ten panicles were placed into the irrigated water in the field by gently bending stems toward the ground with the help of a rope and kept under water for 12 days (lodging treatment).

Viviparous germination in the laboratory conditions was examined by harvesting, five panicles from each genotype at 20, 25, 30, 35, 40 days after flowering and were sandwiched between two wet blotting papers in aluminum trays and were incubated for 12 days (Fig. 4.9). Analysis of viviparity recorded at 20, 25, 30, 35, 40 days after flowering under field and laboratory conditions (Fig. 4.10). It was evident that a wide variability exists in viviparous germination at different days after flowering across rice genotypes. It was found that screening of large number of genotypes for vivipary, laboratory method (at 35 DAF and 40 DAF after six days of incubation) can be an efficient method considering the correlation (intensity of color) with field observation data and convenience of testing.

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

Effect of parboiling on starch digestibility and mineral bioavailability in rice

Parboiling affects rice cooking quality, starch digestibility and phytic acid (PA) content along with minerals bioavailability (Fig. 4.11). Rice grains of 20 genotypes (with different traits; *viz.,* high protein, scented, pigmented and general) were analyzed for parboiling effect. Cooking quality was improved in parboiled brown (PB) and parboiled milled (PM) rice. Parboiling reduced the glycemic index (GI) and Glycemic load (GL) in both PB and PM rice. After parboiling, the GI value was significantly reduced to less than 55 in most of the PB rice while its value was slightly increased to 55±2 after milling in PM rice. The GL value was decreased significantly in both PB and PM rice which is attributed to reduced available carbohydrate in all the genotypes after

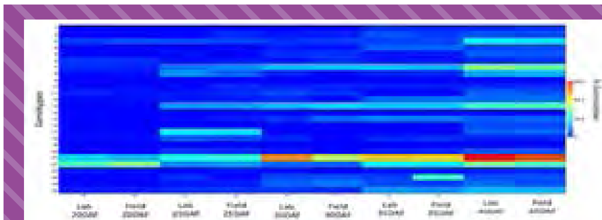


Fig. 4.10. Matrix plot showing the similarity in viviparous germination between the field and lab protocols tested for evaluating 26 diverse genotypes for vivipary. The viviparous germination percentage observed in field and lab protocols at 20, 25, 30, 35, 40 DAF was almost similar.

Fig. 4.9. (a) Labelling of panicles of each genotype according to flowering date in the field; (b) Field protocol (Lodging treatment in the field); (c) Laboratory protocol and (d) Photographs showing the results of vivipary treatment by laboratory and field method in different genotypes showing viviparous germination at different days after flowering.

Fig. 4.11. Effect of parboiling on starch digestibility traits, phytic acid and mineral (Fe, Zn) bioavailability in rice.

thermal processing. Resistant starch (RS) was found to range between 0.63% (Mamihunger) - 2.47% (PB-177) and its content was increased after parboiling in both PB and PM rice, thus reducing the GI. Parboiling further reduced PA but increased Fe content and bioavailability in PM rice due to its inward diffusion. Zn content was lower in PB and PM rice due to its outward movement during parboiling. The impact of Zn retention on its bioavailability was marginal in parboiled rice as compared to non-parboiled rice.

Development of mapping population for low phytic acid (LPA) in rice grain and identification of LPA elite cultivars

A set of 125 rice genotypes, landraces and elite cultivars were constituted for marker traits association analysis for LPA in rice grain. A biparental mapping population was also developed between Manipuri black rice (high phytate) and Bindli (low phytate). One hundred and ninety-one RILs (F_7) were developed and sufficient quality of seed were produced for quality analysis. A set of 75 elite lines were evaluated for LPA content in grain. Out of which 15 lines were found to have LPA in grain. They are IR 14A216, IR 54447-3B-10-2, CR 4384-RGA-249, IR 14V1020, CR 4384-RGA-250, IR 58025 B, CR 4384-RGA-251, IR 09A235, IR 15A2983, IR 02A127, IRRI 186, PIR-26>C0-2071-1-4-2-1, IR 14A150, IR 122310:7-2-2 and CR 4384-RGA-253.

Development of association panel for high resistance starch (HRS)

A set of 300 rice genotypes were evaluated for RS, and a panel of 125 rice genotypes was made on the basis of phenotypic variation. The population was normally distributed and suitable for marker trait association (MTA) analysis. The resistant starch in the panel ranged from 0.5 to 3 % with mean of 1.89%. The panel will be genotyped and the QTLs or gene associated with high resistant starch will be identified through MTA. High resistant starch is negatively correlated with rice starch digestibility, thus is useful for diabetic people.

Rice bran cake-a novel value added food product; comparison with market available cake with respect to sensory and nutritional qualities

Rice bran is a by-product of the milling process. It is a good source of proteins, dietary fibres and functional compounds like γ-oryzanol, phenolics, anthocyanin, phytic acids and tocotrienes. It is the underutilized milling bi-product of rice, which is generally used for cattle feeds and extraction of oil. In this study, the whole bran was used for making the rice bran cake (RBC). The textural profile analysis of the RBC revealed lower hardness but higher adhesiveness and cohesiveness as compared to market available cakes (MAC). With respect to colour parameters, RBC was darker than MAC except chocolate cake. However, RBC was superior than MAC in terms of different nutritional parameters. The minerals (Fe, Zn) content of RBC was higher than MAC. There was no significant difference in case of phenolics content but higher flavonoids and protein content were observed in case of all RBCs. The total soluble sugar content was lower but antioxidant activity (DPPH) was higher in all the RBCs as compared to MACs (Fig. 4.12).

Minerals (Fe, Zn) content of some quality rice cultivars grown in field condition

The mineral content in brown rice of the 17 cultivars were estimated through AAS. Aghonibora (a waxy rice) had higher concentration of Zn while Improved Lalat was having higher Fe content as compared to others. However, considering both the minerals, Improved Lalat and Annapurna (red rice) performed well (Fig. 4.13).

Fig. 4.12. Rice Bran Cake-1; 2: Rice Bran Cake-2; 3: Rice Bran Cake-3; 4: Market Available Cake-1 (PB); 5: Market Available Cake-2 (MA); 6: Market Available Cake-3 (MACH).

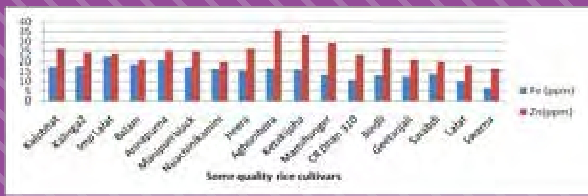


Fig. 4.13. Fe and Zn content in the brown rice of 17 cultivars.

Ammonium assimilation in rice with contrasting grain protein content

Variation in ammonium assimilation in the varieties with contrasting grain protein content (ARC 10075 and CR Dhan 310: high grain protein varieties, Naveen: low grain protein variety) was studied focusing on Glutamine synthetase (GS) and Glutamine oxoglutarate aminotransferase (GOGAT) of the GS/GOGAT cycle. Activity of GS and GOGAT at flowering and 15 DAF were estimated from the flag leaves of the three varieties *viz.,* ARC 10075, CR Dhan 310 and Naveen. At flowering stage, the activity of both GS and GOGAT were found to be similar while at 15 DAF, a substantial increase in the activities of both the enzymes was observed (Fig. 4.14).

Biochemical characterization of germplasm from Kerala

Fifty rice germplasm accessions of Kerala analyzed for total phenol, flavonoid content and total antioxidant activity (CUPRAC, DPPH, ABTS, FRAP Assay). The mean value with the maximum and minimum value has been presented in table 4.5.

Effect of cooking on nutritional composition of pigmented and non-pigmented rice

As compared to non-pigmented rice, pigmented rice is rich in nutritional component. Effect of cooking on the nutritional composition of pigmented (P) and non-pigmented (NP) rice was studied. The total antioxidant content on post cooking was found to be higher in P rice (25-30%). The phenol content significantly reduced (89%) in NP rice as compared to P rice (60%) while the amount of total soluble sugar (TSS) in P rice was found to be reduced (14.2%) as compared to NP rice (10%). It was also observed that the cooking process did not affect the flavonoid and protein content to a significant amount (3% and 1%, respectively). Cooking rice in excess water can significantly reduce the level of total antioxidants and TSS, whereas the protein content may be marginally decreased but the percent change was found to be similar in case of both P as well as NP rice (Fig. 4.15).

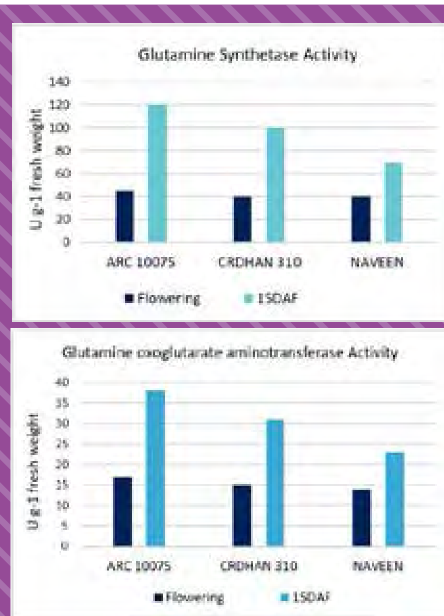


Fig. 4.14. Variation in the enzyme activity of GS and GOGAT at different stages.

Table 4.5. Total phenol content, total flavonoid content and total antioxidant activity in rice germplasm.

Antioxidants assayed	Mean	Max value	Min Value	Highest Value	Lowest Value
Total Phenol (mg catechin/100g)	40.10	114.83	16.17	AC 44322	AC 39565
Total Flavonoid (mg quercetin/100g)	3.20	9.56	0.33	AC 44302	AC 44323
DPPH (% inhibition)	39.85	85.28	6.94	AC 39568	AC 39565
ABTS (% inhibition)	19.68	83.53	5.00	AC 44311	AC 44320
CUPRAC (mg Trolox/ 100g)	201.03	609.08	39.92	AC 44302	AC 39554
FRAP (mg AAE/100g)	18.06	63.50	7.58	AC 44302	AC 44320

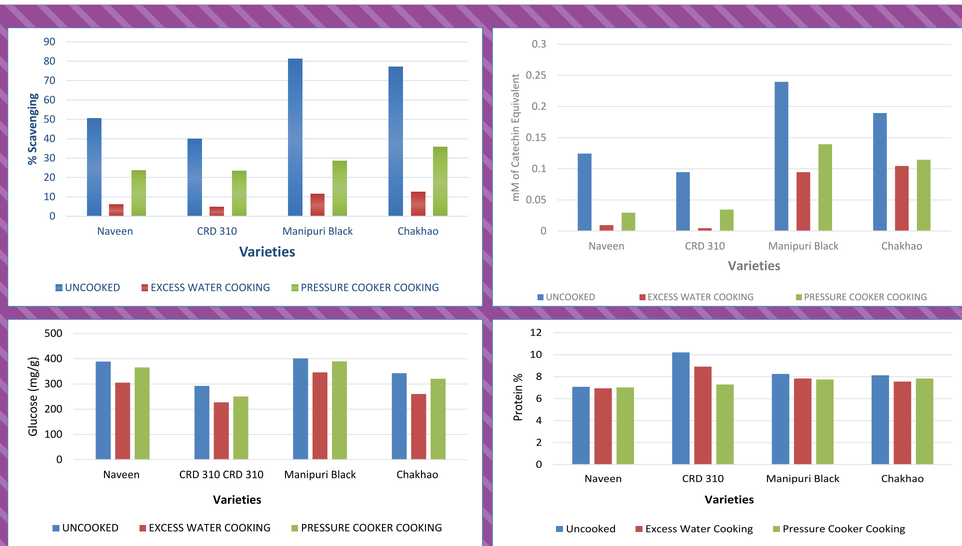


Fig. 4.15. Level of total antioxidant, total soluble sugar, total phenol and protein content in rice before and after cooking.

Through different research activities of the division five unique rice germplasm were identified and registered as novel sources of multiple abiotic stress tolerance. Besides, rice genotypes/varieties having high photosynthesis and biomass production ability, responsive to elevated CO_2 and tolerant to high temperature stress was also identified and relative contribution of different members of *OsDREB* gene families towards osmotic stress tolerance was elucidated. A novel method for evaluation of vivipary (precautious germination) was also standardized. Effect of parboiling on starch digestibility and mineral bioavailability in rice was studied and high mineral bioavailability (Fe and Zn) containing rice cultivars were identified. Besides, ammonium assimilation pathway in high protein rice was studied and rice bran cake, a novel value added food product was developed.

PROGRAMME-5

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

The Social Sciences Division spearheads in development and testing of new extension models, approaches and strategies for technology transfer and socioeconomic research in rice sector. Outreach activities for rapid dissemination of recent technologies to the end users and providing feedback to technologists have always been the major thrust of the division. The division with a total staff strength of twenty (seven scientists, twelve technical staff and one administrative staff) caters to its research mandates through two institute research projects and eight externally aided projects. During the year 2021, thirty newly released rice varieties were demonstrated through 465 farmers' field demonstrations in nine states in close convergence with both government and non-government stakeholders apart from participating farmers. Eighty-seven training programmes of various durations were organized either physically or in virtual mode benefitted 3577 participants including farmers, extension officials, administrative personnel and others. The division participated in exhibitions in different locations of the country, extended advisory services to the visitors, and provided agro-advisory services via different means. The division also played the pivotal role in disbursing diverse sorts of benefits to a wide range of beneficiaries especially the marginalized ones through Scheduled Caste Sub-Plan, Tribal Sub-Plan, Farmer FIRST Programme and *Mera Gaon Mera Gaurav* Programme. Rice database management for time-bound generation and submission of report has been quite efficiently undertaken by the division.

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

Testing and hastening spread of new rice varieties in different rice ecosystems through partnering public institutions (INSPIRE-1.0 Model)

On-farm minikit demonstrations of 28 newly released rice varieties were conducted in farmers' fields during *kharif* 2021 under the institute-developed '**IN**novative extension model for fast **SP**read of varieties **I**n **R**ice **E**cosystems' (INSPIRE 1.0 Model). The new varieties were introduced to 335 participating farmers in 19 districts of nine states namely Odisha, West Bengal, Bihar, Jharkhand, Assam, Madhya Pradesh, Chhattisgarh, Maharashtra and Andhra Pradesh covering over 205 acres area in close convergence with senior officials from respective Krishi Vigyan Kendras (KVKs) and state agriculture departments apart from participating farmers.

All the participating farmers were provided with paddy seed minikits of five kg each through respective collaborating Krishi Vigyan Kendras (KVKs) and District Agriculture Officers (DAOs). Necessary technical guidance was provided through follow up visits, providing relevant literatures, mobile calls and other digital modes. Crop cutting experiments (CCEs) cum Field Days were organized in the presence of collaborating officials, scientists and farmers to evaluate the performance in comparison to already prevailing varieties. Majority of the demonstrated varieties outperformed the existing popular varieties in the same ecology by giving a grain yield advantage of 10 to 20% with ranges from as low as -14.29% in case of CR Dhan 101 in comparison to MTU 1010 in Maharashtra to as high as 67.65 % in case of CR Dhan 507 in comparison to Manika in Odisha.

Fig. 5.1. Demonstration fields in West Bengal, Jharkhand, Bihar and Odisha.

Orienting and empowering private institutions (NGOs, CSR Units and FPOs) for dissemination of suitable rice innovations (INSPIRE-2.0)

While INSPIRE 1.0 model is designed for varietal popularization in various states in collaboration with public institutions, '**IN**novative extension model for fast **SP**read of new technologies **I**n **R**ice **E**cosystems' (INSPIRE 2.0) model initiated during 2020 focussed on collaboration and empowerment of private institutions, like non-government organizations (NGOs), corporate social responsibility units (CSR units), and farmers' producers' organizations (FPOs) for demonstration and dissemination of rice innovations including varieties to end users. As critical inputs, paddy seed minikits of 11 rice varieties were provided to 130 participating farmers in collaboration with leading non-government institutions from three districts of Odisha namely, Nayagarh, Kendrapada and Cuttack for conducting field demonstrations during *kharif* 2021 and capacity building of partnering stakeholders. Some of the demonstrated varieties performed better than the existing popular varieties in the same rice ecology by giving a grain yield advantage of 5-10% with ranges from -13.66% in case of CR Dhan 312 in comparison to MTU 1075 in Bargarh district to 22.96% in case of CR Dhan 307 in comparison of Swarna in Nayagarh district.

Feedback of Participating Farmers on the Varietal Characteristics demonstrated

Feedback on demonstrated varieties with respect to various characteristics from 125 participating farmers under INSPIRE 1.0, ninety participating farmers under INSPIRE 2.0 and 20 collaborating officers from KVKs and state agriculture departments from different states were collected and analyzed (Table 5.1). The average ratings out of 5.0 score are given below. As per the cumulative weighted scores of all the 235 respondents, it can be inferred that 'Plant type' was the most liked criterion of the demonstrated varieties with average score of 3.98, closely followed by 'Disease resistance' (3.97), 'Grain type' (3.93), 'Tillering capacity' (3.90), 'Insect pest resistance' (3.90), 'Germination quality' (3.87) and 'Grain yield' as the least liked criterion with average score of 3.86.

Problem Analysis of Farmers in rice farming

An analysis of problems being faced by rice farmers from Jharkhand revealed that 'non-availability or insufficient water' ranked first with 83% responses followed by problems of seeds (78%), pest and diseases (56%), farm machineries related issues (28%), insufficient storage space (22%), marketing problem (17%), working capital (11%) and unavailability fertilizers (6%).

Developing climate smart model villages in stress-prone rice ecosystems (flood/ submergence and drought)

So as to develop a climate smart model village in a flood and submergence prone area, Kunarpur village of Sain Sasan gram panchayat in Nimapada block of Puri district in Odisha was selected and its base line survey was conducted. It was revealed that there were 240 households with a population of 900 approximately. The village had a total geographical area of about 205 ha, of which 150 ha (rice-145 ha, vegetables-4 ha) was cultivated land with 100 ha irrigated and 50 ha rainfed. Rice-rice, Rice-vegetables-

Table 5.1. Feedback on the varietal characteristics demonstrated in various states

Characteristics of demonstrated varieties	Average rating out of score 5.0				
	Participating farmers under INSPIRE 1.0 (n_1=125)	Participating farmers under INSPIRE 2.0 (n_2=90)	Collaborating officers (n_3=20)	Cumulative weighted average (N=235)	Rank
Plant type	4.10	3.78	4.10	3.98	I
Disease resistance	4.01	3.90	4.00	3.97	II
Grain type	4.08	3.73	3.85	3.93	III
Tillering capacity	4.10	3.64	3.85	3.90	IV
Insect pest resistance	3.90	3.90	3.85	3.90	V
Germination quality	4.35	3.18	4.00	3.87	VI
Grain yield	4.23	3.40	3.60	3.86	VII

fallow, Rice-vegetables-vegetables, Rice-potato-sesame, Rice-green-gram-fallow and Rice-green gram-vegetables were dominant cropping patterns, while rice-based farming system is prevalent in the village. Major occupation of people was agriculturist (75.0%), followed by labourers (12.0%), salaried people (10.0%), and others (3.0%). Important rice varieties grown during *kharif* 2020 season (pre-intervention period) were found to be Pooja, MTU 7029, Kalachampa, RGL 2523, Sarala, CR 1017, Jamuna, and BHU 11; and only about 20 ha area was under Swarna *Sub1* and CR 1009 *Sub1* varieties. Among vegetables, pointed gourd, okra, chilli, brinjal, radish & bitter gourd were more popular.

Flood occurs at least once in every two years; stagnant flood water stays for more than a week and damages the crop up to the extent of 75% area. Similarly, the village being located in the coastal area, faces cyclone every year with crop damage up to 50% area or more. Drought and hail storms occur occasionally with crop loss up to 25% area. Among the biotic stresses, insect-pest and disease problems are faced by farmers every year with a crop loss up to 25%. The major constraints perceived by the farmers in ascending order of rank were found to be flood, cyclone, unavailability of stress tolerant crop varieties, marketing and non-availability of labour.

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

Estimation of economic contribution of NRRI varieties and technologies

Resources for agricultural research are scarce and economic analysis is required to know the social value of scientific knowledge and technologies in terms of aggregated economic benefits generated. A large amount of public resources is invested in the generation of varieties and technologies and these funds are restricted, their opportunity cost is also high. Hence, the method of assessment of the socioeconomic impact of new varieties/ technologies are intended to calculate by using the economic surplus method through aggregation of social benefits of research by computing a variation of consumer and producer surplus through technological changes originated by the research. As first development, the NRRI varieties and their rate of adoption for assessment of economic surplus have been identified and parameters like price, elasticity of production and consumption, etc. were assumed. There were 11 varieties, which covered more than 1 lakh ha area (calculated based on data upto 2014-15) and there were other six varieties, which covered five or more states. Estimation of area coverage of varieties released during the period of 2012-13 to 2019-20 (calculated based on breeder seed indent) revealed that nine varieties have covered more than one lakh ha area. However, the old varieties, which have been considered for further assessment were Pooja, Ranjeet, Swarna *Sub1*, Jaya, Shatabdi, Ratna, Sahbhagidhan and Naveen.

Estimation of economic value of specialty rice and premium seed varieties

There are no evidence of price differentials of high protein rice or premium varieties of seeds at farmer's level. Though price differed at market outlets, farmers hardly received any dividends; and markets are not developed yet for high protein rice. Similarly, availability of premium quality seeds is also not providing differential price to the seed growers. It was intended to measure people's willingness to pay instead of what people actually pay for premium seeds which might rationalize the market price or better dividends to the farmers. The premium seed varieties and specialty rice for valuation through willingness-to-pay (WTP) identified were: CR Dhan 310, CR Dhan 311, Ketekijoha, Kalajeera, Gitanjali, Swarna *Sub1*, Sahbhagidhan, Maudamani, Ranjit, CR Dhan 801, CR Dhan 802 and CR Dhan 206. Choice cards were prepared to elicit responses from different respondents' categories regarding WTP.

Rice consumption pattern in India

Consumption pattern of rice at micro level are not available. Hence, mapping of rice consumption pattern would be helpful in knowing the demand of particular variety at disaggregated level and devise suitable policies and strategies for future research. Estimation of growth trend in domestic consumption of rice in India showed increment from 35 million tonnes during 1960 to 107 million tonnes during 2020 (Fig. 5.2). The production of rice has also been continuously increasing since 1960, but the consumption has not followed the same pattern. During the late 90's, the consumption was the highest in the country, but thereafter it has been gradually decreasing. In comparison to other cereals, rice consumption has always been higher but people have shifted towards non-cereal items during recent years. Fig. 5.3 presents the per capita consumption of rice during last two decades, which shows a decline in the initial years and remained near stable afterwards. The sudden fall in growth rate is due to calamities during that year or subsequent year like war, drought, etc. When we analyzed time series data on the level of consumption of two staple cereals, i.e. wheat vis-à-vis rice since 1960 to 2020, it was observed that quantity of rice consumed was little higher than wheat with the interesting fact that consumption level of both the cereals moved together (Fig. 5.4). Further, as we quest for nexus between rice consumption, population and GDP of the country, it was noticed that domestic consumption of rice move more with the population growth and less likely to relate with the GDP of the country (Fig. 5.5).

Trend of growth and instability in rice area, yield and production in NE states

Decade wise compound annual growth rate (CAGR) of area, production and yield (APY) of rice has been calculated for the North-eastern states of India, *viz.,* Tripura, Sikkim, Nagaland, Meghalaya, Arunachal Pradesh and Mizoram (Table 5.2). Similarly, instability in APY of rice was estimated and rice production growth decomposed into area and yield effect. Results indicated that area under rice increased in Nagaland and Arunachal Pradesh, whereas negative growth was observed for Tripura, Sikkim, Meghalaya and Mizoram; yield growth and production growth were highest for Arunachal Pradesh. Similarly, instability analysis indicated that yield instability was higher than the instability in area, except Tripura and Sikkim, where area instability was greater. Both area and yield instability led to the fluctuations in production during different decades. Further, rice production growth decomposed into area and yield effect and it showed positive contribution of yield for Tripura, Nagaland, Meghalaya and Arunachal Pradesh and negative contribution of area in Tripura.

Increment in cost of paddy cultivation in three states

Cost of paddy cultivation during 2020-21 for three states *viz.,* Bihar, Jharkhand and Madhya Pradesh

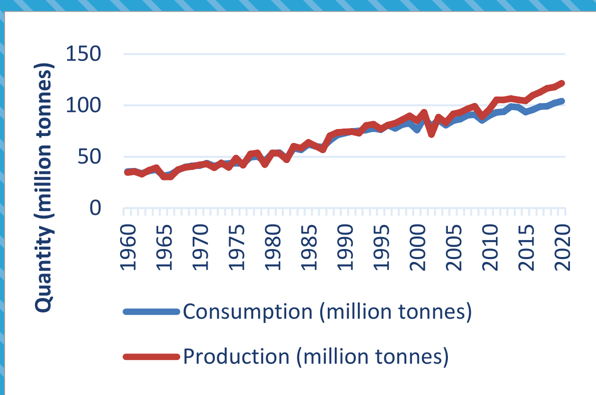


Fig. 5.2. Trend of domestic rice consumption and rice production in India.

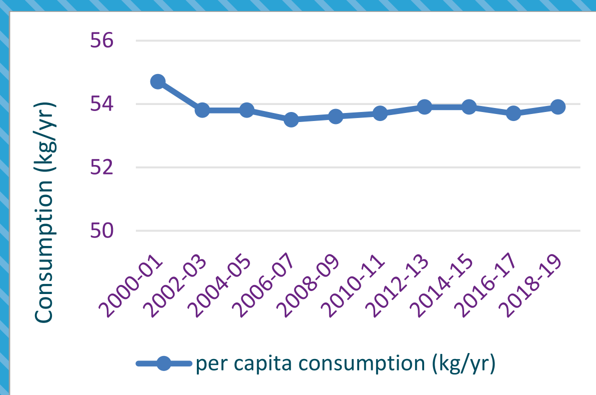


Fig. 5.3. Per capita consumption of rice (kg year^{-1}) in India.

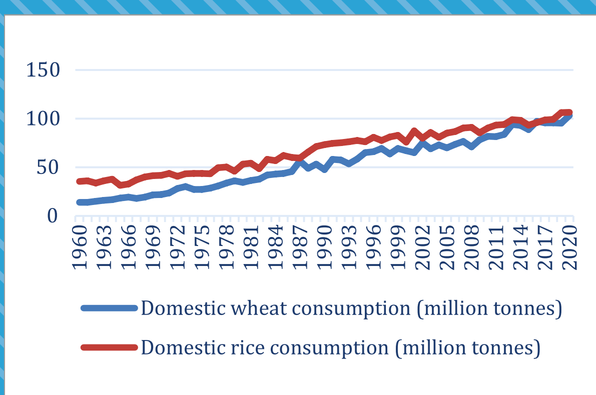


Fig. 5.4. Shift in wheat vs rice consumption in India.

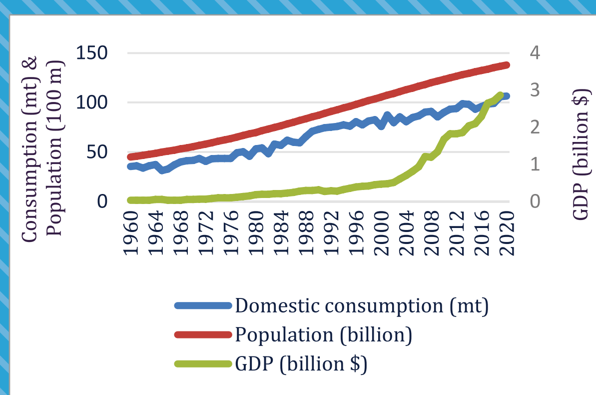


Fig. 5.5. Nexus of rice consumption, population and GDP.

have been calculated and compared with previous years' estimates. The results indicated that different categories of costs increased to higher extent in Jharkhand and Madhya Pradesh than Bihar state (Table 5.3). Further, due to continuous rise in material inputs, extent of increment in Cost-A was higher than Cost-B, which added interest on fixed capital and imputed rent of owned land to the cost A as well as Cost-C, which account for imputed value of family labour (over Cost-B) not changed much due to negligible changes in interest rates, land rent and labour wages in a year. It was also observed that various categories of income increased at greater rates than the increase in cost categories, which was due to the higher yield level in comparison to previous seasons.

Rice export: Basmati and Non-Basmati perspective

Indian rice is price competitive and has the capacity to get a competitive edge in the global market due to premium quality. Since last two decades, rice export from India flourished well, except during 2008-09 to 2010-11, due to ban in export of non-basmati rice and 2015-16 due to drought year (Fig. 5.6). In fact, the share of Non-Basmati rice export in quantity terms was more than that of Basmati rice, yet the revenue from Basmati rice export was higher than that of Non-Basmati rice due to greater market price. However, during the year 2020-21, export of Non-Basmati rice doubled and earned more foreign exchequer than the Basmati rice (Fig. 5.7). In respect of major destinations for the Indian rice, Middle East and European Countries import Basmati rice from India, while African countries are the major destination for Indian Non-Basmati rice. During recent period, Bangladesh has also emerged as a major importer of Indian Non-Basmati rice, but, Nigeria is no longer importing Non-Basmati rice from India due to increase in their domestic production.

Table 5.2. Growth and instability in area, yield and production of rice in NE states of India.

Particulars	CAGR (%)	Instability index	Decomposition of production growth (%)	Particulars	CAGR (%)	Instability index	Decomposition of production growth (%)
Tripura (1990-91 to 2017-18)				*Meghalaya (1990-91 to 2016-17)*			
Area	-0.04	4.26	-2.49	Area	-0.04	1.64	4.04
Yield	2.05	3.94	104.01	Yield	3.39	11.28	90.22
Production	2.01	5.65	-1.52	Production	3.68	11.70	5.73
Sikkim (1990-91 to 2017-18)				*Arunachal Pradesh (1990-91 to 2016-17)*			
Area	-1.77	5.41	160.97	Area	0.45	2.03	13.50
Yield	1.46	4.99	-120.00	Yield	3.84	16.05	79.59
Production	-0.34	6.45	59.03	Production	4.31	16.25	6.91
Nagaland (1990-91 to 2017-18)				*Mizoram (1990-91 to 2016-17)*			
Area	1.72	3.25	53.70	Area	-1.87	10.87	443.46
Yield	2.12	13.82	27.82	Yield	-0.16	25.72	-488.84
Production	3.88	15.01	18.48	Production	-2.03	29.18	145.38

Table 5.3. Cost of paddy cultivation (in '000 Rs. ha^{-1}) during 2020-21 *vis-à-vis* previous years' estimates in three states.

Particulars	Bihar	Jharkhand	Madhya Pradesh
Cost-A	40.78 (5.85)	45.59 (14.69)	43.18 (15.25)
Cost-B	42.22 (1.69)	46.67 (14.03)	44.38 (11.68)
Cost-C	47.34 (0.17)	52.48 (7.24)	47.95 (9.84)
Gross returns	91.37 (25.87)	97.69 (39.53)	107.52 (36.87)
Net returns	33.61 (30.27)	35.34 (29.92)	52.07 (37.46)
Family labour income	38.73 (28.75)	41.15 (28.55)	55.63 (35.60)

Figures in brackets indicate increments in '000 Rs. ha^{-1} over the year 2019-20 for Bihar and Madhya Pradesh and 2018-19 for Jharkhand.

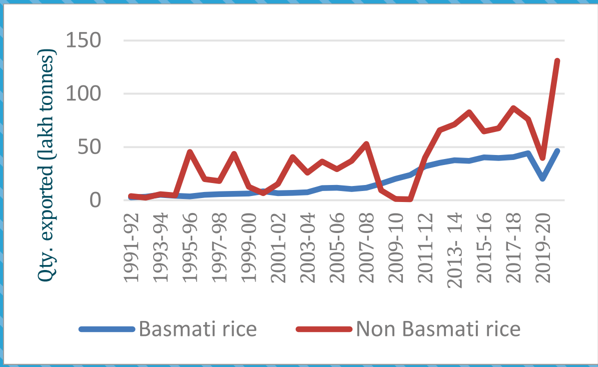


Fig. 5.5. Trend of quantity of rice exported since 1991-92 to 2020-21, by type.

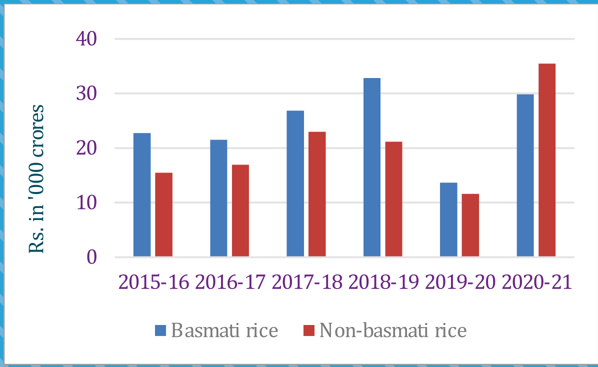


Fig. 5.6. Value of rice exported from India during 2015-16 to 2020-21, by type.

The programme envisages faster diffusion of sustainable and profitable NRRI varieties and technologies primarily through demonstration, awareness generation, and capacity building. It further intends to guide policies around rice research and production. The programme has oriented and empowered private institutions like NGOs, CSR Units and FPOs in profitable and sustainable rice based cropping system management. Development of climate smart model villages in stress-prone rice ecosystems has been a noble initiative under the programme. Estimation of economic contribution of NRRI varieties and technologies, and economic value of specialty rice and premium seed varieties will help in guiding future research and taking crucial decisions pertaining to rice technology development. Analysis of trend of rice consumption, growth and instability in area, yield and production of rice, cost of paddy cultivation, and rice export will render important policy guidance in rice area allocation, increasing crop diversity, and sustainable rice production.

PROGRAMME-6

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

The rice farming communities are facing new challenges of climate change including yield instability, low water availability, higher temperature, poor soil health, low nutrient use efficiency and increased emergence of insects and diseases. The problem is more pronounced in the rainfed upland, rainfed lowland and coastal saline ecologies. The agricultural systems under these ecologies should become more resilient and adaptable to the changing scenarios. The NRRI Regional Stations situated at Hazaribag, Gerua and Naira deal with these concerns through the development of stress tolerant varieties, and improved integrated crop production and protection packages for the small and marginal farmers. The NRRI regional station, Hazaribagh has a cadre strength of eight scientists and eight technical staff operating one institute research project and seven externally-aided projects. In 2021, the station has released one early duration rice variety, CR Dhan 320 (CRR 807-1/IET 27914) for irrigated areas in the states of Jharkhand, Bihar and West Bengal and promoted 11 entries in AICRIP trials. Four traits-specific genetic stocks have been registered by PGRC, ICAR. Altogether 516 accessions were characterized and many promising entries have been identified for multiple abiotic and biotic stress tolerance. With three scientists and four technical staff, NRRI regional station, Gerua focusses on developing thermo-insensitive boro, photo-insensitive *sali* and short duration *ahu* rice varieties, evalution of ecological based pest management tactics and dissemination of rice based technologies. With two scientists, NRRI regional station, Naira conducted surveys for gall midge infestation in AP.

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

Genetic stock registered

Altogether four genetic stocks have been registered by the Plant Germplasm Registration Committee (PGRC) of ICAR, New Delhi during 2021: ING R21114: CRR 747-12-3-B (IET 26337) – registered as a highly drought tolerant elite line Resistant to blast disease, also tolerant to Phosphorus starvation; ING R21177: CRR 363-36 (IET 19251) – registered as an aromatic early maturing rice elite line for rainfed uplands. Long Slender grains; ING R21178: RR 433-2-1 (IET 19252) – registered as a drought tolerant high yielding elite line for rainfed direct seeded upland conditions, and early maturing (95-100 days); and ING R21179: Kalakeri – registered as a drought tolerant, phosphorus starvation tolerant, & Weed competitive genetic stock.

Evaluation of rice germplasm for multiple stress tolerance

A set of 516 accessions were evaluated for agro-morphology characters, drought tolerance and resistance to blast and brown spot disease screening. The drought score and spikelet fertility ranged from 2.3-7.0 and 23.5-63.8%, respectively indicating considerable vegetative and resproductive drought tolerance. A survey of nine DTY-QTLs (*qDTYs*) using 26-linked SSR markers predicted the presence of $qDTY_{2.1}$ in White gora (IC 0640892), Gora (IC 0640899); $qDTY_{2.2}$ in Dani Gora (IC 0640877), Black Gora (IC 0640862); $qDTY_{2.3}$ in Alsanga Gora (IC 0640866), White Gora (IC 0640874); $qDTY_{3.2}$ in White Gora (HRC71)and $qDTY_{6.1}$ in Gora (IC 0640876) and Gora (IC 0640897). Promising entries showing >75% survival under anaerobic conditions are Black Gora (IC 0640862), Black Gora (IC 0640880), Brown Gora (IC 0640885), White Gora (IC 0640884), Dani Gora (IC 0640865), Charka Gora (IC 0640867), Tikra Gora (IC 0640868), Gora (IC 0640871) and Gora (IC 0640881). High genetic diversity was found using 39 SSR markers with 3.95 alleles/locus. The white gora accessions were classified as *indica,* and rest of the cultivars including black gora, brown gora and other gora accessions were found to be *aus.* This study identified several accessions as tolerant to multiple abiotic and biotic stresses (Table 6.1).

Table 6.1. Promising *gora* accessions with tolerance to multiple stresses.

Cultivar	IC Number	Drought (LDS 0-3)	Submergence (Survival > 70%)	Anaerobic germination > 70%)	Blast resistance (Score: 0-3)
Black Gora	IC 0640862	+	+		+
Dani Gora	IC 0640865	+		+	
Brown Gora	IC 0640869	+	+		+
Saria Gora	IC 0640873	+		+	+
Brown Gora	IC 0640879	+		+	+
Black Gora	IC 0640880	+		+	+

Sixty rice germplasm accessions were analysed for genetic diversity using 40 SSR markers and also screened for drought tolerance using *qDTY*-linked markers. The major allele frequency ranged from 0.35 (RM 3825 & RM 16030) to 0.93 (RM 161) with a mean of 0.59. Polymorphism information content (PIC) value ranged from 0.14 (RM 161) to 0.66 (RM 16030) with an average of 0.45. The average heterozygosity was found to be 0.02 and the mean gene diversity was 0.52. Among the different *qDTYs* surveyed, the drought QTLs $qDTY_{12.1}$ (RM 28048) was found maximum in 45% and $qDTY_{2.2}$ (RM 279) was detected minimum in 8.3 % of the germplasm. The $qDTY_{1.1}$ screened with marker RM 11943 and RM 431, was found positive in 19 and 14 germplasm accessions, respectively. Only three accessions were positive for $qDTY_{1.1}$ with both markers. About 23% germplasm were found positive for $qDTY_{1.2}$ (RM3825). Other QTLs, $qDTY_{2.3}$, $qDTY_{3.1}$, $qDTY_{3.2}$, $qDTY_{4.1}$ were also present in 25%, 21%, 20% and 18% germplasm, respectively. Cluster analysis revealed four groups within the germplasm (Fig. 6.1). These germplasm with different combinations of *DTY* QTLs can be useful genetic resources for drought breeding program in rice.

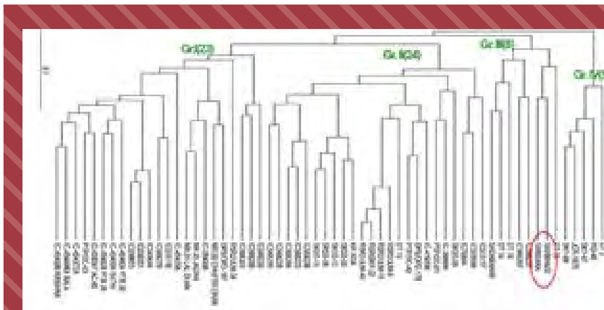


Fig. 6.1. Cluster analysis of 60 rice germplasm accessions using *qDTY*-linked SSRs.

Eighty-eight rice germplasm collected from Majuli island, Assam were evaluated for submergence tolerance during 2019 (*kharif*) and 2020 (*rabi*) seasons at NRRI, Cuttack. The survival under 14-days submergence varied from 7.3-95.5% and elongation from 53.1-238.8%. The list of promising accessions is shown in Table 6.2. Screening of *Sub1* and *SNORKEL* genes revealed that 33 accessions showed homologous amplifications for tolerant *Sub1A* like FR13A. *Sub1 C* was detected in 22 accessions, while *Sub1B* was found in 15 accessions. The *SNORKEL1* gene-specific amplicon was recorded in 13 accessions while, 22 accessions showed the presence of *SNORKEL2*.

Table 6.2. Promising submergence tolerant rice accessions from the Majuli collection.

Treatment	Survival %	Elongation %
Depa Bao	95.52	176.89
Laxman Sali (IC 0635870)	91.98	123.49
Chokuwa (IC 0635849)	85.52	78.87
KhutiJeul	84.49	132.91
Kalabora (IC 0635854)	81.71	132.92
Satlang (IC 0635834)	80.52	154.98
MianSali (IC 0635814)	76.71	140.48
Jahinga (IC 0635847)	75.52	124.7
Biria Bao (IC 0635843)	75.13	182.59
Susuri (IC 0635850)	75.13	137.52
FR13A	**93.34**	**77.37**
Swarna *Sub1*	**90.54**	**53.11**
Swarna	**28.32**	**102.66**
Range	7.3 – 95.5	53.1 - 238.8
CV	21.6	14.5
CD 5% (test vs Control)	30.6	13.9

Varietal development

CR Dhan 320 (CRR807-1/IET27914)

The new variety CR Dhan 320 has been released and notified by CVRC for irrigated areas in the states of Jharkhand, Bihar and West Bengal in 2021 from the cross IR10L146/ IR10L137 (Fig. 6.2). Salient features of this variety are: early duration (117 days), semi-dwarf plant type (99.0 cm), highly vigorous, non-lodging, and having long slender grain with white kernel. It has shown average yield of 5.35 t ha^{-1} in eastern zone (Zone III) during three-years (2018-20) of AICRIP testing. It is moderately resistant to leaf blast (SES score 4.6), brown spot (SES score 5.5), sheath rot (SES score 5.1), brown plant hopper, leaf folder and stem borer (dead heart). CR Dhan 320 possesses very good grain quality attributes, head rice recovery (62.4%), absence of chalkiness, low gelatinization temperature (ASV 7.0), intermediate (26.82%) amylose content and soft (62.5) gel consistency.

Fig. 6.2. CR Dhan 320 - an early maturing high yielding rice variety released for Jharkhand, Bihar and West Bengal.

A new breeding line CRR 514-6-1-1-1-6 (IET 27523) derived from the three-way cross: Brown Gora/N 22 // CR 143-2-2, ranked 1st among the entries in AVT1E-DS and recorded 36% yield advantage over the best check Sahbhagidhan and found promising in drought-prone locations in Gujarat, Jharkhand and Odisha (Fig. 6.3). It has shown average yield of 2.31 t ha^{-1} under direct seeded rainfed drought stressed conditions during 2018-2020 trials. It has long slender grain with 50% flowering duration of 72 days. The entry exhibited high head rice recovery (53.8%), intermediate amylose content (22.1%), moderate gelatinization temperature (ASV-4) and soft gel consistency (34 mm) as desired grain quality traits. This entry is found promising in drought prone locations in Zone VI (Gujarat) and Zone III (Jharkhand and Odisha).

Fig. 6.3. Promising breeding line CRR 514-6-1-1-1-6 (IET27523) for drought prone locations in Zone III and zone VI.

Development of Recombinase polymerase assay for aroma gene in rice

A highly sensitive rapid detection method for the *badh2* gene conditioning aroma in rice has been developed based on recombinase polymerase amplification (RPA) assay. The primers were designed from the 8 bp deletion in exon7 of *badh2* gene. The assay method was validated in a set of diverse aromatic rice germplasm as well as in the hybrids of Sahbhagidhan/ Pusa Basmati 1. The functional polymorphism was efficiently detected using crude leaf sap in RPA, and the results obtained were consistent with PCR-based detection using purified DNA as template. The sensitivity of the RPA and PCR was compared using ten-fold serial dilutions of aromatic purified DNA template and crude sap, and RPA was found to be highly sensitive detecting the gene up to 10^{-7} dilutions in both purified DNA and crude sap (Fig. 6.4).

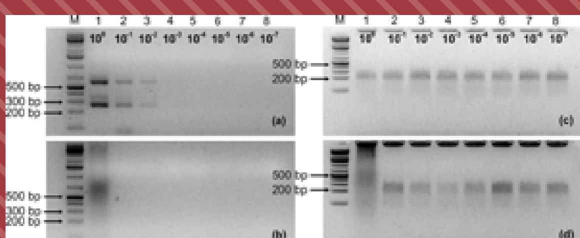


Fig. 6.4. Comparison of sensitivity between PCR and RPA for ten-fold dilutions of DNA template (a & c) and crude sap (b & d); Lane 1-8: serial dilutions of F_1 (Pusa Basmati 1/ Sahbhagidhan) plant DNA and crude sap (10^0-10^{-7}); Lane M, 1 kb plus DNA ladder.

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

Evaluation of nutrient management options for Rice based cropping system

The three years pooled data (2018 - 2020) on grain yield showed that nutrient management had a significant impact on yield in rice alone and rice-pigeon pea intercropping system. In rice alone, the highest yield (2.83 t ha^{-1}) was recorded in T_2 followed by integrated nutrient management T_4 (2.25 t ha^{-1}) and T_3 (1.88 t ha^{-1}). A similar trend was observed in rice-pigeon pea system in relation to different nutrient management options. Yield of rice and pigeon pea was highest under T_2 (1.71 and 0.48 t ha^{-1}, respectively) followed by the T_4 (1.47 and 0.37 t ha^{-1}, respectively). Yield of pigeon pea was converted to the rice equivalent yield (REY) and was observed that irrespective of the nutrient management options, REY was higher in the rice pigeon-pea intercropping system as compared to rice alone. The highest REY was recorded in the T_2 (3.22 t ha^{-1}) followed by integrated nutrient management (T_4 and T_3) (Table 6.3).

Integrated Nutrient management for yield maximization under shallow lowland in drought prone rainfed ecology

In order to evaluate the different nutrient management options for enhancing the productivity, a field experiment was conducted under shallow lowland area. Three nutrient management options [T_1: recommended dose of fertilizers (RDF) 80:40: 40:: N: P_2O_5: K_2O kg ha^{-1} ; T_2: RDF + VAM inoculums at nursery bed; and T_3: Improved management options [RDF (N in three splits) + application of Zn as $ZnSO_4$ (25 kg ha^{-1})] were evaluated with five popular rice varieties [Abhishek (V1), IR 64 *drt1* (V2), CR Dhan 305 (V3), MTU 1010 (V4) and hybrid, PA 6444. (V5)]. It was observed that improved nutrient management options (T_3) resulted superior as compared to other nutrient managements for grain and straw yield as well as yield attributes like grains per panicle and number of tillers per m^2 (Table 6.4). This study implies that, application of micronutrient (Zn) along with the recommended dose of primary nutrient has the prominent role to boost the productivity in shallow lowland of rainfed rice cultivation in drought prone areas of Jharkhand.

Table 6.3. Effect of nutrient management options on rice based cropping system.

Treatments	Rice Alone		Rice Pigeon-pea intercropping		
	Grain yield (t ha^{-1})	REY (t ha^{-1})	Grain yield (t ha^{-1})	Pigeon Pea yield (t ha^{-1})	REY (t ha^{-1})
T_1: Control	1.01[g]	1.01[g]	0.74[e]	0.12[e]	1.13[f]
T_2: 100% RDF*	2.83[a]	2.83[a]	1.71[a]	0.48[a]	3.22[a]
T_3: 50% RDF +FYM @ 5 t ha^{-1}	1.88[c]	1.88[c]	1.29[c]	0.40[b]	2.56[b]
T_4: 50% RDF +FYM @ 5 t ha^{-1}+VAM 1.5 q ha^{-1}+ PSB 4 kg ha^{-1}	2.25[b]	2.25[b]	1.47[b]	0.37[c]	2.64[b]
T_5: 50% RDF +RI	1.60[d]	1.60[d]	1.26[c]	0.34[c]	2.34[c]
T_6: 100% FYM @10 t ha^{-1}	1.19[f]	1.19[f]	0.86[d]	0.29[d]	1.79[d]
T_7: 100% FYM @10 t ha^{-1}+ VAM 1.5 q ha^{-1}+ PSB 4 kg ha^{-1}	1.35[e]	1.35[e]	0.91[d]	0.30[d]	1.87[d]
T_8: 100% FYM @10 t ha^{-1}+RI	1.22[ef]	1.22[ef]	0.84[de]	0.23[e]	1.57[e]

*RDF (60:30:30 N: P_2O_5: K_2O kg ha^{-1}) in rice and (40:30:30 N: P_2O_5: K_2O kg ha^{-1}) in rice-pigeon-pea intercropping.

Table 6.4. Effect of nutrient managements on yield and yield attributes.

	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Grains/ panicle	Tiller m^{-2}
T_1	7.48[b]	13.7[b]	148[b]	248[b]
T_2	7.83[b]	15.1[ab]	161[ab]	257[ab]
T_3	9.03[a]	15.6[a]	164[a]	273[a]

Biotic stress management strategies for rainfed drought-prone ecologies

Screening and identification of promising rice genotypes for biotic stress tolerance

A set of 455 rice genotypes consisting of *gora* cultivars (41) of Jharkhand, 167 north-east rice accessions collected from Majuli (88) and Nagaland (79), and advanced breeding materials (ABM, 240) along with a few traditional and improved check varieties (7) were screened under UBN for blast and brownspot during *kharif* 2020 and 2021. With respect to both the diseases, SES score of 0-3 was categorized as resistant. Out of 455 accessions, 44 were identified as resistant to blast, while only 16 resistant entries were identified against brown spot. A list of resistant genotypes identified for blast and brown spot diseases is given in Table 6.5.

Management of blast and brown leaf spot using newer fungicide molecules

Seven new fungicide molecules [Prochloraz 27% w/w + Tricyclazole 23% w/w SE @ 2 ml l^{-1}, Prochloraz 45% EC @ 2 ml l^{-1}, Tricyclazole 75% WP @ 0.6 g l^{-1}, Trifloxystrobin 25% + Tebuconazole 50% WG @ 0.4 g l^{-1}, Azoxystrobin 18.2% + Difenoconazole 11.4% EC @1 ml l^{-1}, Hexaconazole 5% EC @ 2 ml l^{-1} and Propiconazole 25% EC @1 ml l^{-1}] were applied. The result revealed that the fungicide Azoxystrobin + difenoconazole was most effective in reducing blast incidence and corresponding yield increase of rice (CO-39). The other effective fungicides were Prochloraz + Tricyclazole and Tricyclazole in leaf blast management. But fungicide (Trifloxystrobin + Tebuconazole) was most effective, followed by fungicide (Prochloraz + Tricyclazole) in reducing brown spot incidence and corresponding yield increase in susceptible variety Sahbhagidhan.

Integrated disease management of blast and brown spot of rice

Developed biocontrol based IDM technology for rice blast and brown leaf spot, wherein the treatment T_3 & T_4 (bioagent as seed treatment alone + seed treatment + field application of bioagent + spray of propiconazole were on par and equivalent to control T_5 (Seed treatment with carbendazim (2 g kg^{-1}) + one blanket application of combination fungicide (Trifloxystrobin 25% + Tebuconazole 50%) @ 0.4 g l^{-1} at booting stage) in reducing leaf blast & brown spot disease incidence and corresponding yield increase of paddy (test var. CO-39 for blast and Sahbhagidhan for brown spot) .

Table 6.5. Resistant genotypes identified against blast and brown spot disease.

Stress	Resistant genotypes ((SES score 0-3)
Blast	***Gora* acc. (16) :** Brown Gora (IC 0640860); Brown Gora (IC 0640861); Black Gora (IC 0640862); Brown Gora (IC 0640863); Brown Gora (IC 0640869); White Gora (IC 0640870); Saria Gora (IC 0640873); White Gora (IC 0640874); White Gora (IC 0640878); Brown Gora (IC 0640879); Black Gora (IC 0640880); Brown Gora (IC 0640885); Gora (IC 0640890); White Gora (IC 0640892); Gora (IC 0640897); Black Gora (IC 0640900)
	Majuli acc. (8) : Ranga Sali (IC 0635829); Komal Dhan (IC 0635838); Sohagmani (IC 0635846); Boga Sali (IC 0635851); Motok (IC 0635852); Ranga Joha (IC 0635853); Kalabora (IC 0635854); Ghiu Bora (IC 0635863)
	Nagaland acc. (20) : Kemenya (IC 0635877); Ngoba (IC 0635879); Rulhuo (IC 0635881); Kemenya (IC 0635882); Sayie (IC 0635885); Rulu (IC 0635886); Chaha (IC 0635887); Rshuo (IC 0640918); Khoru (IC 0635891); Khulughi (IC 0640921); Khatanghe (IC 0635897); Khataru (IC 0635902); Yangulo (IC 0635906); Amusumicheghe (IC 0640925); Sahulu (IC 0640928); Khrisü (IC 0635914); Neiju (IC 0635915); Matikhrurie (IC 0635921); Tivelu (IC 0640931); Kuthunyi (IC 0635929)
Brown spot	**Majuli acc. (5) :** Ranga Sali (IC 0640939); Til Bora (IC 0635819); Kalajoha (IC 0635837); Depa Bao (IC 0640943); Ampaki Bora (IC 0635848)
	Nagaland acc. (3) : Teri Shye (IC 0640920); Jondre (IC 0635894); Zacuta ha (IC 0635930)
	ABM (8) : CRR 771-B-B-18; CRR 771-B-B-20; CRR 771-B-B-22-1; CRR 771-B-B-29; CRR 772-B-B-47; CRR 803-B-B-2; CRR 803-B-B-3; CRR 778-B-B-1-1

Integrated disease management of False Smut of rice

An integration of two dates (20 July & 27 July) of transplanting, moderate doses of fertilizer (NPK=80:40:40 kg ha^{-1}) and nine fungicides [Tebuconazole + Trifloxystrobin, Picoxystrobin + Propiconazole, Bavistin, Tricyclazole + Mancozeb, Tricyclazole + Tebuconazole, Tricyclazole, Tebuconazole, Copper Hydroxide and Carbendazim + Mancozeb] were evaluated for the management of false smut of rice (PHB-71). The result revealed that early transplanting (upto 20 July) and the fungicide Tebuconazole + Trifloxystrobin were most effective in management of false smut of hybrid rice [with uniform moderate fertilizer dose (NPK= 80:40:40)].

Morpho-molecular diversity of Magnaporthe oryzae population in Jharkhand

Thirty-two *M. Oryzae* isolates from Jharkhand were characterized for their colony morphology, sporulating ability, mating type and *Avr* gene variability. On PDA media, isolates exhibited varied colony colours such as greyish cottony (14), greyish white (9), brownish white (3), brownish cottony (2), blackish cottony (2), whitish cottony (1) and greyish black (1) (Fig. 6.5). Majority of the isolates formed circular (28) colony followed by filamentous (3) and irregular (1) form. The elevation varied from flat (13), raised (9), crateriform (6) and umbonate (4). Out of 32 isolates, only five isolates (MoJh-43, MoJh-118, MoJh-129, MoJh-134 and MoJh-161) showed sporulating ability on PDA at the temperature range of 25-28°C and the spore count varied from 28,000 to 161,000 spore ml^{-1} suspension. PCR based mating type analysis identified 20 isolates (62.5%) as homothallic. Till date, five *Avr* genes (*AvrPita, AvrPit, AvrPik, AvrPizt, ACE1*) were studied and the frequency distribution ranged from 81-100%.

Development of recombinase polymerase amplification (RPA) assay for rapid detection of false smut pathogen directly from mycelial mat

A RPA based protocol for rapid, specific and sensitive detection of *U. virens* directly from mycelial mat has been developed. Three oligonucleotide primer pairs were designed from the *U. virens* GTP binding

Fig. 6.5. Colony morphology of *M. oryzae* isolates from Jharkhand based on colour, form and elevation.

protein beta subunit (UVGbeta-1) gene (GenBank Acc. GU014921). RPA was performed with all the three primer pairs using the Twist Amp Basic Kit at an isothermal condition (37°C) for 30 min (Fig. 6.6). The developed RPA assay efficiently detected *U. virens* even in crude sap extracted from fungal mycelia. The specificity of the RPA primers was evaluated using DNA from other rice pathogens, as well as, by sequencing the RPA amplicons. Further, the sensitivity of RPA assay was compared with the reported loop-mediated isothermal amplification (LAMP) and nested PCR protocol. Other than RPA, both LAMP and nested PCR assay failed to detect *U. virens* from crude sap. The developed assay can be a potential PCR alternative for rapid and specific screening of *U. virens*.

Fig. 6.6. Detection of *U. virens* by RPA using purified DNA (a) and crude extract (b) as a template. The "+" indicates DNA/crude extract from U. virens isolate and "-" indicates water control. On upper panel (a) analysis of RPA amplicons generated from three primer pairs on 2% agarose gel after following treatment; lane 1-2: direct RPA product from + and - sample; lane 3-4: RPA product from + and - sample incubated at 65°C for 10 min. lane M: 100 bp DNA ladder.

Breeder seed production

About 244.5 quintals of breeder seeds of nine varieties (Anjali, Abhishek, CR Dhan 40, Hazaridhan, IR 64 *drt1*, Sadabahar, Sahbhagidhan, Vandana and Virendra) were produced to fulfil the DAC indent and other requirements.

Rice production and productivity improvement in Rainfed lowland ecosystem

Maintenance of rice germplasm

Maintained 766 accessions of rice germplasm during *boro* 2020-21 and *kharif* 2021 and recorded data on days to 50% flowering, plant height, number of effective tillers and grain yield.

Rice varieties *viz.*, CR Dhan 307, CR Dhan 309, CR Dhan 310, CR Dhan 311, CR Dhan 801, CR Dhan 802, CR Dhan 500, CR Dhan 505, CR Dhan 506, CR Dhan 508 and CR Dhan 909 were grown in 3.22 ha area during *kharif* 2021 for breeder seed production and produced 5.5 q seeds. Besides, about 2.6 q TL seeds were also produced on the stations.

Efficacy of fungicide against Rice Bakanae disease

Application of carbendazim @ 2 gm l^{-1} and propiconazol @ 2 ml l^{-1} of water in seeding root dip treatments for two hours before transplanting and spray treatments at 15 days after transplanting (DAT) were evaluated against rice bakanae disease during *boro* 2021. Spray of propiconazole at the rate of 2 ml l^{-1} of water at 15 days after transplanting recorded the lowest 2.52, 1.25 and 0.32 per cent incidence of bakanae disease at 15, 30 and 40 days after treatment, respectively and recorded the highest yield of 3.98 t ha^{-1}.

Effect of different transplanting dates on rice stem borer infestation in rainfed lowland

Rice variety Naveen was transplanted in three different dates at 15 days intervals during *boro* 2020-21. Rice transplanted in first fortnight of February recorded the lowest incidence of rice stem borer (0.76%) as compared to second fortnight of February (1.70%) and first fortnight of March (2.95%). Crop transplanted in first fortnight of February recorded the highest yield of 5.12 t ha^{-1} as compared to crop transplanted at second fortnight of February (5.08 t ha^{-1}) and first fortnight of March (4.98 t ha^{-1}).

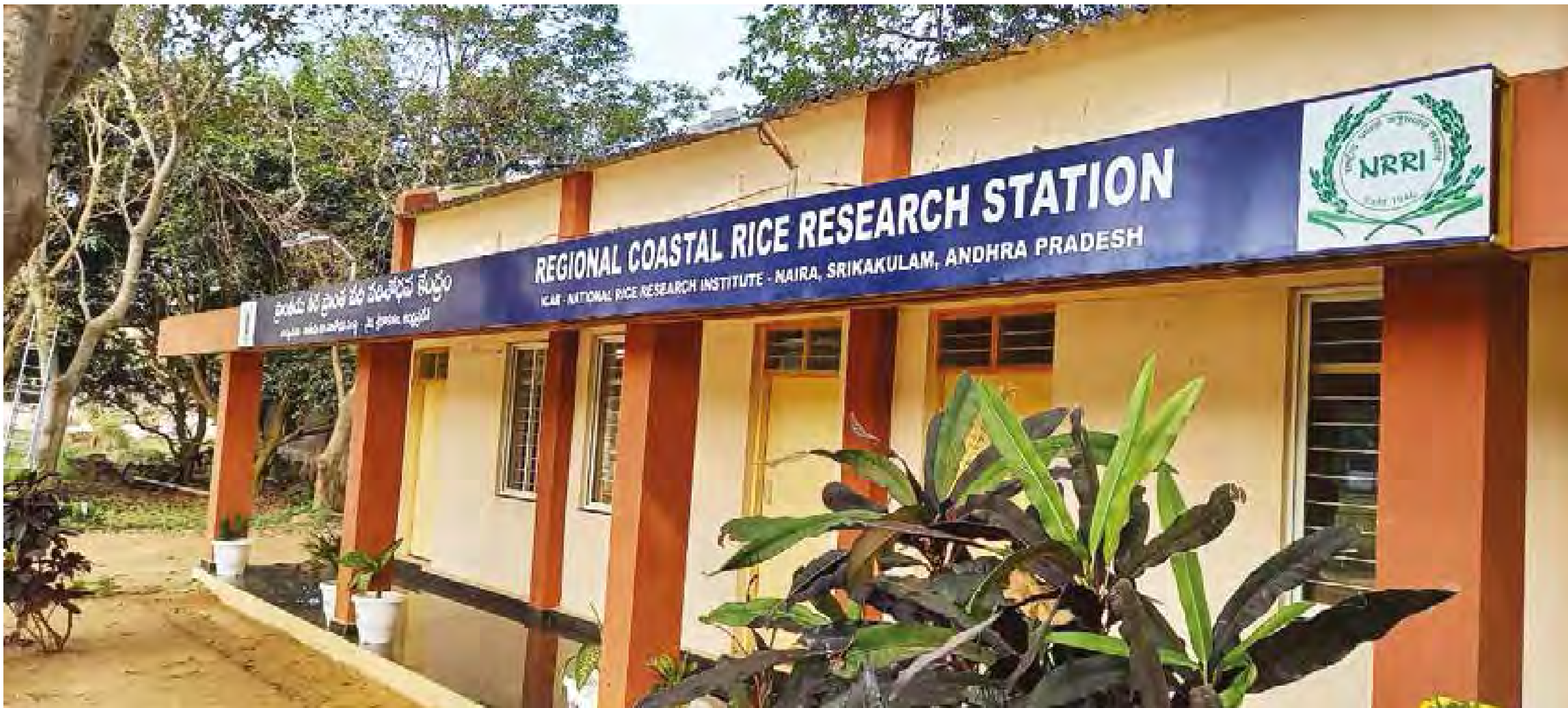
Frontline demonstration of HYV in Assam

Frontline demonstration on Naveen, CR Dhan 310 and CR Dhan 311 were conducted in Nalbari, Baksa, Barpeta and Darrang districts of Assam covering an area of 36.71 ha during 2021. Total beneficiary farmers were 141. Naveen yielded 4.8 t ha^{-1} in comparison to local check Baishmuthi (3.6 t ha^{-1}). Bio-fortified rice variety CR Dhan 310 and 311 were introduced in 26.71 ha area and their yield varied from 4.27 to 4.74 t ha^{-1} and 4.78 to 5.32 t ha^{-1}, respectively.

Development of Resilient Technologies for Coastal Rice Ecology

Survey to monitor the rice insect pest in coastal ecosystem

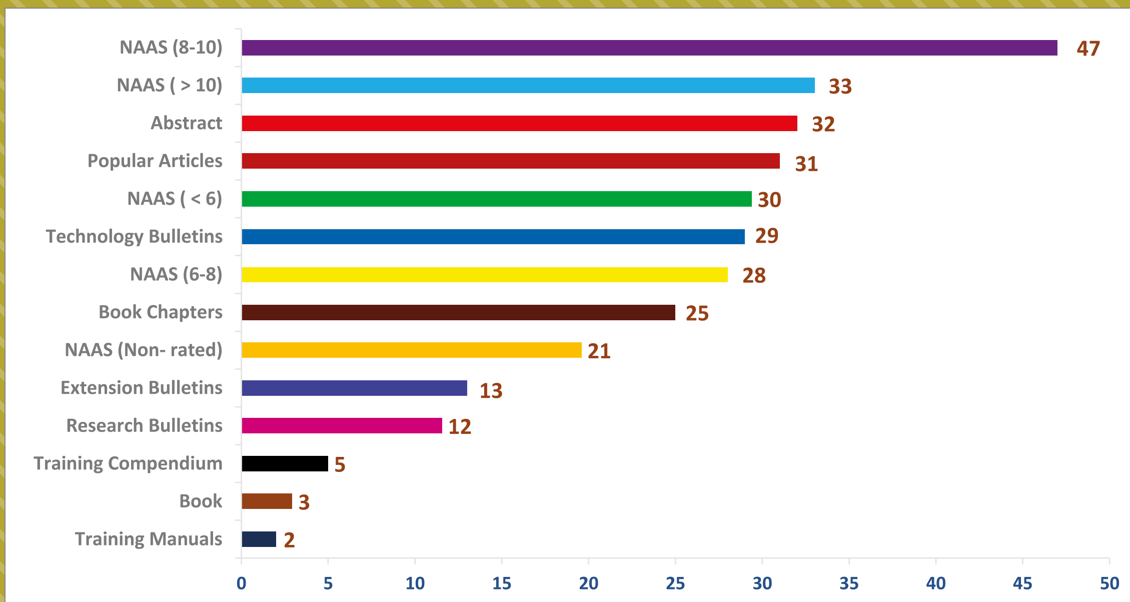
Three coastal districts of Andhra Pradesh namely, Srikakulam (Kotturu, Sompeta and Santhabommali villages), Krishna (Kanchadam and Malleswaram villages) and Guntur (Murukupadu village) were surveyed and observed the insect pest incidence in rice crop (*var.* MTU 1061). The highest yellow stem borer (YSB) whiteheads numbers (>5 m^{-2}) were counted in both the villages of Krishna district. Whereas, YSB whiteheads number was enumerated to ≤ 2 m^{-2} in the villages of Srikakulam and Guntur districts. Also, gall midge infestation manifested in silver shoots is observed >10% in Murukupadu village of Guntur district.



NRRI Research Stations situated at Hazaribag, Gerua and Naira have developed and validated several climate resilient technologies including rice varieties suitable for drought-prone ecologies and associated crop management practices for improving the productivity and sustainability of rainfed drought-prone ecologies. The research and extension activities undertaken through the Program 6 has greatly promoted these technologies over the years. The farming communities in the target ecologies have also been benefitted from regular training programs organized on various aspects of rice.

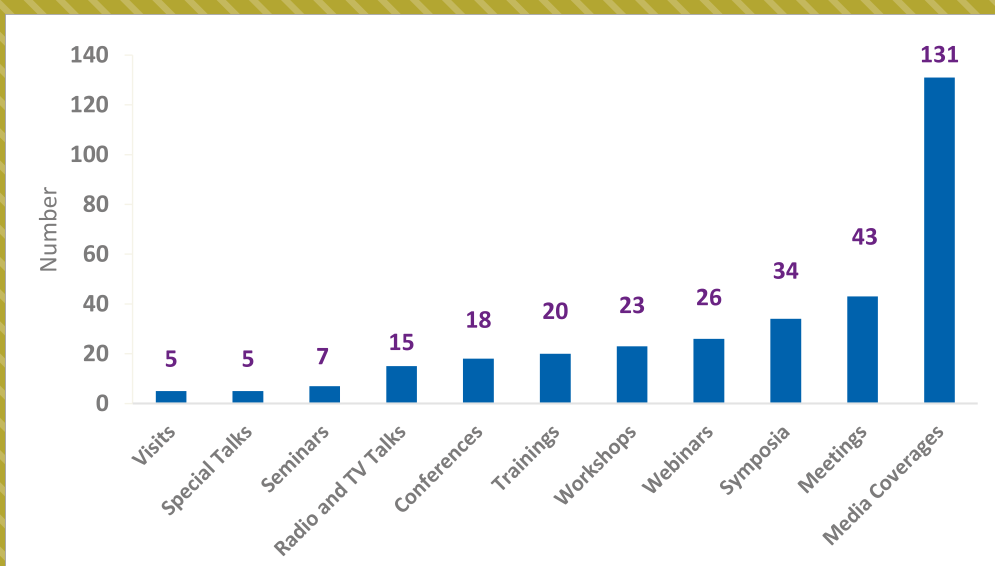
Publications & Participation in Scientific Events

During the year 2021, The institute has published different research, technology and extension materials which is shown by the below given figure.



For More Details, Please Visit - http://icar-nrri.in/publications/

Participation in Webinars/Conferences/Trainings/Visits/Workshops/Meetings/Symposia/Seminars/Media Coverages/Radio and TV Talks



Activities and Events

During the year 2021, ICAR-NRRI 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
27th Research Advisory Committee, 26 October 2021	Prof. SK Sopory (C), Dr. KK Jena (M), Dr. BC Viraktamath (M), Dr. AR Sharma (M), Dr. VV Sadamate (M), Dr. Chandish R Ballal (M), Shri SK Panigrahi (M), Shri A Mishra (M), Dr. D Maiti (M), ADG (FFC) (M), Dr. RM Sundaram (SI), Dr. BC Patra (MS).
34th IMC Meeting, 25 March 2021	Dr. D Maiti (C), Dr. YP Singh, ADG (FFC), ICAR, New Delhi (M), Dr. BK Sahoo, Director (A&FP), Dr. AK Nayak (M), Dr. (Mrs.) P Swain (M), Dr. D Sarkar, Principal Scientist, CRIJAF, Kolkata, (M), Dr. LV Subba Rao, Principal Scientist, ICAR-IIRR, Hyderabad, (M), Shri RK Singh (M), Shri A Mishra, (Non-Official) (M), Shri SK Panigrahi, (Non-Official) (M), Shri SK Das, Sr. F&AO (I), Dr. BC Patra (I), Dr. GAK Kumar (I), Dr. PC Rath (I) and Shri I Muduli, Head of Office, NRRI, (MS).
41st Institute Research Council Meeting, 13-15 & 19 July 2021	Dr. D Maiti, (C), Dr. (Mrs.) Padmini Swain, (MS), Head of Divisions and Scientists of the Institute and KVKs
The 22nd Scientific Advisory Committee meeting of KVK, Cuttack, 22 July 2021	Dr. D Maiti (C)
The Scientific Advisory Committee meeting of KVK, Koderma, 30 April 2021	Dr. D Maiti (C)

C: Chairman; M: Member; MS: Member Secretary; I: Invitee

B) **Events**

Sl. No.	Events	Participants
1.	National Horticulture Fair-2021 (NHF-21) on 10 February 2021, NRRI-KVK, Cuttack	63
2.	National Science Day on 28 February 2021, NRRI-KVK, Koderma	50
3.	International Women's Day, 2021 on 8 March 2021, NRRI, Cuttack, KVK, Cuttack, KVK, Koderma	200
4.	An Awareness Programme on 'IPR with special reference to Geographical Indications (GI) of Odisha' on 15 March 2021, NRRI, Cuttack	100
5.	World Water Day on 22 March 2021, NRRI-KVK, Cuttack, NRRI-KVK, Koderma	80
6.	ICAR-National Rice Research Institute, Cuttack celebrated the 'Platinum Jubilee Foundation Day' on 23 April 2021	250
7.	World Veterinary Day on 24 April 2021, NRRI-KVK, Cuttack	37
8.	Akshaya Tritiya Celebrated on 15 May 2021, ICAR-NRRI, Cuttack	20
9.	World Bee Day on the theme *'Augmenting Rural Income: The Beekeeping Way'* on 20 May 2021, NRRI-KVK, Cuttack	44
10.	International Honey Day on 20 May 2021, NRRI-KVK, Koderma	85

11.	ICAR-NRRI, Cuttack, Conducted Mega Vaccination Drive for Employees and Family Members during 24, 25 and 28 May 2021	717
12.	International Milk Day on 1 June 2021, NRRI-KVK, Koderma	78
13.	Seminar on "Food and Nutrition for Farmers" along with webcasting of Hon'ble Minister of Agriculture and Farmer Welfare, Shri Narendra Singh Tomar on 26 August 2021	40
14.	ICAR-NRRI granted with DGCA permission for pesticide spraying using Drone, on 27 August 2021	20
15.	Mr. Ronald Verdonk, Career Minister-Counselor and Dr. Santosh Singh, Agricultural Specialist of US Embassy, New Delhi visited ICAR-NRRI, Cuttack on 14 September 2021	50
16.	Hindi Fortnight Celebration-2021 during 14-30 September 2021, ICAR-NRRI, Cuttack	74
17.	Campaign on 'Nutri-Garden and Tree Plantation' on 17th September, 2021 to launch the 'International Year of Millets-2023', ICAR-NRRI, Cuttack and NRRI-KVK, Cuttack	120
18.	ICAR Institutes–SAU–State Departments Interface Meet for Odisha virtually on 22 September 2021, ICAR-NRRI, Cuttack	100
19.	Telecasting of Honourable Prime Minister's interaction programme on 28 September 2021, ICAR-NRRI, Cuttack and NRRI-KVK, Cuttack	105
20.	World Rabies Day Celebrated, on 28 September 2021, NRRI-KVK, Cuttack	45
21.	World Egg Day Celebrated on 8 October 2021, NRRI-KVK, Cuttack	200
22.	Mahila Kisan Diwas, on 15 October 15 2021, NRRI-KVK, Cuttack	46
23.	Live Telecast of Prime Minister-Farmers Interaction Meet, on 16 December 2021, ICAR-NRRI, Cuttack	800
24.	World Food Day Celebrated, on 16 October 2021, NRRI-KVK, Cuttack	50
25.	Dr. VV Sadamate, Member of Institute Research Advisory Committee (RAC) visited various demonstrations in farmers' fields of Jagatsignpur and Cuttack districts on 18 October 2021	200
26.	Rice Day, on 12 November 2021, NRRI-RRLRRS, Gerua	71
27.	Dr. Trilochan Mohapatra, Secretary (DARE) & Director General (ICAR), visited ICAR-NRRI, Cuttack on 19 November 2021	50
28.	Shri Bishweswar Tudu, Hon'ble Minister of States for Tribal Affairs and Jal Shakti, Govt. of India, visited ICAR-NRRI, Cuttack on 22 November 2021	60
29.	National Milk Day Celebrated, on 26 November 2021, NRRI-KVK, Cuttack	200
30.	Vigilance Awareness Week-2021, on 26 October to 1 November 2021, ICAR-NRRI, Cuttack	36
31.	World Soil Day Celebrated, on 5 December 2021, ICAR-NRRI, Cuttack	50
32.	Diamond Jubilee National Symposium on 'GenNext Technologies for Enhancing Productivity, Profitability and Resilience of Rice Farming, on 16-17 December 2021, ICAR-NRRI, Cuttack	300
33.	Swachhata Pakhwada-2021, on 16-31 December 2021, ICAR-NRRI, Cuttack and NRRI-KVK, Cuttack	271
34.	30th Dr. Gopinath Sahu Memorial Lecture, on 2 November 2021, ICAR-NRRI, Cuttack	100

Commercialization of ICAR-NRRI Technologies

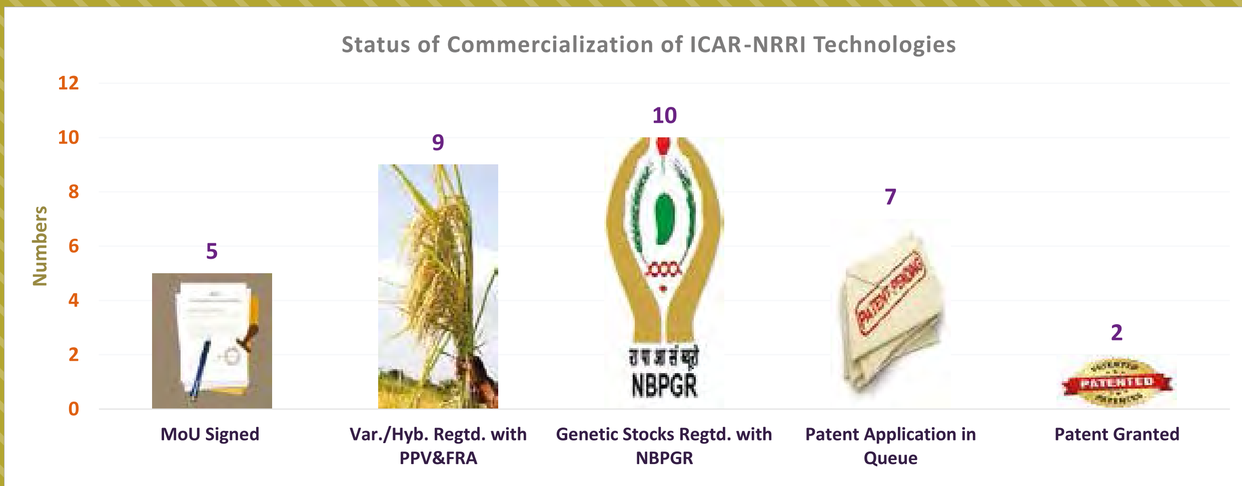


Fig. Status of Commercialization of ICAR-NRRI Technologies

Patent Granted

1. Patent granted for invention of Alternate Energy Light Trap (AELT) on 8 February, 2021 with Patent No. 357993. - Dr. SD Mohapatra, Principal Scientist (Entomology) and Dr. (Mrs.) Mayabini Jena, Former Principal Scientist & Head of Crop Protection Division of ICAR-NRRI, Cuttack.

2. Patent granted for invention of Multiuse composition for biocontrol of plant pathogen infestation and growth enhancement on 3 December 2021 with patent No. 383679. - AK Mukherjee, T Adak, H Swain, SP Behera, U Dhua, M Jena, TB Bagchi, P Bhattacharya, A Kumar and TK Dangar.

INTELLECTUAL PROPERTY INDIA

GOVERNMENT OF INDIA

THE PATENT OFFICE

PATENT CERTIFICATE

CENTRAL RICE RESEARCH INSTITUTE (CRRI)

It is hereby certified that a patent has been granted to the patentee for an invention entitled ALTERNATE ENERGY LIGHT TRAP as disclosed in the above mentioned application for the term of 20 years from the 18th day of March 2014 in accordance with the provisions of the Patents Act,1970.

क्रमांक : 033118306
SL No :

INTELLECTUAL PROPERTY INDIA

भारत सरकार
GOVERNMENT OF INDIA
पेटेंट कार्यालय
THE PATENT OFFICE
पेटेंट प्रमाणपत्र
PATENT CERTIFICATE
(Rule 74 Of The Patents Rules)

पेटेंट सं. / Patent No.	:	383679
आवेदन सं. / Application No.	:	1240/KOL/2015
फाइल करने की तारीख / Date of Filing	:	02/12/2015
पेटेंटी / Patentee	:	DIRECTOR, CENTRAL RICE RESEARCH INSTITUTE

It is hereby certified that a patent has been granted to the patentee for an invention entitled A MULTI-USE COMPOSITION FOR BIOCONTROL OF PLANT PATHOGEN INFESTATION, AND GROWTH ENHANCEMENT as disclosed in the above mentioned application for the term of 20 years from the 2nd day of December 2015 in accordance with the provisions of the Patents Act,1970.

अनुदान की तारीख : 03/12/2021
Date of Grant

पेटेंट नियंत्रक
Controller of Patent

Note. - The fees for renewal of this patent, if it is to be maintained will fall / has fallen due on 2nd day of December 2017 and on the same day in every year thereafter.

Awards and Recognition

During the year 2021, ICAR-National Rice Research Institute and its staff members have bagged several prestigious awards. The details of the awards are given below.

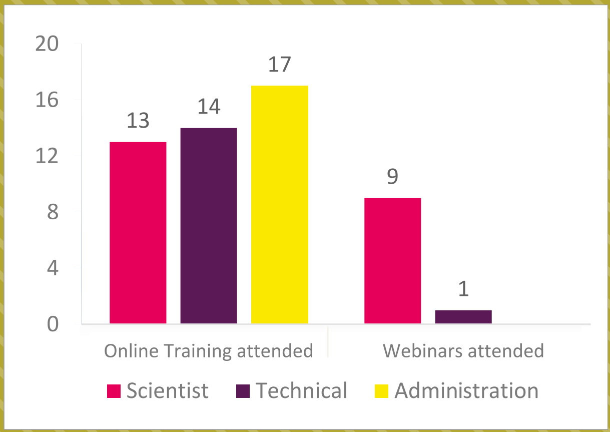
1.	Prestigious Nanaji Deshmukh Award for Outstanding Interdisciplinary Team Research in Agricultural and Allied Sciences by Indian Council of Agricultural Research (ICAR) on the occasion of 93rd ICAR foundation day on 16 July 2021- Dr. AK Nayak, Dr. Sangita Mohanty, Dr. Rahul Tripathi, Dr. Mohammad Shahid, Dr. Upendra Kumar, Dr. Dibyendu Chatterjee, Dr. Anjani Kumar, Dr. SD Mohapatra and Dr. J Meher
2.	2nd Prof. EA Siddiq Award for the biennium 2017-18 from IARI, New Delhi- Dr. SK Pradhan
3.	Lal Bahadur Shastri Outstanding Young Scientist Award (NRM & Ag. Eng.) - 2020 from ICAR, New Delhi- Dr. U Kumar
4.	SCON Award 2021 for Excellence in Science on 23rd December 2021- Dr. AK Nayak
5.	SCON Recognition Award 2021- Dr. U Kumar
6.	Prestigious membership of Indian National Young Academy of Sciences (INYAS), New Delhi- Dr. Kutubuddin Molla
7.	Outstanding Scientist Award of 2021 by the VDGOOD Professional Association, India in Engineering, Science and Medicine- Dr. SK Pradhan
8.	3rd position for working in official languages Hindi in the Workshop cum Six monthly meeting of NRAKAS, Hazaibag on 28 August 2021- NRRI-CRURRS, Hazaribag
9.	Life Time Achievement Award for working in official languages Hindi in the Workshop cum Six Monthly meeting of NRAKAS, Hazaribag on 28 August 2021- Dr. SM Prasad
10.	Sir CV Raman Life Time Achievement National Award-2021 by IRDP Group of Journals, Chennai on 19 December 2021 during IRDP International Conference held at Chennai- Dr. S Lenka
11.	Eminent Scientist Award 2021-22 in Crop Biochemistry from Hindustan Agricultural Research Welfare Society, Agra, U.P.- Dr. Awadhesh Kumar
12.	Selected as Associate Fellow of West Bengal Academy of Science & Technology (WAST), Kolkata-Dr. Koushik Chakraborty
13.	International Scientist Awards on Engineering, Science and Medicine, Trivandrum, India for 2021- Dr. JL Katara
14.	Dr. Mahamaya Patnaik Memorial Award given by Vigyan Prachar Samiti, Odisha- Dr. S Samantaray
15.	Golden Jubilee Young Scientist Award 2021 from Indian Society of Soil Science, New Delhi- Dr. Dibyendu Chatterjee
16.	Fellow of Indian Phytopathological Society (FPSI- 2019) during 73rd Annual Meeting (virtual mode) held at Division of Plant Pathology, ICAR-IARI, New Delhi on March 25-27, 2021- Dr. Rupankar Bhagawati and Dr. MK Bag
17.	ARRW Fellow Award in Basic Science Category- Dr. Padmini Swain
18.	ARRW Fellow (Crop Production)- 2020 from ARRW society, NRRI, Cuttack- Dr. U Kumar
19.	ARRW Fellow for the year 2021 of the Association of Rice Research Workers, Cuttack, Odisha- Dr. Anjani Kumar
20.	Fellow of Indian Society of Genetics and Plant Breeding, New Delhi- Dr. K Chattopadhy
21.	Fellow of Association of Rice Research Workers, Cuttack- Dr. K Chattopadhy
22.	Fellow of ARRW (FRA) in the discipline of Social Science for the year 2020 conferred by Association of Rice Research Workers, Cuttack- Dr. NN Jambhulkar
23.	Selected as Assistant Features Editor of the prestigious Journal 'The Plant Cell' (American Society of Plant Biologist)- Dr. Kutubuddin Molla
24.	Young Scientist Award 2021 conferred by Institute of Researchers, Kerala- Dr. NN Jambhulkar
25.	Young Scientist Award by Animal Nutrition Association on the eve of 100 year of Animal Nutrition Research in India- Dr. RK Mohanta

Other Recognition		
26.	Editor of Referred Journals	3
27.	Office bearer/Executive Member of Academic/Professional Societies/IMC	11
28.	Lead Lecture/ Invited Talk	8
29.	Best Oral Presentation Award	13
30.	Best Poster Presentation Award	8

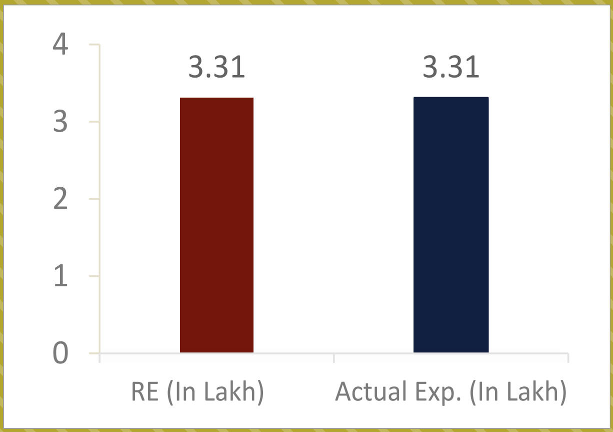
Human Resources Development and Capacity Building

Human Resource Development (HRD) cell of NRRI 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 targets and achievements of HRD cell of the institute is presented below.

Physical targets and achievements of HRD Cell

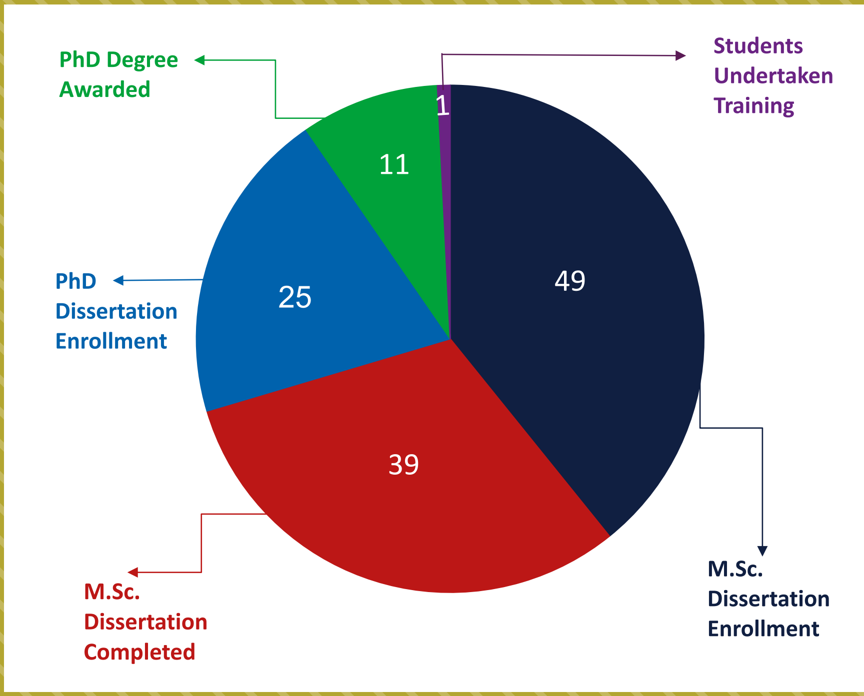


Financial targets and achievements of HRD Cell



During the year of 2021, 49 M.Sc. students have completed their dissertation; 25 students have enrolled for PhD programme; 11 PhD students have completed dissertation among other achievements of HRD cell.

Achievements of the HRD programmes for the students during 2021



Extension Activities

With the purpose to impart knowledge and develop skill to various groups of stakeholders, ICAR-NRRI, Cuttack had undertaken several extension activities during 2021 as specified below:

Field demonstrations

Several field demonstrations of newly released rice varieties and crop production as well as protection technologies in the farmers' field were conducted. About 28 promising rice varieties were demonstrated with 335 participating farmers in nineteen districts of nine states namely Odisha, West Bengal, Bihar, Jharkhand, Assam, Madhya Pradesh, Chhattisgarh, Maharashtra and Andhra Pradesh covering over 205 acres with the support of Krishi Vigyan Kendras (KVKs) and state agriculture department officials under '**IN**novative extension model for fast **SP**read of varieties **I**n **R**ice **E**cosystems' (INSPIRE 1.0) Model. Similarly, '**IN**novative extension model for fast **SP**read of new technologies **I**n **R**ice **E**cosystems' (INSPIRE 2.0) model initiated in collaboration with private institutions, like non-government organizations (NGOs), corporate social responsibility (CSR) units, and farmers' producers' organizations (FPOs) and covered 130 participating farmers from three districts of Odisha, namely, Nayagarh, Kendrapada and Cuttack with 11 rice varieties. Further, demonstrations were also conducted to showcase the production and protection technologies, demonstrations under Farmer's FIRST Programme, SCSP and TSP programmes. 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 two 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

Due to pandemic situation, physical visits by different categories of visitors were lesser than earlier years. A total of 620 visitors comprising of farmers & farmwomen, students and agriculture officers from the states of Jharkhand, Karnataka, Odisha, Tamil Nadu, Telangana and West Bengal visited experimental sites and demonstration plots, net-houses, agricultural implement workshop and *Oryza* museum of the institute during the year.

Fortnightly agro-advisory services

Overall 25 agro-advisories on rice were issued on fortnightly basis in English as well as Odia language including one Contingent Agro Advisory Services for Rice during Cyclone 'YAAS' during the year 2021. 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 also were issued through 'NRRI Video *Barta*' every fortnight and circulated through social media for wider reach.

Training programmes for farmers and extension professionals

A total of 3577 participants including farmers, extension officials, administrative personnel and others were trained through 87 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

The Institute is working in three tribal villages of Kandhamal under TSP programme for their all-round development through demonstration of improved rice varieties and production technologies as well as other developmental activities. About 21 quintals of seeds of improved crop varieties were distributed to 150 tribal farmers, seed treatment with biocontrol agents as well as need based non-chemical insect pest and disease management were demonstrated. Seeds of seasonal vegetables for *kharif*, *rabi* and summer season were distributed for backyard gardening and oil seeds and pulses were distributed for utilisation of rice fallow. Fifty demonstrations on honey bee production and vermi-composting were conducted. Farm inputs like tarpaulins, MS garden nets, storage bins, etc. were distributed to about 80 farm families. Training programmes were conducted on vermicompost production, *dhingiri* mushroom production, package and practices on *rabi* field crops, seed treatment with biocontrol agents were also conducted. To remove the darkness from the area, about 20 solar street lights were installed at two villages. The CRURRS, Hazaribag also conducted demonstration programmes at two adopted villages and small farm implements/ tools (improved sickle, garden rake, spade, shovel, improved *khurpi* and vermi beds, etc.) were distributed to 100 tribal farm families.

Scheduled Caste Sub-Plan (SCSP) Programme

During the second year of SCSP programme, three more villages were selected in addition to earlier adopted three villages. During *kharif* 2021, about 124 quintal paddy seeds of improved varieties were distributed to farmers and bio-control agents were provided for control of pest. Vegetable seeds like french beans, chilli and tomato were distributed to every households for kitchen gardening. Eight more User Groups were created (all farmers are member of one or other group) through Gramsabha meeting at three villages taken up later and large machines were distributed for creation of custom-hiring centre. Farm tools/equipments like sprayer, power thresher, pump sets, etc. were distributed to the beneficiaries as per the need assessed. Small tools like cono-weeders, spade, and household items like thermosflask, grain storage container, face mask, hand-wash and sanitizers were also distributed to the beneficiaries. Two exposure visits were organized and about 80 farmers visited the Institute to see the research and demonstration farms and have interaction with the scientists.

NEH Programme

With the aim to utilized fellow land after harvest of winter paddy, 400 kg paddy seed of Naveen variety along with required quantity of fertilizers and pesticides were distributed to twenty farmers belonging to Namkhola and Chotoma village of Nalbari district under NEH Component. Naveen was cultivated in an area of 10 ha in *boro* 2020-21 and average yield was 4.8 t ha^{-1}.

Personnel (January-December 2021)

Dr. (Mrs.) Padmini Swain, Director (Acting)

CROP IMPROVEMNENT DIVISION

Scientist								
BC Patra (I/c Head)	ON Singh	MK Kar	SK Pradhan	LK Bose	K Chatto-padhyay	S Samantaray	L Beherea	SK Dash
H Subudhi	A Anandan	M Cha-karaborti	J Meher	RL Verma	S Sarkar	Md Azha-rudheen TP	RP Sah	BC Marndi
P Sangham-itra	JL Katara	K Ali Molla	Parames-waran C	Devanna	Anil Kumar C	Reshmi Raj KR		
Technical Staff								
B Nayak	JS Anand	PL Dehury	LK Singh	M Soren	N Barik	KC Mallik	B Mondal	B Mishra
D Nayak	D Samal	B Behera	RP Rao	A Parida	D Majhi	B Hembram	B Ray	M Patra
S Sarkar	P Pandit	R Rana						
Administrative Staff								
M Swain								
Skilled Support Staff								
G Dei	FC Sahoo	J Biswal	P Dei	R Dei				

CROP PRODUCTION DIVISION

Scientist								
AK Nayak (I/c Head)	PK Nayak	S Saha	BB Panda	P Bhat-tacharya	A Poonam	P Panneer selvam	R Tripathi	S Mohanty
Md Shahid	BS Satap-athy	S Munda	A Kumar	D Chatter-jee	D Bhaduri	Vijaykumar S	U Kumar	K Kumari
PK Guru	BN Totaram	M Debanath	S Chaterjee	R Khanam	M Siv-ashankari	S Priyadar-sani	BR Goud	
Technical Staff								
R Chandra	KK Suman	AK Mishra	B Das	JP Behura	SK Ojha	KC Palaur	BC Behera	P Behera
P Moharana	S Panda	PK Jena	AK Moha-rana	R Jamunda	SC Sahoo	S Baskey	EV Ramaiah	A Meena
G Mandi	SP Lenka	P Saman-taray	S Mohanty	A Pal	G Bihari	D Behera	PK Ojha	D Parida
D Baral	PK Parida	R Beshra	CK Ojha	S Pradhan	JK Sahu	AK Suman	KK Meena	S Kumar
SP Sahoo	TK Behera							
Administrative Staff								
S Sur	SK Bhoi							
Skilled Support Staff								
S Biswal	B Marandi	B Khatua	PK Das	J Marandi				

CROP PROTECTION DIVISION

Scientist								
PC Rath (I/c Head)	KR Rao	SD Mohapatra	S Mondal	AK Mukherjee	MK Bag	S Lenka	T Adak	NKB Patil
Basan Gowda G	GP Pandi G	G Prasanthi	M Annamalai	MK Yadav	Aravindan S	Raghu S	Prabhu Karthikey-an SR	MS Baite

Keertha-na U	Rupak Jena							
Technical Staff								
R Swain	PK Sahoo	SK Rout	MK Nayak	A Panda	SK Sethi	C Majhi	H Pradhan	A Mohanty
EK Pradhan	A Malik	M Meena	S Biswal	AK Naik	MN Das	D Dash	JP Das	KC Barik
S Das	Md Shadab Akthar	NK Meena						
Administrative Staff								
B Mahana								
Skilled Support Staff								
L Murmu	B Bhoi	D Naik						

CROP PHYSIOLOGY & BIOCHEMISTRY DIVISION

Scientist								
P Swain (I/c Head)	MJ Baig	K Chakra-borty	PS Hanjagi	SM Awaji	TB Bagchi	A Kumar	N Basak	G Kumar
Technical Staff								
C Tudu	J Bhoi	P Kumar	J Senapaty	S Banerjee	DB Sahoo	S Haldhar	S Kumar	
Administrative Staff								
Nil								
Skilled Support Staff								
G Sahoo	J Dei							

SOCIAL SCIENCE DIVISION

Scientist								
GAK Kumar (I/c Head)	SK Mishra	B Mondal	NN Jam-bhulkar	JP Bisen	Sudipta Paul	AK Pradhan		
Technical Staff								
P Kar	B Behera	SR Dalal	G Sinha	DR Sahoo	AK Parida	SK Moha-patra	A Anand	SK Tripathy
AK Panda	HS Sahoo	SK Roul						
Administrative Staff								
L Trivedi								
Skilled Support Staff								
Surubali Hembram								

NRRI Research Station, Hazaribagh

Scientist								
D Maiti (Ex-D (A) & OIC)	NP Mandal (OIC)	S Bhagat	SM Psrasad	S Roy	BC Verma	A Banerjee	Priya Medha	Soumya Saha
Technical Staff								
AN Singh	R Tirky	S Oran	U Saw	J Prasad	HR Meena	SC Meena	S Akhtar	

Administrative Staff								
CP Murmu	R Paswan	S Kumar	CR Dangi	AK Das	SK Pandey			
Skilled Support Staff								
R Ram	L Mahato	S Devi	N Devi	B Oran	P Devi	K Devi	D Devi	T Ram
S Gope	G Gope	HC Bando						

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B Das	R Soren							

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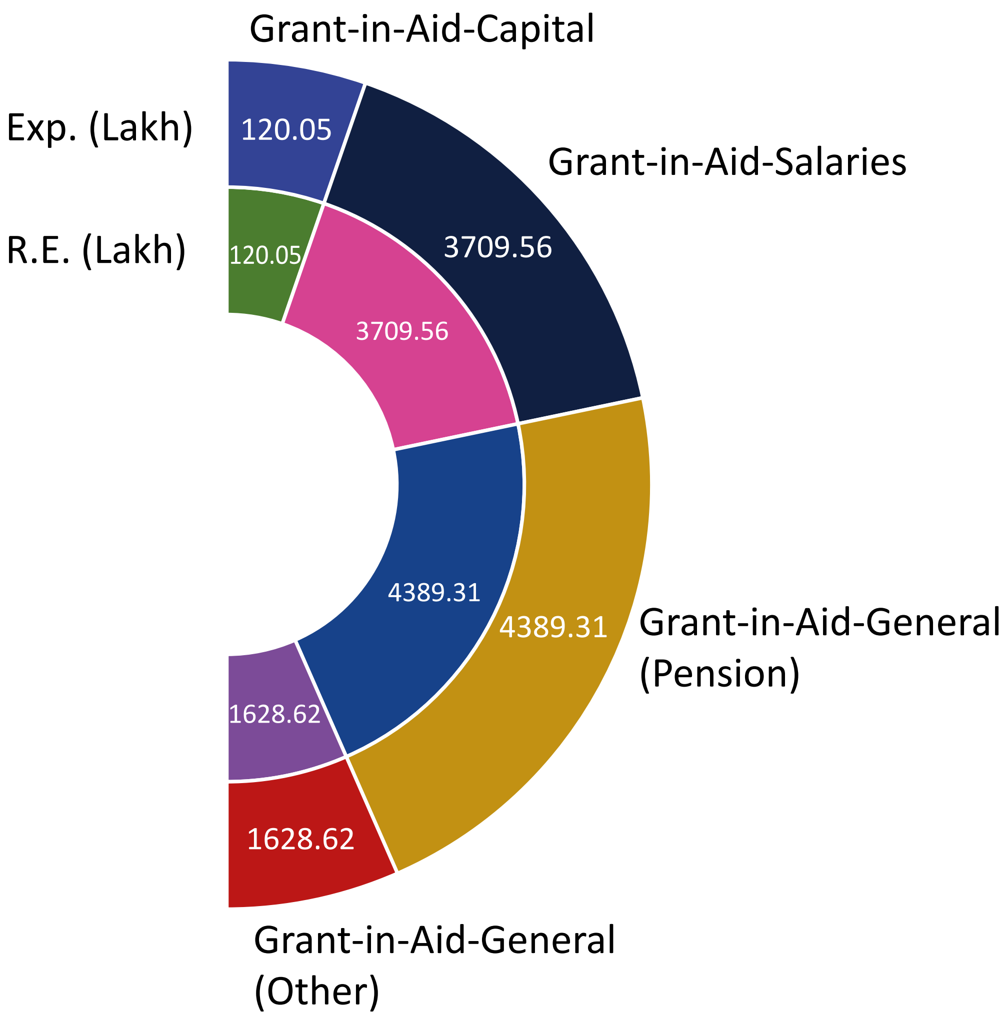
Financial Statement (January-December 2021)



Institute Research Programmes for the year 2021-22

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, PL- BC Patra		
1.1	Managing Rice genetic resources for sustainable utilization	BC Patra, BC Marndi, P Sanghamitra, S Samantaray, M Chakraborty, JL Katara, Md. Azharudheen TP, Anilkumar C, Devanna, Parameswaran C, NN Jambhulkar, Somnath Roy
1.2	Maintenance Breeding and Genetic dissection of seed Quality Traits.	BC Marndi, RP Sah, Md. Azharudheen TP, Anilkumar C, AK Mukherjee, Awadhesh Kumar, NKB Patil, Raghu S, Annamalai M, Gourav Kumar, BC Patra, 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, Md. Azharudheen TP, BC Patra, SK Dash, KA Molla, P Sanghamitra, JL Katara, Parameshwaran C, Devanna, PC Rath, S Lenka, AK Mukherjee, Guru Pirasanna Pandi G, S Sarkar *Associates:* P Swain, K Chakraborty, NP Mandal, Awadhesh Kumar, N Basak, Gaurav Kumar, BC Marndi
1.4	Developing genetic solutions for enhancing input use efficiency in rice for rainfed and irrigated ecologies	A Anandan, J Meher, RP Sah, Parameswaran C, SK Dash, LK Bose, Reshmi Raj KR, P Swain, P Panneerselvam
1.5	Breeding for Aroma and Grain Quality in Rice	S Sarkar, MK Kar, K Chattopadhay, SK Dash, A Anandan, HN Subudhi, B Mondal, J Meher, M Chakraborti, S Roy, A Banerjee, TB Bagchi, P Sanghamitra, N Basak, Basana Gowda G, Sivashankari M, Reshmi Raj KR
1.6	Gene mapping and precision breeding for enhancing climate resilience in lowland varieties	SK Pradhan, RP Sah, Md. Azharudhin TP, P Sanghamitra, Reshma Raj KR, M Annamalai, Sushma M Awaji, L Behera *Associates:* AK Mukherjee, MK Bag, P Hanjagi, Guru Pirasanna Pandi G, K Chakraborti, J Meher, Devenna, S Lenka, LK Bose
1.7	Genetic Enhancement for Multiple Stress Tolerance in Rice for Coastal Ecosystem	K Chattopadhyay, BC Marndi, K Chakraborty, LK Bose, KR Rao, A Poonam, KA Molla *Associates:* Devanna, AK Nayak, SD Mohapatra, AK Mukherjee
1.8	Hybrid rice for enhancing yield, quality and sustainability	RL Verma, JL Katara, Reshmi Raj KR, S Sarkar, S Samantaray, Parameswaram C, BC Patra, A Anandan, SK Dash, Devanna *Associates:* SD Mohapatra, AK Mukherjee, B Satpathy, N Mondal, BC Marndi
1.9	Development of New Generation Rice for enhancing yield potential in favourable ecology	SK Dash, MK Kar, J Meher, HN Subudhi, S Sarkar, L Behera, JL Katara, Parameswaran C, Devanna, Anilkumar C, RL Verma, LK Bose, S Roy, SD Mohapatra, P Swain, A Banerjee
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, Awadhesh Kumar, Sushma M Awaji *Associates:* SK Lenka, Raghu S, Basana Gowda G
1.11	Development of Novel Genomic Resources for Rice Improvement	L Behera, Devanna, Parameswaran C, RP Sah, Md. Azharudheen TP, M Chakraborti, J Meher, Guru Pirasanna Pandi G, Raghu S, P Hanjagi, A Kumar, SK Dash, SK Pradhan, MK Kar, A Anadan
Programme 2: Enhancing the productivity, sustainability and resilience of the rice-based system, PL- AK Nayak		
2.1	Enhancing nutrient use efficiency in rice through advance agronomy using smart sensors, models and nano fertilizers	S Mohanty, AK Nayak, Rahul Tripathi, D Bhaduri, D Chatterjee, Anjani Kumar, M Shahid, U Kumar, R Khanam, BC Verma, PK Nayak
2.2	National level zonation of rice ecologies, site specific planning and development of cropping and farming system models	A Poonam, Rahul Tripathi, BS Satapathy, D Chatterjee, B Raghvendra Goud, Kavita Kumari, NN Jambhulkar *Associates:* S Saha, M Nedunchezhian, SC Giri, GC Acharya, SK Lenka, Basanna Gowda G, U Kumar, SM Prasad
2.3	Vulnerability analysis and assessment of climate smart agricultural technologies for enhancing resilience in stress prone rice ecologies	M Shahid, AK Nayak, Vijaykumar S, Rubina Khanam, D Chatterjee, S Mohanty, D Bhaduri, S Munda, Rahul Tripathi, P Bhattacharyya, BB Panda and B Mondal
2.4	Developing agronomy for new generation rice and rice-based cropping systems	BB Panda, BS Satapathy, Anjani Kumar, S Munda, SK Dash, B Raghavendra Goud
2.5	Ecosystem services quantification and analysing the nexus of climate change-land use change-food security in rice production systems	Rahul Tripathi, AK Nayak, M Shahid, P Bhattacharyya, S Mohanty, D Bhaduri, D Chatterjee, PK Nayak, BB Panda, S Priyadarsani, B Mondal, JP Bisen, B Raghvendra Goud
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, BS Satapathy, N Borkar, S Priyadharshini, Sivsankari M, Kavita Kumari, BC Verma

Code No.	Title of the Projects	Programme Leader (PL), Principal Investigator (PI) and Co PIs
2.7	Harnessing microbiome for enhancing rice productivity and improving soil health.	P Panneerselvam, U Kumar, Guru Pirasanna Pandi G, Parameshwaran C, A Anandan, Anjani Kumar, AK Nayak
2.8	Development of weed management strategies and assessing the risk of herbicide resistance in rice weeds	S Saha, S Munda, BS Satapathy, B Mondal, Kavita Kumari, B Raghavendra Goud
2.9	Development and Refinement of Farm implements, Post-harvest and Value addition Technologies for small farm mechanization	Sivashankari M, NT Borkar, S Priyadarsani, TB Bagchi, Awadhesh Kumar *Associates:* P Panneerselvam, S Sarkar
2.10	Enhancing water use efficiency in rice-based cropping system	Anjani Kumar, AK Nayak, Rahul Tripathi, BB Panda, Kavita Kumari, D Chatterjee, R Khanam, PS Hanjagi, BC Verma *Associates:* D Bhaduri, S Munda, S Mohanty, P Panneerselvam
Programme 3: Biotic stress management in rice, PL- PC Ratha		
3.1	Identification and characterization of donors against biotic stresses	MK Bag, PC Rath, AK Mukherjee, SD Mohapatra, S Mandal, S Lenka, Guru Pirasanna Pandi G, NKB Patil, Basana Gowda G, A Banerjee, Annamalai M, Raghu S, SR Prabhukartikeyan, MS Baite, Keerthana U, Prasanthi G *Associate:* MK Kar
3.2	Ecology, diversity and interaction of plant, pests & natural enemies in rice	KR Rao, SD Mohapatra, Guru Pirasanna Pandi G, Annamalai M, Gourav Kumar, M K Bag, A K Mukherjee, U Keerthana, Prasanthi G, Prabhukarthikeyan SR, Kiran Gandhi B *Associates:* T Adak, Basana Gowda G
3.3	Use of Precision Tools and Techniques in Rice Insect Pest and Disease Management	SD Mohapatra, Rahul Tripathi, Raghu S, MS Baite, 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, Guru Pirasanna Pandi G, Prabhukarthikeyan SR, KA Molla, MS Baite, P Golive, TB Bagchi, Devanna, M Yadav
3.5	Plant protection molecules: efficacy, distribution, toxicity and remediation	T Adak, PC Rath, MK Bag, S Lenka, Prabhukarthikeyan SR, Annamalai M, MS Baite, Raghu S, Aravindan S, Basana Gowda G, NKB Patil, Guru Pirasanna Pandi G, U Kumar *Associates:* AK Mukherjee, P Bhattacharyyaa
3.6	Dissemination of integrated pest management strategies for insect pest, diseases and nematodes in rice	Guru Pirasanna Pandi G, PC Rath, AK Mukherjee, SK Lenka, SD Mohapatra, T Adak, NKB Patil, Basana Gowda G, Annamalai M, Raghu S, MK Bag, Prabhukarthikeyan SR, MS Baite, GAK Kumar, A Banerjee
Programme 4: Photosynthetic enhancement, abiotic stress tolerance and grain nutritional quality in rice, PL- P Swain/MJ Baig		
4.1	Photosynthesis and productivity of rice under changing climate	MJ Baig, P Swain, K Chakraborty, KA Molla, PS Hanjagi, N Basak, Gaurav Kumar, Susma M Awaji
4.2	Evaluation of rice genotypes for new sources of multiple abiotic stress tolerance and understanding the underlying mechanism	K Chakraborty, P Swain, MJ Baig, PS Hanjagi, Susma M Awaji, M Chakraborti, KA Molla, Anilkumar C
4.3	Characterization of rice genotypes for improved Physico-chemical and Nutritional properties	Awadhesh Kumar, TB Bagchi, N Basak, Gaurav Kumar, Sivashankari M, RP Sah
Programme 5: Research to enhance socio-economic well being of rice stakeholders, PL- GAK Kumar		
5.1	**R**eaching stakeholders to **E**nhance their socio-economic **CAP**acities (**RECAP**) through rice technologies	SK Mishra, GAK Kumar, B Mondal, NN Jambhulkar, JP Bisen, AK Pradhan, S Paul, BS Satapathy, S Priyadarsani, S Saha, SK Pradhan, AK Mukherjee, KR Rao, S Lenka, SM Prasad, K Saikia, Anjani Kumar
5.2	Working to Increase farm Net Gain through Socioeconomic research **(WINGS)**	B Mondal, GAK Kumar, SK Mishra, NN Jambhulkar, JP Bisen, AK Pradhan, S Paul, SM Prasad, K Saikia *Associates:* SK Pradhan, MK Kar, S Saha, K Chattopadhyaya, SK Dash, S Sarkar, MK Bag S Roy, BS Satapathy, RP Sah, KR Rao, Basana Gowda G
Programme 6: Development of Climate Resilient Technologies for Rainfed Upland, Rainfed Lowland and Coastal Rice Ecology, PL- R Bhagawati, NP Mandal, KR Rao		
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, P Swain, L Behera, S Saha, K Chakraborty, D Bhaduri, N Basak
6.2	Rice production and productivity improvement in Rainfed lowland ecosystem	R Bhagawati, K Saikia
6.3	Development of Resilient Technologies for Coastal Rice Ecology	Kiran Gandhi B, B Gayatri *Associates:* KR Rao, K Chattopadhyay, BC Marndi, MK Kar, SK Pradhan, Rahul Tripathi, M Shahid, MS Baite

Externally Aided Projects (EAPS)

Sl. No.	Project No.	Title of the Project/ PI & Co-PIs	Source of Funding
1.	EAP-27	Revolving fund scheme for seed production of upland rice varieties at CRURRS, Hazaribag - NP Mandal	AP Cess
2.	EAP-36	National Seed Project (Crops) - BC Marndi, Anil Kumar, AK Mukherjee, NKB Patil, RP Sah	NSP
3.	EAP-49	Revolving fund scheme for breeder seed production - BC Marndi, RP Sah, Md. Azharudheen, Anil Kumar	NSP/Mega seed
4.	EAP-60	Front line Demonstration under Macro-Management scheme of Ministry of Agriculture – New High Yielding Varieties - BC Verma	DAC
5.	EAP-100	Seed Production in Agricultural Crops - BC Marndi, Anil Kumar, Md. Azharudheen, Raghu S, M Annamalai	ICAR
6.	EAP-130	All India Network Project on Soil Biodiversity – Bio fertilizers - D Maiti	ICAR
7.	EAP-139	AICRP on energy in agriculture and agro-based industries - NT Borkar, PK Guru	AICRP (DRET-SET/ DRET-BCT)
8.	EAP-140	Intellectual Property Management and Transfer/ commercialization of agricultural technology under National Agricultural Innovation Fund (NAIF) - BC Patra, GAK Kumar	ICAR
9.	EAP-141	DUS Testing of Rice and documentation - BC Patra, Anilkumar C	PPV&FRA
10.	EAP-178	National Initiative on Climate Resilient Agriculture - Sudhanshu Shekhar	NICRA (ICAR)
11.	EAP-183	Characterization of toxins of *Bacillus thuringiensis* isolated from rice genotypes and their virulence assessment against leaf folder (*Cnaphalocrocis medinalis* Guenee) - Sonali Acharya (TK Dangar)	DST Inspire
12.	EAP-184	Utilization of fly ash on amelioration and source of nutrients to rice-based cropping system in eastern India - Sanghamitra Maharana (AK Nayak)	DST Inspire
13.	EAP-185	Development of crop and nutrient management practices in rice for Odisha state - S Saha, BC Patra, S Munda	ICAR-IRRI STRASSA
14.	EAP-186	Use of microbes for management of abiotic stresses in rice - AK Mukherjee	ICAR-IRRI
15.	EAP-189	Front Line Demonstrations under NFSM - AK Pradhan, SK Mishra, B Mondal	DAC –IIRR (NFSM)
16.	EAP-192	DNA marker based pyramiding and study of interactions among QTLs for higher grain number in rice (*Oryza sativa* L.) - Gayatri Gouda (L Behera)	DST Inspire
17.	EAP-193	Future rainfed lowland rice systems in Eastern India (Climate-smart management practices: Crop and Natural resource management for stress-tolerant rice varieties in Odisha) - AK Nayak, M Shahid, D Bhaduri, R Tripathi, K Chakraborty, BR Goud	ICAR-IRRI Collaboration
18.	EAP-195	Artificial induction of chlamydospore in *Trichoderma* sp. and identification of genes expressed during the process - HK Swain (AK Mukherjee)	DST Inspire
19.	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
20.	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
21.	EAP-199	Incentivizing Research in Agriculture: Towards understanding the C_3-C_4 intermediate pathway in *Poaceae* and functionality of C_4 genes in rice - MJ Baig, P Swain, L Behera, Gaurav Kumar, A Kumar, KA Molla	ICAR Plan
22.	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

23.	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 - MK Kar, L Behera, A Mukherjee, Mathew Baite, NP Mandal, S Samantaray, M Azharudheen, Devanna, KA Molla, M Chakraborti	ICAR Plan
24.	EAP-204	CRP on Agro-biodiversity: PGR Management and Use of Rice (Component I & II) - BC Patra, GP Pandi, AK Mukherjee, K Chakraborty	CRP on Agro-biodiversity (ICAR)
25.	EAP-207	Conservation agriculture for enhancing the productivity of rice based cropping system in Eastern India - AK Nayak, R Tripathi, B Lal, BB Panda, M Shahid, P Gautam, S Munda, S Saha, SK Mishra, SD Mohapatra, P Guru, R Khanam, B R Goud	CAP - ICAR
26.	EAP-209	CRP on hybrid technology- RL Verma, JL Katara	CRP - ICAR
27.	EAP-210	Fine mapping and identification of candidate gene/QTL for brown plant hopper resistance in rice cultivar, Salkathi - P Patnaik (L Behera)	DST Inspire
28.	EAP-211	CRP on molecular breeding - MK Kar, L Behera, GP Pandi, A Mukherjee, M Chakraborti, PC Rath	CRP - ICAR
29.	EAP-212	Multilocational monitoring of Rynaxypyr 20SC against *Scirpophaga incertulas* in rice and rice hopper susceptibility survey in India for DPH-RAB55 106SC against *Nilaparvata lugens* and *Sogatella furcifera* - SD Mohapatra, M Jena, B Gowda	M/s Du Pont India Pvt Ltd
30.	EAP-213	Maintenance, characterization and use of EMS of upland variety Nagina 22 for functional genomics in rice – Phase II - MK Kar, P Swain, AK Mukherjee, M Chakraborti, S Saha	DBT
31.	EAP-215	Agri-Business Incubation Centre - GAK Kumar, BC Patra, NC Rath, S Saha, RK Sahu, BB Panda, B Mondal, AK Mukherjee, PK Guru, JP Bisen, GP Pandi NN Jambhulkar	NAIF, IP&TM – ICAR
32.	EAP-217	Development of high yielding, water and labor saving rice varieties for dry direct seeded aerobic conditions utilizing recent discoveries on traits, QTLs, genes and genomic technologies - A Anandan, S Sarkar, SK Dash	DBT
33.	EAP-220	Delivering food security on limited land (DEVIL) - AK Nayak, M Shahid, R Tripathi, B Mondal, SD Mohapatra, H Pathak, P Bhattacharyya	Min. Earth Science, GOI
34.	EAP-223	Marker-assisted introgression of yield-enhancing genes to increase yield potential in rice - L Behera, M K Kar, SK Dash, SK Pradhan, N Umakanta	DBT
35.	EAP-224	Understanding mechanism of tolerance to low light intensity in rice - MJ Baig, P Swain, SK Pradhan	NASF -ICAR
36.	EAP-225	Forewarning of major crop pests on special scale for their integrated management - SD Mohapatra, MK Yadav, G Pandi, S Bhagat	SAC-ISRO
37.	EAP-227	Creation of seed hub for increasing indigenous production of pulses in India - S Sethi, DR Sarangi, TR Sahoo, M Chourasia, RK Mohanta	DAC &FW
38.	EAP-228	Increasing productivity and sustaining the rice-based production system through farmer FIRST approach - SK Mishra, 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
39.	EAP-230	Developing microbial consortium for horticultural crops in rice based cropping system to promote growth, nutrient uptake and disease management in organic farming in Sikkim - P Paneerselvam, U Kumar	DBT (NER-BPMC)
40.	EAP-233	Accelerated decomposition of rice straw using novel Trichoderma strain and its mutants - A Mukherjee, T Adak	BRNS – DAE
41.	EAP-234	Gene staking for submergence tolerance, bacterial blight resistance and yield potential in rice variety Swarna through classical and molecular breeding approaches - SK Pradhan, S Mohapatra	DST, Gov. Odisha
42.	EAP-236	ICAR-CSISA collaborative project (phase III) – Research to quantify near and long term effects of sustainable intensification technologies at National Rice Research Institute (NRRI) - R Tripathi, AK Nayak, BB Panda, M Shahid, D Chatterjee	CSISA
43.	EAP-239	Pyramiding and understanding the interaction of QTLs for deeper rooting and phosphorous uptake in rice (*Oryza sativa* L.) - E Pandit (SK Pradhan)	DST (WOS-A)
44.	EAP-240	Potential gene mining from salt tolerant grasses for improvement of stress tolerance in crops - C Parameswaran	NASF-ICAR

45.	EAP-242	Targeting rice- fallows: a cropping system based extrapolation domain approach - BB Panda, R Tripathi, AK Nayak	IRRI - Odisha
46.	EAP-243	Phenotyping based on chlorophyll fluorescence imaging under salinity-stagnant flooding stress and identification of quantitative trait loci of chlorophyll fluorescence traits in rice - RK Sarkar	ICAR Emeritus scheme
47.	EAP-244	Validation and promotion of IPM in Rice in Tribal Region of Jharkhand - S Bhagat, A Banerjee, D Maiti	ICAR-NCIPM
48.	EAP-245	Strategic research component of National Innovation in climate resilient agriculture (NICRA) - P Swain, A K Nayak, P Bhattacharyya, K Chattopadhya, A Anandan, S Mohanty, D Chatterjee, K Chakraborty, H Pathak	ICAR Net work
49.	EAP-246	Raising productivity and profitability of rice-based cropping system in Odisha through rice crop manager - S Saha, S Munda, BS Satapathy	IRRI
50.	EAP-247	Bio-efficacy evaluation of 'Agri-Booster™KSi' against major insect pests and diseases of rice - M Annamalai, T Adak, GP Pandi, B Gowda, MK Yadav	Noble Alchem Pvt. Ltd., Indore
51.	EAP-248	Accounting greenhouse gases (GHGs) emission and carbon flow in temporal shift of tropical mangrove to agriculture - P Bhattacharyya	ICAR- National Fellow
52.	EAP-249	Strengthening seed system of STRVs through innovative demonstrations and extension approaches in Odisha - BC Marndi, RP Sah, P Sanghamitra	IRRI-Odisha
53.	EAP-250	Validation and promotion of IPM in rice based cropping system - SD Mohapatra, S Lenka, U Kumar, BS Satapathy, Raghu S, G Prasanthi, S Bhagat, D Maiti, A Banerjee, SM Prasad	NRRI-NCIPM
54.	EAP-251	IT-enabled Self-sufficient Sustainable Seed System for Rice - GAK Kumar, BC Patra, B Mondal, AK Mukherjee, P Sanghamitra, R P Sah, NKB Patil, BS Satapathy	RKVY, Odisha
55.	EAP-252	Development and demonstration of Rice based integrated farming system for livelihood security of small and marginal farmers in coastal Odisha - A Poonam, AK Nayak, S Saha, BS Satpathy, GAK Kumar, PK Sahu, K Chattapadhyay, SK Lenka, L Bose, PK Guru	RKVY, Odisha
56.	EAP-253	Genomics-assisted breeding for increasing yield potential and durable resistance to major biotic stresses (BPH, Blast, BB, Sheath blight) of Indian elite cultivars - MK Kar, L Behera, SK Pradhan, SK Dash, LK Bose, GP Pandi, AK Mukherjee, PC Rath	IRRI
57.	EAP-254	Cereal Systems Initiative for South Asia (CSISA) - KVK, Cuttack- DR Sarangi, TR Sahoo, M Chourasia, RK Mohanta	IRRI- CSISA Project
58.	EAP-256	Utilization and refinement of haploid / doubled Haploid induction systems in rice, wheat and maize involving molecular and in-vitro strategies - S Samantray, N Umakanta, JL Katara, Parameswaran C, RL Verma, A Anandan, K Chattopadhaya, K Awadhesh, Devanna	NASF
59.	EAP-257	Genetic improvement of rice for yield, NUE, WUE, abiotic and biotic stress tolerance through RNA guided genome editing (CRISPR-cas 9/ Cpf 1) - Parameswaran C, N Umakanta, S Samantray, K Awadhesh, Devanna	NASF
60.	EAP-260	Development of climate smart practices for climate resilient varieties - Anjani Kumar, H Pathak, AK Nayak, S Saha, BR Goud	IRRI
61.	EAP-261	Establishment of State of Art of Pesticide Residue Analysis in Odisha for its Optimum and Safe Use - T Adak, GP Pandi G, NKB Patil, B Gowda, Raghu S, S Munda, PC Rath, Prabhukarthikeyan SR	RKVY
62.	EAP-262	Enhancing resilience of rice based production system to climate change - AK Nayak, SK Pradhan, P Bhattacharya, MK Bag, GAK Kumar, K Chakraborty, Anjani Kumar, PK Nayak	DST
63.	EAP-263	From QTL to variety: Genomics-Assisted Introgression and field evaluation of rice varieties with genes/ QTLs for yield under drought, flood and salt stress - JL Katara, BC Marandi, P Swain, K Chakraborty	DBT
64.	EAP-264	From QTL to variety: Genomics-Assisted Introgression and field evaluation of rice varieties with genes/ QTLs for yield under drought, flood and salt stress - NP Mandal, Somnath Roy, Amrita Banerjee	DBT
65.	EAP-265	Prospects of interactions of multi-strain stress resilient beneficial phytotonic microbes and rice to improve productivity under environmental adversities (Emeritus Scientist Project) - TK Dangar	ICAR Emeritus scheme
66.	EAP-266	A comparative study on the effect of cold and histone deacetylase inhibitor pre-treatment on the callus inducing ability in anthers of elite rice hybrids - B Cayalvizhi, S Samantray	N-PDF (SERB)

67.	EAP-267	SPDT Transporter based identification of low Phosphorus / phytate rice to reduce the removal of phosphorus from soil and eutrophication of waterways - Awadhesh Kumar	SERB
68.	EAP-269	Identification and mapping of QTLs / genes associated with high grain number in rice - Niharika Mohanty, L Behera	DST, Odisha (Biju Pattanaik Research Fellowship)
69.	EAP-270	Evaluation and utilization of BPH resistant rice gene pool for multiple insect resistant traits - M Jena	ICAR Emeritus scheme
70.	EAP-271	Harvest Plus Programme : Biofortification of rice - K Chattopadhyay, Awadhesh Kumar, P Sanghamitra, G Kumar, LK Bose	IFPRI & CIAT
71.	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, MJ Baig, G Kumar, S Priyadarsani, Sivashankari M, TB Bagchi	RKVY-Odisha
72.	EAP-273	Introgression of saltol and Sub-1 genes into restorer line of popular rice hybrid Ajay and Rajalaxmi through marker assisted selection - JL Katara	SERB, DST, Govt. of India
73.	EAP-274	Bio-Bank: Production and promotion of biocontrol agents and entrepreneurship development in aspirational districts of Odisha - Basana Gowda G, NKB Patil, G P Pandi, T Adak, Prasanthi G, M Annamalai, Raghu S, Prabhukartikheyan SR, PC Rath, AK Mukherjee	RKVY-Odisha
74.	EAP-275	Setting up of model bio-fertilizer production unit for supply of quality bio-inoculants for rice and rice-based cropping systems in Odisha - U Kumar, P Panneerselvam, AK Nayak, SK Mishra, PK Nayak, Anjani Kumar	RKVY-Odisha
75.	EAP-276	Inclusive development through knowledge, innovative extension methods, networks and capacity building in Odisha - Rahul Tripathi, S Samantray, GP Pandi G	IRRI
76.	EAP-277	New high yielding rice varieties for irrigated and rainfed ecosystem through TRB - SK Dash, RL Verma, JL Katara, S Sakar, Rameswar Sah, J Meher	IRRI
77.	EAP-280	Impact of futuristic climate change on weed dynamics, herbicide efficacies and developing adaptive solutions for direct-seeded rice - S Saha, BS Satapathy	IRRI
78.	EAP-281	Upgradation and validation of existing alternate energy (solar) light trap developed by ICAR-NRRI - SD Mohapatra	M/s Fine trap India
79.	EAP-282	Application of Next-Generation breeding, Genotyping and digitalization approaches for improving the genetic gain in Indian staple crops - SK Pradhan, L Behera, SK Dash, M Chakraborti	ICAR-BMGF
80.	EAP-283	Building climate resilience of Indian small holders through sustainable intensification and agro-ecological farming systems to strengthen food and nutritional security (RESILIENCE) - AK 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
81.	EAP-284	RKVY-RAFTAAR - Agribusinees incubation - GAK Kumar, BC Patra, RK Sahu, AK Mukherjee, Sanjoy Saha, BB Panda, N Borkar, M Sivashankari, B Mondal, Rameswar Sah, Sutapa Sarkar	RKVY
82.	EAP-285	Early detection and estimation of biotic stresses in rice due to major insect pests and diseases using hyperspectral remote sensing from field to landscape scale - SD Mohapatra, R Tripathi, Keerthana U	SAC-ISRO
83.	EAP-286	Bio-efficacy of triflumezopyrim 5% w/v + spinetoram 9% w/v (14% SC) and and triflumezopyrim 5% w/w + spinetoram 12% w/w (22%) WDG against yellow stem borer, leaf folder and sucking pests (BPH & WBPH) - SD Mohapatra	M/s Du Pont India Pvt. Ltd.
84.	EAP-287	Enhancement of reproductive stage salinity tolerance in rice - K Chattopadhyay, BC Marandi, K Chakraborty, LK Bose, AK Nayak	IRRI
85.	EAP-288	Study and investigation of molecular mechanism of ethylene and its downstream signaling during grain filling stage in rice - Sudhanshu Sekhar (L Behera)	DBT-RA Fellowship
86.	EAP-289	Newton Bhaba virtual centre on nitrogen efficiency of whole-cropping systems for improved performance and resilience in agriculture (NEWS Project) - D Chatterjee, S Mohanty, AK Nayak, H Pathak	DBT
87.	EAP-290	Advance breeding technologies to speed up genetic gain, create durable resistance to biotic stresses and increase indian farmers and consumers food and nutritional security - SK Pradhan	IRRI-India

88.	EAP-291	Attracting and Retaining Youth in Agriculture (ARYA) - S Sethi, DR Sarangi, TR Sahoo, RK Mohanta	ICAR
89.	EAP-292	Paramparagat Krushi Vikas Yojana (PKVY) - TR Sahoo, RK Mohanta	ICAR
90.	EAP-293	New Extension Methodologies and Approaches (NEMA) - GAK Kumar	ICAR
91.	EAP-294	Efficacy of Chlorantraniliprole 625g/l FS (Lumivia) for the management of stem borer and leaf folder in Direct Seeded Rice (DSR) - NKB Patil, B Gowda, M Annamalai, PC Rath	E I Dupont India Pvt. Ltd.
92.	EAP-295	Greenhouse gas emission, mitigation & adaptation: strategies for better inventory and management of such gases in rice ecosystems of two agro-climatic zones of Assam - P Bhattacharya, H Pathak, S Chatterjee	DBT
93.	EAP-296	Development of multiple stress tolerant versions of rice varieties Gomati and Tripura Chikan Dhan through molecular breeding - SK Pradhan, M Chakraborti, AK Mukherjee	DBT
94.	EAP-297	Exploration and utilization of endophyte diversity in wild rice for health management of rice crops- Rupalin Jena (AK Mukherjee)	DST Inspire
95.	EAP-298	Amelioration of soil borne diseases in rice using endophytic community of wild rice of Odisha for benefit of rice farmers - Soma Samanta (AK Mukherjee)	DST- Women Scientist (B)
96.	EAP-299	Leveraging institutional innovations for inclusive and market led agricultural growth in Eastern India - B Mondal, BS Satapathy, AK Pradhan, SK Rout, SR Dalal	ICAR
97.	EAP-300	Performance evaluation of PAN Seed rice varieties - R P Sah, R L Verma, BC Patra, Raghu S, NKB Patil, Awadesh Kumar	PAN Seed
98.	EAP-301	Effect of Biogas digestate on rice growing and greenhouse gas emission - Anjani Kumar, D Chatterjee, S Mohanty	KSBT, Bhubaneswar
99.	EAP-302	Establishment of Biotech KISAN Hub at Central Rainfed Upland Rice Research Station (CRURRS), ICAR-NRRI, Hazaribag, Jharkhand - D Maiti, SM Prasad, BC Verma, S Roy, A Banerjee	DBT
100.	EAP-303	Insect Pest and disease forecasting and decision support system (ICAR-IRRI Collaborative Project - SD Mohapatra, G Prasanthi	ICAR-IRRI
101.	EAP-304	CRISPR / Cas based editing of susceptibility gene promoters to develop bacterial blight and sheath blight resistant rice plants avoiding pleiotropic effects - Subhasis Karmakar	DBT-RA
102.	EAP-305	To evaluate the bio-efficacy of PIX 10082 44% EW against insect pest of rice - GP Pandi G, PC Rath, M Annamalai, Sankari Meena, Somnath Pokhare	PI Industries Pvt. Ltd.
103.	EAP-306	Develop and validate crop establishment practices for drought-tolerant/ new varieties in a rainfed upland environment of Jharkhand. (Under programme: Climate smart management practices) - BC Verma	IRRI
104.	EAP-308	IRRI-ICAR collaborative Project- "Accelerating impact and equity"- M Sivashankari	IRRI
105.	EAP-309	Establishment of Biotech KISAN Hub at Regional Rainfed Lowland Rice Research Station (RRLRRS) - R Bhagawati	DBT
106.	EAP-310	Development of superior haplotype based near isogenic lines (Haplo- NILs) - SK Pradhan, L Behera, Devanna, K Chakraborty, GP Pandi	DBT
107.	EAP-311	Paddy straw residues management through in-situ microbial decomposition with mechanical interventions - P Paneerselvam, U Kumar, A Kumar, M Shahid	NASF
108.	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 - SK Pradhan, L Behera, JL Katara, BC Marndi, Devanna, A Banerjee, S Roy, K Chakraborty, MK Bag, PK Hanjagi, G Kumar, Aravindan S, M Annamalai	DBT
109.	EAP-313	Integration of in-vitro based Doubled Haploid, Marker Assisted Selection, Transgenic and CRISPR- Cas 9 technology in rice improvement (Training Project) - S Samantaray, JL Katara, Parameswaran C, Devanna, RL Verma	DBT
110.	EAP-314	Adaptive study trial of Council Active 30EG (Triafamone 20%+ Ethoxysulfuron 10%) for broad spectrum weed control in rice - S Saha	Bayor Crop Science Ltd.
111.	EAP-315	ICAR-IRRI collaborative Project on climate smart management practices- Development of appropriate machinery systems for rice mechanization - N Borkar, S Priyadarshi	IRRI

112.	EAP-316	Double haploid breeding in development of rice variety for enhancing resilience against biotic and abiotic stresses - S Samantaray, A Anandan, JL Katara, Parameswaran C, Devanna, RL Verma	BIRAC, India
113.	EAP-317	Bio-efficacy studies of E2Y45828-R120 5% tablet against Yellow stem borer (*Scirpophaga incertulas*) and rice leaf folder (*Cnaphalocrocis medinalis*) in rice - SD Mohapatra	FMC India Pvt. Ltd.
114.	EAP-318	Exploring insecticide induced hormesis to develop superior strain of egg parasitoid, *Trichogramma japonicum* and its molecular characterization - Basana Gowda G, T Adak, NKB Patil	Science and Technology Deptt., Odisha
115.	EAP-319	Evaluation of zinc oxide suspension concentrate (39.5% Zn) on rice against Zn SO_4 through soil application with urea - M Shahid, AK Nayak	Yara Fertilizer India Pvt. Ltd.
116.	EAP-320	Effect of polypropylene woven bags on paddy quality during storage - Anil kumar C, RP Sah	M/s Lohia Corp Ltd., Kanpur
117.	EAP-321	Promotion of pheromone traps for managing fall army worm and related insect pests of various crops - KR Rao, M Annamalai, T Adak, PK Nayak, G Kumar, Bapatla Kiran Gandhi, SK Das	RKVY
118.	EAP-322	Global challenges research fund (GCRF) South Asian Nitrogen Hub (GCRF-SANH Project) - D Chatterjee, A Anandan, S Mohanty, J Meher, B Mondal, A K Nayak	GCRF
119.	EAP-323	Value chain and nutritional research output: Fish for nutritional and health of women and children - GAK Kumar, Sujata Sethy, R Mahanta	CGIAR (WorldFish-ICAR W3)
120.	EAP-324	Study on impacts of primary and secondary pollutants on soil and crops around Vedanta Limited factory, Jharsuguda - M Shahid, AK Nayak, U Kumar, R Khanam	Vedanta Ltd
121.	EAP-325	Standardizing the pesticide application using an unmanned aerial vehicle for rice - Basana Gowda G, T Adak, Raghu S	M/s UPL Pvt. Ltd.
122.	EAP-326	Accelerated genetic gain in rice (AGGRI- Alliance) - Irrigated rainfed (Drought, salinity & submergence) and DSR ecologies - SK Pradhan, SK Dash, NP Mandal, A Anandan, K Chattopadhyay, S Roy	IRRI
123.	EAP-327	Evaluation of GF-4857 for bio-efficacy, phytotoxic effect and impact on natural enemies in rice ecosystem - NKB Patil, Basana Gowda G, T Adak, GP Pandi G, PC Rath	E I DuPont India Pvt. Ltd.
124.	EAP-328	Creation of seed infrastructure facility (only for construction) - RL Verma	Government of India Ministry of Agriculture & Farmers Welfare
125.	EAP-329	Formation and promotion of FPOs in Odisha - GAK Kumar, BC Patra, SK Das, B Mondal, RP Sah, Basana Gowda, AK Mukherjee, AK Pradhan, SR Dalal, S Paul	NABARD
126.	EAP-330	Formation and promotion of FPOs in Balasore - GAK Kumar, BC Patra, SK Das, B Mondal, RP Sah, Basana Gowda, AK Mukherjee, AK Pradhan, SR Dalal, S Paul	NCDC
127.	EAP-331	Study on chemical constituents of rice root modulating herbivory by the rice root knot nematode: a chemical ecology perspective - T Adak	DST
128.	EAP-332	Bio-efficacy of PIX 10172 64%WG against rice blast and sheath blight - S Lenka, Raghu S, Prabhukarthikeyan, GP Pandi G, PC Rath	PI Industries Pvt. Ltd
129.	EAP-333	E-pest surveillance in fruits and vegetables through light traps in Odisha state - SD Mohapatra	M/s Fine Trap India
130.	EAP-334	DST Inspire Fellow - Sonali Panda (MJ Baig)	DST Inspire
131.	EAP-335	Exploring AUS rice for drought, submergence and phosphorus starvation tolerance: Mining superior alleles and deciphering mechanism of tolerance - S Roy, NP Mandal, A Banerjee, BC Verma, K Chakraborty, P Swain	NASF
132.	EAP-336	Creation of Seed Infrastructure Facilities under Sub-Mission on seeds and Planting Material (SMSP) (only for construction) - BC Marndi, RP Sah, Md Azharudheen TP, Anilkumar C	Ministry of Agriculture & Farmers Welfare
133.	EAP-337	Formation and promotion of FPOs in Odisha - GAK Kumar, BC Patra, SK Das, B Mondal, RP Sah, B Gowda, A K Mukherjee, AK Pradhan, SR Dalal, A Anand, S Sethi, SK Rout, BK Jha, SM Prasad, S Paul	Govt. of India (SFAC)

134.	EAP-338	Enhancing productivity of organically managed rice using Hydronano M - D Chatterjee, AK Nayak, M Shahid	Invati Creations Pvt. Ltd., Kolkata (Contractual Project)
135.	EAP-339	Ph.D Dissertation work - Priya Das (MJ Baig)	DBT JRF
136.	EAP-340	Targeting serotonin and senescence pathways for enhancing brown plant hopper resistance and yield in rice - Bijayalaxmi Sahoo (Parameswaran C)	DST Inspire fellowship
137.	EAP-341	Evaluation of bio-efficacy and phytotoxicity of IIF-1516 against diseases of paddy - Prabhukarthikeyan SR	Indofil Industries Ltd.
138.	EAP-342	To evaluate the bio-efficacy and phytotoxicity of IFC067 against major rice diseases (bacterial blight, false smut and blast) - Raghu S, Mathew S Baite, Prabhukarthikeyan SR, Basana Gowda, PC Rath	Indofil Industries Ltd.
139.	EAP-343	AICRIP on Seed (Crops) - BC Marandi, Anil Kumar, AK Mukherjee, NKB Patil, RP Sah, Md. Azharudheen, Raghu S, M Annamalai	ICAR
140.	EAP-345	Evaluation of bio efficacy of MCI 9197 10% WG against sucking insect pest of rice - GP Pandi G, T Adak, PC Rath	PI industries ltd
141.	EAP-346	Bio-Efficacy and phytotoxicity of pesticides applied through drone technology in rice - Basana Gowda G, T Adak, PC Rath, RP Sah	M/s Mahindra and Mahindra Mumbai
142.	EAP-347	Droplet deposition and phyto-toxicity studies of Tetraniliprole 200 g/l SC (Vayego) and Tebuconazole 50% + Trifloxystrobin 25% WG Native in rice crop using an unmanned aerial vehicle (UAV) - Basana Gowda G, T Adak, RP Sah	M/S Bayer Crop Science Limited, Mumbai
143.	EAP-348	Evaluating performance of Nano Urea with respect to yield and nitrogen use efficiency of rice -Sangita Mohanty	Indian Farmers Fertilizer limited (IFFCO)
144.	EAP-349	Evaluation of bioefficacy of BAS 764 00 F against major rice diseases (Blast, sheath rot, false smut & Sheath blight) in rice - Raghu S, Mathew S Baite, Prabhukarthikeyan SR, GP Pandi G, PC Rath	BASF India Ltd.
145.	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
146.	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)
147.	EAP-352	Decrypting the chemical interaction of rice and its specialist herbivore, *Scirpophaga incertulas* - T Adak, Basana Gowda	SERB, DST
148.	EAP-353	Network programme on precision agriculture (NePPA) - R Tripathy, AK Nayak, S Mohanty, SD Mohapatra, Raghu S, BR Goud	ICAR
149.	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 - GP Pandi G, T Adak, Raghu S	DST, Odisha
150.	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
151.	EAP-356	Understanding the effect of aerobic adaptation loci on yield of drought tolerant rainfed shallow lowland cultivar rice using genome editing tool - Parameswaran C, Devanna	SERB
152.	EAP-357	Identification of genomic region(s) for 21 days submergence tolerance in rice using sequence based trait mapping approach - JL Katara, S Samantray, Parameswaran C	SERB

Weather

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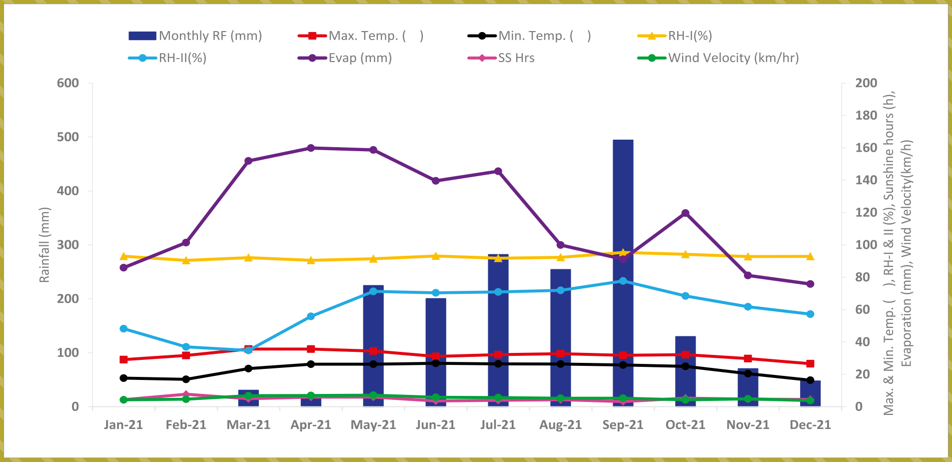

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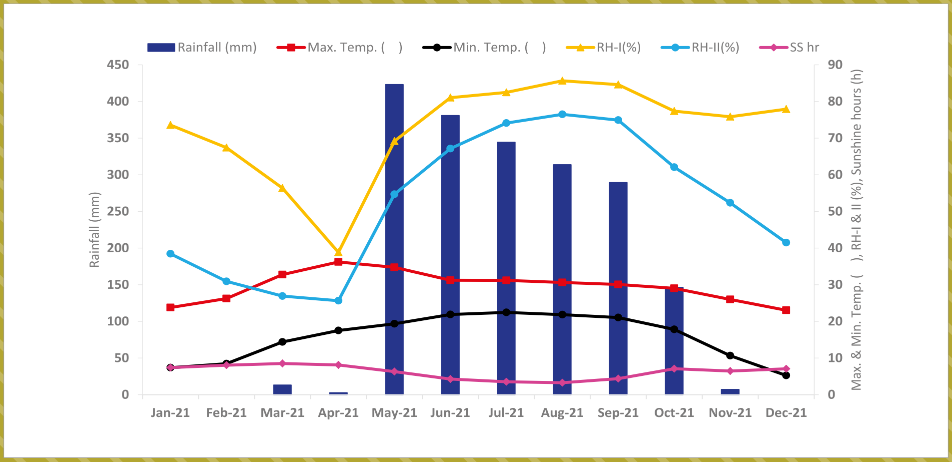
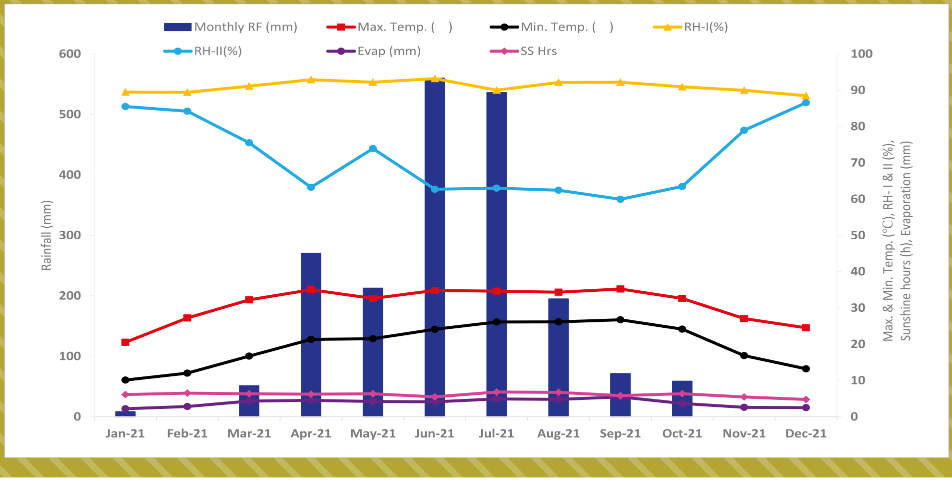


NRRI REGIONAL STATION, GERUA



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