NRRI
वार्षिक प्रतिवेदन
ANNUAL REPORT
2018-19

भाकृअनुप-राष्ट्रीय चावल अनुसंधान संस्थान
ICAR-National Rice Research Institute

An ISO 9001 : 2015 Certified Institute

NRRI

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भाकृअनुप - राष्ट्रीय चावल अनुसंधान संस्थान
कटक (ओडिशा) 753 006, भारत
ICAR - National Rice Research Institute
Cuttack (Odisha) 753 006, India
An ISO 9001:2008 Certified Institute

Correct Citation
ICAR-NRRI Annual Report 2018-19, Pub.,
ICAR - National Rice Research Institute, Cuttack

ISBN 818840910-3

Published By
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Director, NRRI

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Printed in India by the Print-Tech Offset Pvt. Ltd., Bhubaneswar-751024 (Odisha). Published by the Director for ICAR - National Rice Research Institute, Cuttack-753006 (Odisha).

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Cover Page: Mural paintings on the boundary wall of ICAR-National Rice Research Institute, Cuttack, Odisha displaying heritage, culture, customs and traditions of rice farming in India.

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NRRI

PREFACE

People of India have been cultivating rice for last 7000 years. It is the staple food for more than two thirds of the Indian population. Prior to 1950, rice cultivation was mostly monsoon dependent with traditional technologies. Abiotic stresses like drought and flood were often occurring with widespread crop failures, starvation deaths and even famines including the Great Orissa Famine (*Na' Anka Durbhiksha*) of 1866 with death toll of about 10 lakhs of people and the Great Bengal Famine of 1943 with a death toll of about 20 lakhs of people. At the backdrop of the later famine, the Government of India established Central Rice Research Institute (CRRI), now named as National Rice Research Institute (NRRI) on April 23, 1946 at Bidyadharpur, Cuttack, Odisha.

The Institute, so far has developed 133 high-yielding rice varieties, and several crop production and protection technologies and farm implements. Varieties released by this Institute are cultivated in 18-20% rice area of the country. The Institute has contributed significantly in increasing rice production of the country from about 20 million tons in 1950 to 112.8 million tons in 2017-18.

In the year of report, the Institute developed state-of-the-art laboratory and equipment facilities to carry out cutting edge research on rice. It has root scanlyzer; nitrogen auto-analyzer; chlorophyll fluorescence imaging system; gas chromatograph; atomic absorption spectrophotometer and inductive coupled plasma-optical emission spectrometer; PCR/thermal cycler enables; RT-PCR; biolog; nano-spectrometer; denaturing gradient gel electrophoresis; fluorescence microscope and stereo zoom microscope.

The Institute recently established an advanced Genomics and Quality Laboratory; constructed new buildings for social science research, administrative building for Krishi Vigyan Kendra at Santhapur and an auditorium.

During 2018-19, the Institute worked on 31 research projects under 7 research programmes, 108 externally-aided projects and 4 flagship projects. 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 5 rice varieties i.e., CR Dhan 309, CR Dhan 510, CR Dhan 511, CR Dhan 801, CR Dhan 802 (Subhas) were notified by Central Variety Release Committee (CVRC). Four varieties i.e., CR Dhan 311 (Mukul), CR Dhan 204, CR Dhan 306, CR Dhan 205 were notified by State Variety Release Committee (SVRC) of different states. During the year under report, the Institute has published more than 180 research papers with average NAAS score of 7.01; 1 Book; 3 Research Bulletins; 3 Technical Bulletins and 41 Farmer Training Manuals/Leaflets.

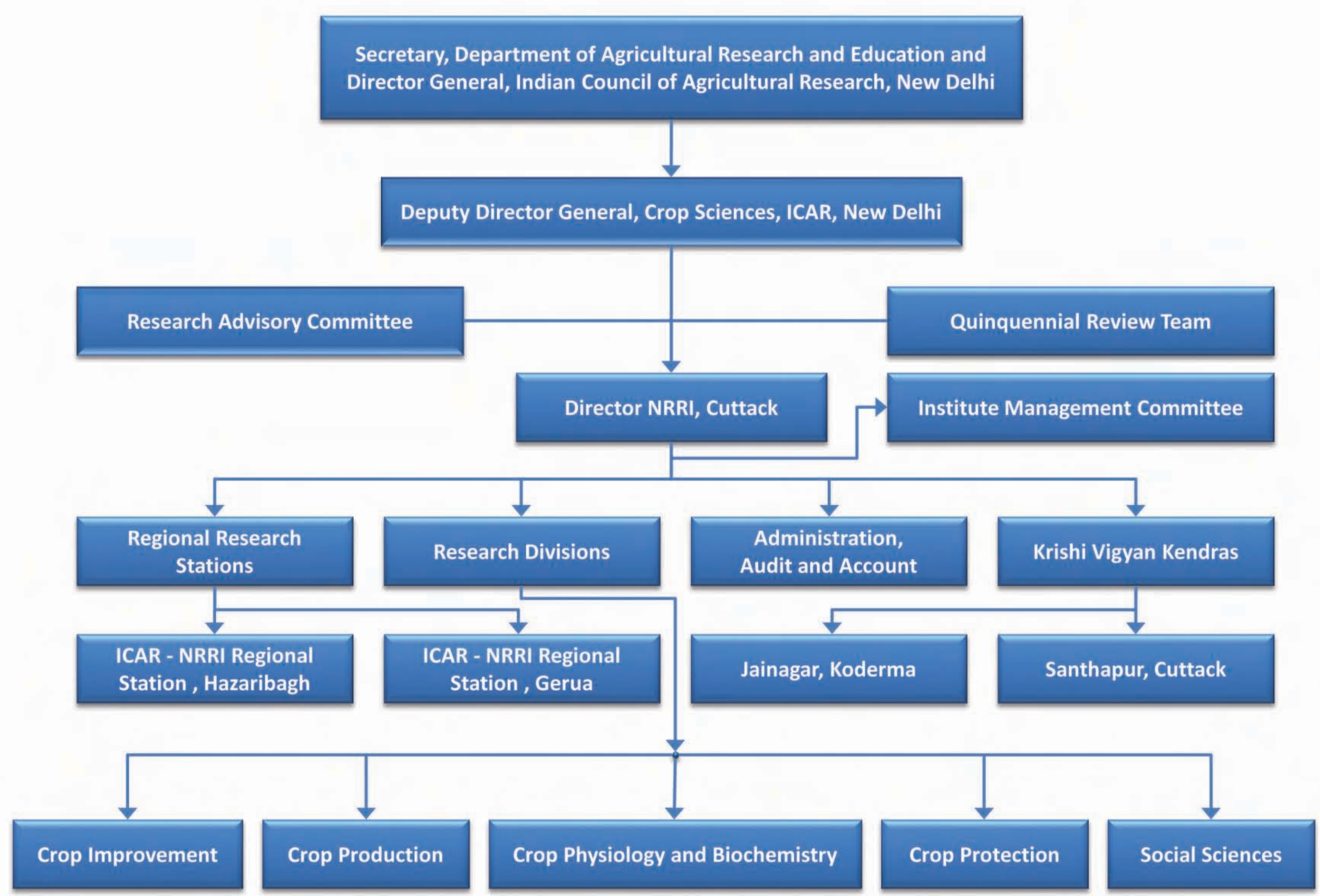
The Institute sincerely acknowledges the guidance and encouragements received from Dr. T. Mohapatra, Director General, ICAR and Secretary, DARE in guiding various research and development programmes. Our sincere thanks are due to Shri C. Roul, Special Secretary, DARE and Secretary, ICAR; Shri B.N. Tripathi and Shri B. Pradhan, Additional Secretaries, DARE and Financial Advisors, ICAR for their continuous support and guidance. Valuable guidance, encouragement and support received from Dr. S.K. Datta, Chairman and other esteemed members of Research Advisory Committee; Dr. A.K. Singh, DDG (Crop Sciences), ICAR; esteemed members of Institute Management Committee and Institute Research Council (IRC) are sincerely acknowledged. Thanks are due to Dr. I.S. Solanki and Dr. R.K. Singh, ADGs (FFC), ICAR; Dr. Dinesh Kumar, Principal Scientist and other officials of the Council for their constant support and guidance.

I sincerely thank the Heads of the Divisions, Officer In-Charges of Regional Stations, and Administration and Finance sections of the Institute for their whole-hearted efforts and dedication in carrying out the activities of the Institute. My sincere thanks are due to the 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.

ICAR-NRRI is progressing at an accelerated pace in respect of infra-structure development and innovative research to address the emerging challenges and develop super-yielding, climate-smart, nutrient-efficient and nutrient-rich varieties; C4 rice and agro-technologies for higher productivity, profitability, climate resilience and sustainability of rice farming. I sincerely hope that the Annual Report will be useful for the researchers, policy makers, development functionaries, farmers, farm-women and students and help in promoting rice research and development.

(Himanshu Pathak)
Director

ORGANOGRAM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Crop Protection
Social Sciences

Executive Summary

The country has made significant progress in rice production. During 2017-18, production of rice has been 112.8 million tons. Despite this achievement, rice farmers face serious challenges of low income, degradation of natural resource base, climate change related amplification of both biotic and abiotic stresses, which require all the ingenuity of sciences to deal with. ICAR-National Rice Research Institute, Cuttack accordingly has reoriented its research agenda to address these challenges. Salient achievements of various research programmers of the institute during 2018-19 are briefly presented below.

This year, five improved rice varieties *viz*. CR Dhan 309, CR Dhan 510, CR Dhan 511, CR Dhan 801, CR Dhan 802 (Subhas), developed through conventional as well as molecular breeding approaches were released and notified by CVRC. Other four varieties *viz.* CR Dhan 311 (Mukul), CR Dhan 204, CR Dhan 306 and CR Dhan 205 were notified for cultivation in different states by SVRC. About 555 q breeder seeds consisting of 46 varieties and nine parental lines were produced. Besides, 905 q TL seeds were produced under farmer's participatory seed production programme in three villages were sold to farmers. Seeds of 4781 accessions of rice germplasm were supplied to researchers of various organizations for utilization.

Mapping population (RIL) from crosses Swarna/Rahspunjar and Savitri/Pokkali (AC 39416a) were developed for tolerance to salinity, water logging and germination stress oxygen deficiency. Bacterial blight resistant genes (*Xa21, xa13, xa5 and Xa4*) were introgressed in CRMS 31A and CRMS 32A. Seventy-three double haploid lines derived from hybrid 27P63 showed a wide variation in protein content ranging from 7.16% to 12.01% (M-129-1). Mapping population consisting 300 F_2 lines developed from the cross TN1 and Salkathi (BPH tolerant) were genotyped with flanking SNP markers and corresponding F_3 lines were screened for reaction to BPH. Association mapping for seedling vigour was carried out using 96 genotypes. Seventy-nine rice varieties were genotyped with nine markers associated with heat stress tolerance.

Carbon footprints (CFs) of rice production in different states of India were estimated. Mean CFs of rice in India was 2.31 t CO_2e ha^{-1}, where northern India (4.12 t CO_2e ha^{-1}) and north-east India (0.46 t CO_2e ha^{-1}) showed the highest and lowest CFs, respectively. Source sink relationship for six rice varieties with contrasting N use efficiency were analyzed; variety Birupa and Naveen were grouped as efficient at low N, whereas Indira and Surendra were grouped as responder to higher N. The seasonal variations of water vapour flux (FH_2O) in lowland paddy were assessed and validated using open path eddy-covariance system. A zero tillage-based rice-maize cropping system involving real time N management using leaf colour chart was demonstrated resulting system productivity *at par* with conventional practices while saving Rs. 6600 ha^{-1} as cost of production. Diversification of rice-rice system with rice-green gram system along with incorporation of rice residue resulted in highest yield of rice as compared to the conventional practice. Two microbial formulations having commercialisation potential *i.e. Azolla*-based formulations for livestock feed and *Azolla*-based microbial growth medium were developed. Other microbial formulation *Azotobacter chroococcum* (AVi2) promoted rice growth under drought condition due to enhanced ascorbic acid formation. One power operated two-row wetland weeder for rice was developed with weeding efficiency and plant damage at 40 days after transplanting was 68.5% and 3.0%, respectively.

Rice germplasm were screened for resistance reaction against different insect pests and diseases. Out of 153 different land races and 102 Manipuri rice screened, 18 showed resistance against BPH and four against WBPH. Bina Dhan-8 showed resistantce against Angoumois grain moth (*Sitotroga cerealella*). Out of 1383 genotypes screened, two entries showed bacterial blight resistance reaction, 16 rice genotypes were moderately resistant against sheath blight and eight rice varieties showed high degrees of resistance against bakanae. NRRI formulation of *Trichoderma* seed treatment increased vigour index, growth and yield of rice. Pesticide combination Chlorantraniprole + Carbendazim + Mancozeb was effective against stem borer, leaf folder, gundhi bug and blast disease of rice. Similarly, combination of Azoxystrobin 11%+ Tebuconazole 18.3% w/w SC @ 1.5 ml l^{-1} was effective against sheath blight.

Six ARC accessions and five released varieties were identified as drought tolerant donors with SES score '1' in two consecutive years. Relative gene expression of Sedoheptulose 1-7 bisphosphate of T. Basmati under different light intensities had maximum expression showing its photosynthetic adaptability to low light stress. Drought tolerant lines AC3577, IC516009, Parijat, PAU 9, Mahulata and Rameswari, showed 65-80% survival under two weeks of complete submergence imposed at early vegetative stage, further AC1303 and AC39416A showed tolerance to combined stress of submergence with saline water indicating their multiple stress tolerance ability. Genotypes like AC42088, AC42087 and AC1303 were found to withstand 3-weeks of complete submergence. Pokkali (AC41585), a good Na^+-excluder managed to sequester higher Na^+ load in the roots with little upward transport while, moderately salt-tolerant Luni Dhan found to have less selectivity in Na^+-transport, but possessed higher capacity to Na^+-sequestration in leaves. For enhancing photosynthetic efficiency, introduction of C4 *Sorghum bicolor* Carbonic anhydrase (CA) enzyme in rice was done. Study in the *SbCA* gene expression showed enhanced expression levels (2-5 fold higher CA enzyme activity) in the transgenic than the control and vector control plant.

Demonstrations were conducted in farmers' fields with 20 newly released varieties of ICAR-NRRI in five states (Odisha, West Bengal, Assam, Bihar and Jharkhand). Most of the NRRI varieties outperformed the competing varieties by giving an average grain yield advantage of 10-15%. Varietal demonstrations-cum-experiments revealed gap from the potential yields to the extent of 7% to 47%. Analysis of farm-level data collected from Odisha and Jharkhand indicates the gap from technically efficient yield as 14% and 16%, respectively for the two states. Among the farm-level characteristics, extension contact possesses positive influence and land holding possess negative influence on technical efficiency for the farmers at two states. Five Farmer Producer Companies (FPCs) were registered in five blocks of Odisha (Mahanga, Athagarh, Niali, Badamba and Banki) under Company Act, 2013 of the Govt. of India for sustaining local seed production system and marketing of quality paddy seeds under 4S4R model. More than 920 quintals of Foundation and Certified seeds of four popular rice varieties *viz.,* Pooja, Sarala, Gayatri and Swarna-*Sub1* were produced during *kharif* 2018 by 77 seed growers. In addition, three FPCs were also registered under OSSOPCA (Mahanga, Athagarh and Niali) as producing agencies, while 130 FIGs were formed under these three FPCs with 2600 members. The water footprint of rice exported to the other countries indicates that virtual water export increased by six times in the last decade from 8.63×10^6 m^3 to 5.10×10^7 m^3.

Under rainfed upland rice cultivation, genotypes screened for different traits showed that (i) *Gora* rice possess multiple stress tolerance (drought, blast disease, P deficiency and submergence); (ii) 57 germplasm suitable for growing under rainfed uplands, were identified to be drought tolerant. Seed priming options of soaking in (a) *Syzygium cumini* aq. extract (1.7%), (b) GA (100 ppm) coupled with soil application of *Arbuscular mycorriza* and phosphorus solubilising bacteria resulted yield enhancement to the tune of 8.8 to 12.2% under direct seeded rice (DSR). During *sali/kharif* 2018, a total of 27 advanced breeding lines (Semi deep and deep water rice) were evaluated and six entries performed better than the check.

During the year, the Institute has published 180 research papers with average NAAS score of 7.01; 1 Book; 3 Research Bulletins; 3 Technical Bulletins and 41 Farmer Training Manuals/Leaflets.

During 2018-19, 41 MSc and 5 PhD students completed their research work from the Institute. In addition, 16 students completed their summer training. This year, NRRI-IRRI scholars' programme with 15 scholarships for MSc and 10 for PhD was initiated to develop a new generation rice scientists and research leaders for India.

कार्यकारी सारांश

देश ने चावल उत्पादन में उल्लखेनीय प्रगति की है। 2017-18 के दौरान चावल का उत्पादन 112.8 मिलियन टन रहा है। इस उपलब्धियों के बावजूद, चावल किसानों को कम आय, प्राकृतिक संसाधन आधार के क्षरण, जलवायु परिवर्तन से संबंधित जैविक और अजैविक दोनों प्रकार के दबावों का सामना करना पड़ता है जिससे निपटने के लिए विज्ञान के सभी कौशल की आवश्यकता होती है। भाकृअनुप-राष्ट्रीय चावल अनुसंधान संस्थान, कटक ने तदनुसार इस चुनौनितयों का समाधान करने के लिए अपने अनुसंधान कार्यसूची को तैयार किया है। 2018-19 के दौरान संस्थान के विभिन्न अनुसंधान कार्यक्रमों की मुख्य उपलब्धियां संक्षेप में प्रस्तुत है।

इस वर्ष, पाँच उन्नतशीत चावल की किस्मों सीआरधान 309, सीआर धान 510, सीआर धान 511 सीआर धान 801, सीआर धान 802 (सुभाष) पारंपरिक के साथ-साथ आणविक प्रजनन उपायों से विमोचित किया गया और केंद्रीय किसम विमोचन समिति द्वारा अधिसूचित किया गया। अन्य चार किस्में जैसे सीआर धान (मुकुल), सीआर धान 204, सीआर धान 306 और सीआर धान 205 को राज्य किस्म विमोचन समिति द्वारा विभिन्न राज्यों में खेती के लिए अधिसूचित किया गया था। 46 किस्मों और नौ पैतृक वंशों से युक्त लगभग 555 क्विंटल प्रजनक बीज का उत्पादन किया गया। इसके अतिरिक्त, तीन गांवों में किसान भागीदारी बीज उत्पादन कार्यक्रम के तहत 905 क्विंटल विश्वसीनय लेबल के बीज का उत्पादन किया गया। चावल जननद्रव्य के 4781 प्रविष्टियों के बीज को विभिन्न संगठनों के शोधकर्ताओं के उपयोग के लिए आपूर्ति की गई।

स्वर्णा/राहसपंजर और सावित्री/पोक्कली (एसी 39416 ए) के क्रॉसिंग से आरआईएल मैंपिंग संख्या विकसित की गई। राहसपंजन और एसी 39416ए और लुणा सुवर्णा की किस्में लवणता, जलाक्रांत और अंकुरण दबाव ऑक्सीजन की कमी के प्रति सहिष्णु हैं। संकर 27पी63 से व्युत्पुन्न तेहत्तर डबल हाप्लाएड वंशों का मूल्यांकन प्रोटीन मात्रा के लिए किया गया जिसकी सीमा 7.16 प्रतिशत से 12.01 प्रतिशत की बीच था। उच्चतम प्रोटीन मात्रा (12.01 प्रतिशत) एम-129-1 में पाई गई। क्रॉस टीएन1 और सालकाथी (भूरा पौध माहू सहिष्णु) से विकसित 300 एफ2 वंशों से युक्त मानचित्रण संख्या को एसएनपी मार्करों के साथ जोड़ा गया था और एफ3 वंशों की भूरा पौध माहू की प्रतिक्रिया के लिए परीक्षण की गई। इसके अतिरिक्त, पौध ओज से जुड़े जीन/क्यूटीएल की पहचान करने के लिए एसोसिएशन मैपिंग 96 जीनप्ररूप को शामिल करके किया गया। तापमान के दबाव सहिष्णुता से जुड़े नौ मार्करों के साथ उन्नासी चावल की किस्मों को जीनटाइप किया गया।

भारत के विभिन्न राज्यों में चावल उत्पादन के कार्बन फुट प्रिंट की औसत गणना 2.31 टन प्रति हैक्टर के रूप में की गई और चावल का कार्बन फुट प्रिंट उत्तरी भारत में सबसे अधिक (4.12 टन प्रति हैक्टर) पाया गया तथा सबसे उत्तर पूर्व भारत में (0.46 टन प्रति हैक्टर) पाया गया। नाइट्रोजन प्रयोग क्षमता के लिए चावल की छह किस्मों में विपरित नाइट्रोजन के स्रोत सिंक संबंध का विश्लेषण किया गया-नवीन एवं बिरूपा को कम नाइट्रोजन प्रयोग क्षमता के रूप में तथा ईंदिरा और सुरेंद्र को उच्च नाइट्रोजन प्रत्युत्तर के रूप में वर्गीकृत किया गया।

निचलीभूमि धान में जल वाष्प के प्रवाह की मौसमी विविधताओं का आलकन किया गया और खुले मार्ग एडी-कोवारियांस प्रणाली का उपयोग करके इसे मान्य किया गया। एक शुन्य जुताई आधारित चावल-मक्का फसल प्रणली जिसमें वास्तविक समय पर लीफ करल चार्ट का उपयोग करके नाइट्रोजन प्रयोग का प्रदर्शन किया गया जिससे पारंपरिक खेती प्रथाओं के अनुरूप प्रणाली उत्पादकता मिली और उत्पादन की लागत के रूप में 6000 रुपये प्रति हैक्टर की बचत हुई। चावल के अवशेषों को शामिल करने के साथ चावल-चना की प्रणाली के साथ चावल-चावल प्रणाली के विविधीकरण के परिणामस्वरूप पारंपरिक खेती की तुलना में चावल की सबसे अधिक उपज हुई। व्यावसायीकरण की क्षमता वाले दो माइक्रोबॉयल विकास माध्यम विकसित किए गए। अन्य माइक्रोबॉयल सूत्रीकरण अजोटो बैक्टीरोक्रोकम (एवीआई 2) ने एस्कार्बिक एसिड गठन के कारण सूखे की स्थिति में चावल के विकास को बढ़ावा दिया। चावल के लिए कतारवाले आर्द्रभूमि शक्तिचालित वीडर विकसित की गई जिसकी खरपतवार दक्षता रोपाई करने के 40 दिनों बाद 68.5 प्रतिशत है तथा पौधों की क्षति 3.0 प्रतिशत है।

चावल के विभिन्न नाशककीटों और बीमारियों के विरुद्ध प्रतिरोधिता प्रतिक्रिया के लिए चावल जननद्रव्यों का परीक्षण किया गया। 153 विभिन्न भूमिजातियों और 102 मणिपुरी चावल की किस्मों की परीक्षण की गई जिसमें से 18 ने भूरा पौधा माहू के विरुद्ध प्रतिरोधिता दिखाई। 1383 जीनोटाइप्स में से दो प्रविष्टियों ने जीवाणुज अंगमारी प्रतिरोधिता दिखाई, सोलह चावल जीनोटाइप आच्छद अंगमारी के विरुद्ध मामूली प्रतिरोधिता और आठ चावल किस्मों ने बकाने रोग के विरुद्ध उच्च प्रतिरोधिता दिखाया। एनआरआरआई के ट्राइकोडर्मा बीज उपचार के सूत्रण से पौध की ओज वृद्धि और उपज में वृद्धि हुई। चावल की तना छेदक, पत्ता मोड़क, गंधी बग और

प्रध्वंस रोग के विरुद्ध कीटनाशक मिश्रण क्लोरानट्रानिपोल अ कार्बेन्डाजिम अमैंकोजाब प्रभावी था। इस तरह, एजोक्सिस्ट्रोबिन प्रतिशत एवं टेबुकोनाजोल 18.3 प्रतिशत डब्लयू एसजी 1.5 मिलीमीटर/लीटर दर से प्रयोग आच्छद अंगमारी के विरुद्ध प्रभावी था।

छह एआरसी प्रविष्टियों और पांच विमाचित किस्मों को लगातार दो वर्षों में एसईएस के स्कार '1' के साथ सुखा सहिष्णु दाताओं के रूप में पहचाना गया। अलग-अलग प्रकाश तीव्रता के तहत टी.बासुमती के 1.7 बाइसफोस्फेट के सापेक्ष जीन की प्रकटीकरण में अधिकतम प्रकाश अभिव्यक्ति थी जो कम प्रकाश दबाव के लिए प्रकाश संश्लेषी अनुकूलनशीलता देखने को मिला। सुखा सहिष्णु वंश एसी 3577, आईसी 516009, पारिजात, पीएयू 9, माहूलता और रामेश्वरी ने प्रारंभिक वृद्धि अवस्था में लगाए गए पूर्ण जलमग्नता के दो सप्ताह के भीतर 65-80 प्रतिशत उत्तरजीवित्ता दिखाई, एसी303 और एसी3946ए में जलमग्नता लवणता के साथ-साथ संयुक्त दबाव की सहिष्णुता देखने को मिला जो लवणीय जल के जलमग्नता के साथ उनकी विविध दबाव सहिष्णुता क्षमता को दर्शाता है। एसी 4088, एसी 4087 और एसी 303 जैसे जीनप्ररूप 3 सप्ताह तक पूर्ण जलमग्नता को सहन करते पाए गए। पोक्कली (एसी 4585), एक बहुत अच्छा लवण अलगावकर्ता है, जडों में उच्च नत्रजन भार को अलग करने में सफल रहा, जबकि मध्यम रूप से लवण सहिष्णु लुणी धान नत्रजन के पारवहन में कम चयनात्मकता पाया गया लेकिन पत्तों में नत्रजन के परिशोधन के लिए उच्च क्षमता है। प्रकाश संश्लेषक क्षमता बढाने के लिए चावल में सी4 सोरगम बाईकलर कार्बोनिक एनहाईड्रेज एंजाईम की शुरूआत की गई। एसबीसीए जीन अभिव्यक्ति के अध्ययन ने नियंत्रण और वेक्टर नियंत्रण पौध की तुलना में ट्रांसजेनिक में वर्द्धित 2-5 गुना उच्च सीए एंजाएम गतिविधि अभिव्यक्ति स्तर दिखाया।

पांच राज्यों -ओडिशा, पश्चिम बंगाल, असम, बिहार और झारखंड में भाकृअनुप-एनआरआरआई की 20 नई विमोचित किस्मों को किसानों के खेतों में प्रदर्शन किया गया। एनआरआरआई की नई विमोचित किस्मों में से 10-15 प्रतिशत की औसत उपज का लाभ देकर प्रतिस्पर्धा किस्मों को पीछे छोड दिया। भारत सरकार की कंपनी अधिनियम, 2013 के अनुसार 4एस4आर मॉडल के तहत स्थानीय बीज उत्पादन प्रणाली को बनाए रखने और गुणवत्ता वाले धान के बीज के विपणन के लिए ओडिशा के पांच खंडों-महांगा, आठगढ, नियाली, बडंबा एवं बांकी में पांच किसान उत्पादक कंपनियों को पंजीकृत किया गया। 2018 के खरीफ के दौरान 77 बीज उत्पादकों द्वारा चार लोकप्रिय चावल किस्मों पूजा, सरला, गायत्री एवं स्वर्णा सब1 का फाउंडेशन एवं प्रमाणित बीज के 920 क्विंटल से अधिक बीज का उत्पादन किया गया। इसके अतिरिक्त, तीन किसान उत्पादक कंपनियों को ओएसएसओपीसीए (महांगा, आठगढ, नियाली) में भी उत्पादन अभिकरणों के रूप में पंजीकृत किया गया जबकि ये 3 तीन किसान उत्पादक कंपनियों के तहत 130 एफआईजी का गठन 2600 सदस्यों सहित किया गया। पांच राज्यों - ओडिशा, पश्चिम बंगाल, असम, बिहार और झारखंड में विभिन्न प्रदर्शनों-सह-प्रयोगों से संभावित उपज अंतर 7 प्रतिशत से 47 प्रतिशत के बीच पाया गया। ओडिशा और झारखंड में एकत्रित प्रक्षेत्र स्तर के आंकडों के विश्लेषण तकनीकी रूप से दोनों राज्यों के लिए कुशल उपज क्रमशः 14 प्रतिशत और 16 प्रतिशत के अंतर को दर्शाता है। दो राज्यों के प्रक्षेत्र स्तर को विशेषताओ में, विस्तार संपर्क में सकारात्मक प्रभाव और भूमिधारण किसानों के लिए तकनीकी दक्षता पर नकारात्मक प्रभाव रखता है। अन्य देशों को निर्यात किए गए चावल से पानी प्रयोग यह सूचना मिली कि पिछले दशक के समय से वरच्युल जल निर्यात छह गुना वृद्धि हुई है।

विभिन्न लक्षणों के लिए परीक्षण किए गए वर्षाश्रित ऊपरीभूमि जीनप्ररूप से पता चला कि 1-गोरा चावल जीनप्ररूप में कई दबाव सहिष्णुता (सुखा, प्रध्वंस रोग, फोस्फोरस की कमी और जलमग्नता) है, 2-वर्षाश्रित ऊपरीभूमि के लिए उपयुक्त 57 जननद्रव्य की पहचान सुखा सहिष्णु के रूप में की गई। क-सिजियम क्यूमिनी जलीय निचोड (1.7 प्रतिशत) में डूबोकर बीज प्रामिंग विकल्प। ख-जीए (100 पीपीएम) आरबूस्क्यूलार माईकोरिजा और फॉस्फोरस विलयन जीवाणु की मिट्टी के प्रयोग से सीधी बुआई चावल में 8.8 से 12.2 प्रतिशत की वृद्धि हुई। 2018 के साली खरीफ के दौरान कुल 27 उन्नत प्रजनन वंशों (अर्ध गहरे और गहरे जल चावल) का मूल्यांकन किया गया तथा छह प्रविष्टियों ने चेक किस्म से बेहतर प्रदर्शन किया।

इस अवधि के दौरान संस्थान ने 7.01 के औसत एनएएएस स्कोर के साथ 180 से अधिक शोधपत्र, 1 पुस्तक, 3 अनुसंधान बुलेटिन, 3 तकनीकी बुलेटिन और 4 किसान प्रशिक्षण नियमावली/पत्रक प्रकाशित किए हैं।

2018 के दौरान 41 एमएससी और 5 पीएचडी छात्रों ने संस्थान से अपना शोध कार्य पूरा किया। इसके अतिरिक्त 16 छात्रों ने संस्थान में ग्रीष्मकालीन प्रशिक्षण पूरा किया। इस वर्ष एनआरआरआई-आईआरआरआई अध्येतावृत्ति कार्यक्रम में एमएससी के लिए 15 और पीएचडी के लिए 10 छात्रवृत्ति आरंभ की गई जो भारत के लिए एक नई पीढी के चावल वैज्ञानिकों और अनुसंधान नेतृत्व को विकसित करने के लिए थी।

Introduction

National Rice Research Institute (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, for 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 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 stastistics 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 IRRI, Philippines and ICRISAT, Patencheru.

Location

The institute is located at Cuttack about 35 km from Bhubaneswar airport and 7 km from the Cuttack railway station on the Cuttack-Paradeep State Highway. The annual rainfall at Cuttack is 1200 mm to 1500 mm, received mostly during June to October from the southwest monsoon.

PROGRAMME : 1

Genetic Improvement of Rice for Enhancing Yield, Quality and Climate Resilience

The genetic improvement of rice is conducted through basic, applied and strategic researches involving genetic and genomic resources, conventional and molecular marker assisted breeding and quality seed production. Under PGR activities, two explorations were conducted for collection of trait specific rice germplasm. A set of 6518 accessions of rice germplasm were rejuvenated, characterised and conserved in rice gene bank. Seeds of 4781 accessions of rice germplasm/elite lines /donors / varieties were supplied to researchers for their utilization. Under quality seed research, panicle progeny rows of 47 varieties were grown for maintenance breeding. A total of 14.61q nucleus seed of 47 varieties were used to produce breeder seed as per DAC indent. About 554.99 q breeder seeds consisting of 46 varieties and 9 parental lines were produced. Besides, 905.00q TL seed were produced under farmer's participatory seed production programme.

CR Dhan 312 (CR 3808-13, IET 25997), a selection from male sterility facilitated recurrent selection population was identified for release for irrigated areas of Chhattisgarh and Maharashtra. Several hybridizations were carried out between F_1s of elite genotypes (Swarna, CR Dhan 307 and donors for resistance to sheath blight like CR 1014, Tetep, Jasmine 85 and two accessions of *O. rufipogon* (AC 100444 and AC 100015), for brown plant hopper two accessions of *O. rufipogon* (AC 100005, AC 100034) and yellow stem borer *O. brachyantha* derived line (B2-11) and recipient parents.

Gobindbhog, a popular aromatic short grain landrace of high commercial value of West Bengal was purified. The climate-smart variety, CR Dhan 801 and Subhas (CR Dhan 802) have been notified in the Gazette, Department of Agriculture and Co-operation, Ministry of Agriculture for cultivation in Odisha, West Bengal, Telengana, Andhra Pradesh and Uttar Pradesh. Mapping population (RIL) from crosses Swarna/Rahspunjar and Savitri/Pokkali (AC 39416a) were developed for tolerance to salinity, water logging and germination stress oxygen deficiency. Phenotyping under control and water logging condition (50 cm depth) of RIL population derived from Savitri/AC 39416a revealed normal distribution of component traits. CRMS 56A (Kalinga-1), a medium-late duration CMS developed under nucleus background of DH 79 (CRMS32B/RTN12B) having large dual stigma exsertion and >40% out-crossing might be useful in development of late duration hybrids with substantial seed producibility. One late duration hybrid, CRHR 113 (IET 26976) was promoted to AVT-1Late trials. Bacterial blight resistant genes (*Xa21, xa13, xa5* and *Xa4*) were introgressed in CRMS 31A and CRMS 32A. Total 215.0 kg breeder seeds of 13 parental lines and 636.0 kg truthfully labelled seeds of 42 hybrid combinations were produced.

The elite line CR 3724-1 (IET 25692) was identified by VIC for release in *boro* situation of Assam and Tripura as CR Dhan 602**.** The average yield is 5.79 t/ha and potential yield of 9.4 t/ha. The maturity duration is 154-163 days with semi-dwarf plant type (101-104.5cm). It is non-lodging type and possesses long slender grains besides having moderately resistance to leaf blast and other insect pests. Attempt was made to enhance the callus response for androgenesis by manipulating the chemical factors from which histone deacetylase inhibitors along with growth hormones were found potent in increasing callus response up to ~ 80% in rice hybrids such as Arize Tez Gold and Rajalaxmi. A total of 73 DH lines derived from a quality rice hybrid 27P63, were evaluated for high protein content ranging from 7.16% to 12.01%. The highest protein content (12.01%) was found in M-129-1. Mapping population consisting of 300 F_2 lines developed from the cross TN1 and Salkathi (BPH tolerant) were genotyped with flanking SNP markers and corresponding F_3 lines were screened for reaction to BPH. Linkage analysis confirmed the position of previously identified QTLs for BPH resistance in Salkathi. *Insilco* analysis identified 15 candidate genes associated with BPH resistance in Salkathi. Besides, association mapping to identify genes/ QTLs associated with seedling vigour was carried out through a mini core diversity panel consisting of 96 genotypes including biochemical traits at 6 days, 14 days and 28 days after germination. Seventy-nine rice varieties were genotyped with 9 markers associated with heat stress tolerance. Association analysis indicated that RM242 could reduce the spikelet sterility significantly by 6%. Based on the performance over 3 seasons, 3 best genotypes were identified and used to generate biparental mapping population.

Exploration, characterization and conservation of rice genetic resources

Exploration and collection of rice germplasm

Two exploration programmes were conducted in different parts of the country for collection of trait specific rice germplasm. One was for collection of rice landrace diversity in four districts of Nagaland namely, Kohima (27), Wokha (16), Zunheboto (14) and Phek (31). A total of eighty-eight (88) accessions were collected with their passport data. Nagaland is inhabited by 16 major tribes and each tribe is unique in its own distinct customs, language and costume/ dress and has preferences of rice with respect to colour, taste, aroma and cooking quality. The traditional jhum (shifting cultivation) and wet terrace rice cultivation (TRC) methods are practiced by the farmers.

Another programme was conducted in collaboration with ICAR-NBPGR Base Center, Cuttack for collection of rice germplasm from Barpeta, Bongaigaon and Chirang districts of Assam. A total of 43 acc. were collected.

Rejuvenation of the conserved germplasm and the new collections

Periodic monitoring of seed viability was done for the stored gene bank accessions. Around 7000 accessions

Fig. 1.1. Terrace rice fields in Phek district of Nagaland

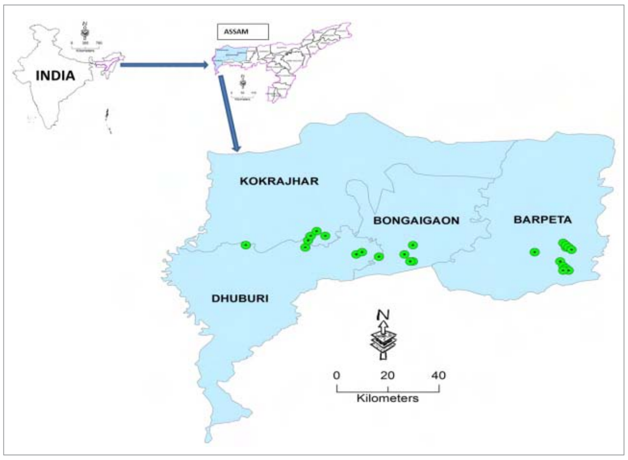


Fig. 1.2. Collection of sites in four districts of Assam

were rejuvenated in the field for seed increase and seed supply to different researchers all over the country.

Characterization of the germplasm for agro-morphological traits & molecular aspects

Agro-morphological characterization

A total of 6171 accessions of rice germplasm were grown which include 700 farmers' varieties of Odisha for characterization on agro-morphological traits. All the 30 morphological observation data on 19 qualitative characters and 11 quantitative characters were recorded at appropriate stages of crop growth and maturity as per the descriptors.

Molecular characterization and diversity analysis of 48 landraces collected from different regions of India

A total of 48 rice landraces collected from Assam, Odisha, Kerala, Manipur, Chhattisgarh, UP and WB along with two varieties were characterized using STMS markers. Out of 54 STMS markers tested, 45 markers produced polymorphism among 50 genotypes (Fig. 1.3). The amplicons were observed in the range of 70 to 380bp. The highest and lowest amplicon size was found in RM21522 (70bp) and RM26969 (380bp) respectively. The maximum PIC value (0.499) was observed with the marker RM171 while RM 27015 showed the minimum value of 0.041. RM297, RM27534 markers showed unique alleles in Annapurna and Saathi, respectively.

For the genetic similarities analysis, 54 SSR markers were used to construct a dendrogram by using UPGMA method of pooled SSR profile led to the segregation of the 50 rice genotypes into several clusters by discriminating all the genotypes examined (Fig. 1.4). Interestingly,

Table 1.1. Variability observed for quantitative traits in farmers varieties of Odisha

Sl. No.	Character	Mean±S.E	Range	C.V. (%)
1.	Plant height (cm)	156.4±0.74	86.6-196.78 (AC34294-AC21726)	12.34
2.	Leaf length (cm)	37.24±0.31	20.2– 61.67 (AC 21445-AC21218)	21.28
3.	Leaf width (cm)	1.28±0.01	0.82-2.02 (AC 34232-AC21679)	15.89
4.	Days to 50% flowering	108.00+0.33	91-120 (AC 35078 - AC 35082)	7.99
5.	No. of Effective tillers	8.80±0.08	4.2-18.8 (AC 33421 -AC21579)	24.96
6.	Panicle length (cm)	23.95±0.09	16.83-30.33 (AC34338-AC35688)	9.62
7.	100 grain weight (gm)	2.67±0.01	0.96-3.13 (AC36455-AC34392)	13.81
8.	Fertility (%)	69.67±0.57	17.82-93.74 (AC-34276-AC34304)	20.43
9.	Grain yield (gm/plant)	24.92±0.52	6.08-92.39 (AC43360-AC36466)	54.20
10	Maturity duration (days)	108.56±0.51	71.0-146.0 (AC35642-AC35329)	12.20

Saathi, a landrace of UP was completely diversed from all 49 genotypes used in this study.

Documentation, conservation of the rice genetic resources and seed supply to researchers

Two sets of 6518 accessions of rice germplasm were conserved at NRRI in MTS. Four thousand seven hundred and eighty-one accessions of rice germplasm/elite lines /donors / varieties were supplied to researchers for their utilization. Out of 4781 accessions, 1359 accessions were shared with different institutes/ organizations throughout the country with proper signing of Material Transfer Agreement (MTA). Five hundred ninety-seven accessions of rice germplasm/ breeding lines were acquired from International Rice Research Institute, Philippines and Institute of Biological & Environmental Science, United Kingdom for collaborative research.

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

Nucleus seed and breeder seed production

Panicle progeny rows of 47 varieties were grown for maintenance breeding. After thorough rouging, true to the type panicles were collected for nucleus seed production. A total of 14.61q nucleus seed of 47 varieties were produced (Table 1.2). The nucleus seed

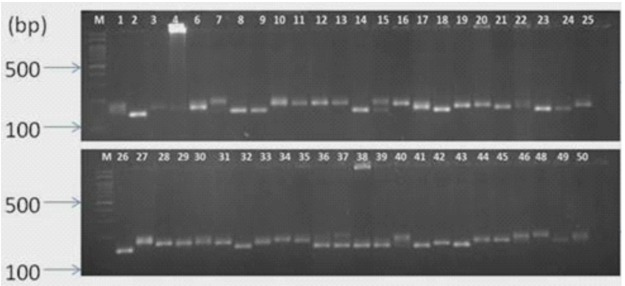


Fig. 1.3. STMS profile of 50 rice genotypes amplified with RM18360

was used to produce breeder seed as per DAC indent. A total of 554.99 q of breeder seed consisting of 46 varieties and 9 parental lines were produced (Table 1.3).

Participatory Seed Production

Under NSP, farmer's participatory seed production was undertaken with Mahanga Krushak Vikash Manch (Goudagop), Mahatma Gandhi Farmer's Club (Kendrapara) and Achyutananda Farmer's Producer Company Ltd (Kendrapara). Four popular varieties (Pooja, Sarala, Gayatri and Swarna *Sub 1*) were produced in 3 villages under the supervision of NRRI Scientists. A total of 905.00 q seed qualified the TL seed standard and were procured back for sale to farmers.

Identification of QTLs/Candidate genes associated with seed vigour

A set of 216 lines were phenotyped and genotyped for seed vigour traits. The seed vigour was tested using 5

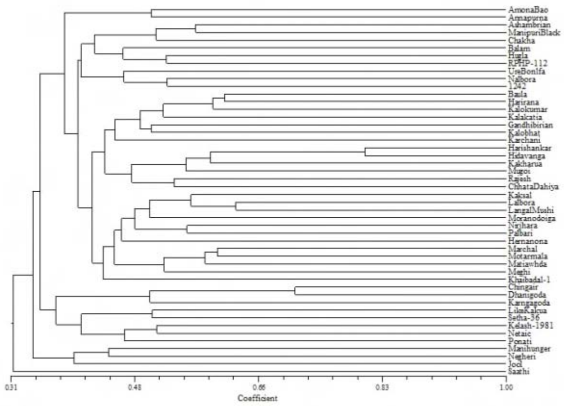


Fig. 1.4. Dendrogram depicting genetic relationship based on Jaccards' similarity matrix derived from 54 SSR markers among 50 rice genotypes

different methods suggested by ISTA and DAC. The evaluation was done in 4 sets of seed each. Only 4 lines *viz.*, IRGC-11486-1, IRGC-26413-1, IRGC-28995-1 and IRGC-45992-1 were high in seed vigour across the methods. Association between genotypes and phenotypes were performed and several QTLs/candidate genes were identified across different chromosomes. Validations of putative QTLs/candidate genes are under progress.

Traits associated with seed vigour in rice

120 diverse rice genotypes were phenotyped based on 25 physical and physiological traits to identify the traits associated with seed vigour. Among physical traits, seed vigour index (germination value x seedling length) was found significantly positively correlated with seed breadth, thickness, l/b ratio and seed thickness. However, among physiological traits high correlation was observed between germination percentage (r^2 =0.68) and seed vigour index.

Identification of CR Dhan 312 by CVRC

CR Dhan 312 (CR 3808-13, IET 25997), a selection from male sterility facilitated recurrent selection population was identified (Fig. 1.5) for irrigated areas of Chhattisgarh and Maharashtra under medium duration by Variety Identification Committee. It produces medium slender grains, 280-300 panicles per m^2 with 105-110 days to 50% floweirng, moderate tillering (8-10), compact panicles with test weight of 21.8 g. This is moderately resistant to leaf blast, neck blast and rice tungro virus. The genotype has high response to fertilizer application, good hulling and milling quality with white kernels, medium slender grains, no chalkiness and possesses desirable alkali spreading value.

Wide hybridization for developing pre-breeding lines and mapping population

In order to develop pre-breeding lines, back cross hybridization was carried out between F_1s of elite genotypes (Swarna, CR Dhan 307 and identified donors for resistance to sheath blight like CR 1014, Tetep, Jasmine 85 and two accessions of *O. rufipogon* (AC 100444 and AC 100015), for brown plant hopper two accessions of *O. rufipogon* (AC 100005, AC 100034) and yellow stem borer *O. brachyantha* derived line (B2-11) and recipient parents. In order to develop mapping population for sheath blight and BPH resistance, backcrosses were made between F_1s of susceptible (BPH: TN1; Sheath blight: Annapurna) and resistant donors {BPH: O. *rufipogon* (AC 100005, AC 100034), Sheath blight: *O. rufipogon* (AC 100444, AC 100015)} and recipient parents (Fig. 1.6).

Cross transferrable molecular marker resources for *Oryza coarctata* in relation to *Oryza sativa* complex

Among the 25 species available in genus-*Oryza*, *O. coarctata* is unique with respect to its habitat. Seventy-nine markers were identified which are cross transferable between *O. coarctata* and all the other eight species of *Oryza sativa* complex (Fig. 1.7). These markers were validated and were clearly differentiated into two different genomes. A subset of hyper variable SSR markers from this set was used for characterization of salinity susceptible and resistant panels and dendrogram was constructed (Fig. 1.8). Besides pre-breeding, the identified markers will also be helpful for germplasm characterization and population structure analysis.

Fig. 1.5. CR Dhan 312 (CR 3808-13, IET 25997)

Table 1.2. Nucleus Seed Production

Sl. No.	Variety name	Nucleus seed produced
1.	Annada	20
2.	Binadhan-12	55
3.	Ciherung Sub 1	25
4.	CR 1009 Sub 1	27
5.	CR 1014	6
6.	CR Boro Dhan 2	8
7.	CR Dhan 10	6
8.	CR Dhan 201	75
9.	CR Dhan 300	10
10.	CR Dhan 303	45
11.	CR Dhan 304	60
12.	CR Dhan 307	110
13.	CR Dhan 310	18
14.	CR Dhan 401 (Reeta)	25
15.	CR Dhan 405	15
16.	CR Dhan 500	85
17.	CR Dhan 501	11
18.	CR Dhan 505	10
19.	CR Dhan 601	16
20.	CR Sugandh Dhan 907	6
21.	CR Sugandh Dhan-3	10
22.	Dharitri	20
23.	Durga	2
24.	Gayatri	32
25.	Geetanjali	14
26.	Improved Lalat	5
27.	Ketakijoha	6
28.	Khitish	24
29.	Luna Sampad	12
30.	Luna Suvarna	13
31.	Moti	3
32.	Naveen	56
33.	Nua Chinikamini	4
34.	Nua Kalajeera	4
35.	Padmini	5
36.	Phalguni	6
37.	Pooja	112
38.	Poorna Bhog	2
39.	Ranjit	12
40.	Ratna	3
41.	Sahbhagidhan	15
42.	Sarala	38
43.	Savitri	30
44.	Shatabdi	96
45.	Swarna Sub 1	275
46.	Utkalprava	3
47.	Varshadhan	26
	Total	**1461**

Table 1.3. Breeder Seed Production

Sl. No.	Variety	*Rabi* 2017-18	*kharif* 2018	Total
1	Annada	28.30	-	28.30
2	CR Boro dhan 2	0.70	-	0.70
3	CR Dhan 201	17.30	-	17.30
4	CR Dhan 203	95.00	-	95.00
5	CR Dhan 300	0.50	-	0.50
6	CR Dhan 303	8.00	-	8.00
7	CR Dhan 304	4.30	-	4.30
8	CR Dhan 305	0.20	-	0.20
9	CR Dhan 307	1.90	-	1.90
10	CR Dhan 311	0.20	-	0.20
11	CR Dhan 502	0.10	-	0.10
12	CR Dhan 601	1.20	-	1.20
13	Geetanjali	1.85	-	1.85
14	Khitish	15.55	-	15.55
15	Luna Sankhi	0.50	-	0.50
16	Naveen	20.00	-	20.00
17	Phalguni	0.50	-	0.50
18	Ratna	0.20	-	0.20
19	Sahbhagidhan	0.30	-	0.30
20	Shatabdi	19.10	-	19.10
21	CR 1009 *Sub 1*	-	9.90	9.90
22	CR 1014	-	0.40	0.40
23	CR Dhan 310	-	2.10	2.10
24	CR Dhan 407	-	1.35	1.35
25	CR Dhan 500	-	35.40	35.40
26	CR Dhan 501	-	3.30	3.30
27	CR Dhan 800 (Swarna –MAS)	-	0.60	0.60
28	CR Dhan 907	-	0.75	0.75
29	CR Dhan 910	-	0.10	0.10
30	CR Sugandh Dhan-3	-	1.50	1.50
31	Dharitri	-	2.85	2.85
32	Gayatri	-	11.40	11.40
33	Ketakijoha	-	2.10	2.10
34	Luna Sampad	-	1.50	1.50
35	Luna Suvarna	-	1.95	1.95
36	Nua Chinikamini	-	0.60	0.60
37	Nua Kalajeera	-	1.20	1.20
38	Padmini	-	0.45	0.45
39	Pooja	-	75.60	75.60
40	Poorna Bhog	-	0.02	0.02
41	Ranjit	-	6.60	6.60
42	Sambha Mahsuri *Sub 1*	-	7.50	7.50
43	Sarala	-	19.50	19.50
44	Savitri	-	10.20	10.20
45	Swarna *Sub 1*	-	128.40	128.40
46	Varshadhan	-	11.10	11.10
47	Ajay 'A'line	-	0.67	0.67
48	Ajay 'B'line	-	0.20	0.20
49	Ajay 'R'line	-	0.20	0.20
50	Rajalaxmi 'A' line	-	0.55	0.55
51	Rajalaxmi 'B' line	-	0.20	0.20
52	Rajalaxmi 'R' line	-	0.20	0.20
53	CR Dhan 701 'A' line	-	0.50	0.50
54	CR Dhan 701 'B' line	-	0.20	0.20
55	CR Dhan 701 'R' line	-	0.20	0.20
	Total	**215.70**	**339.29**	**554.99**

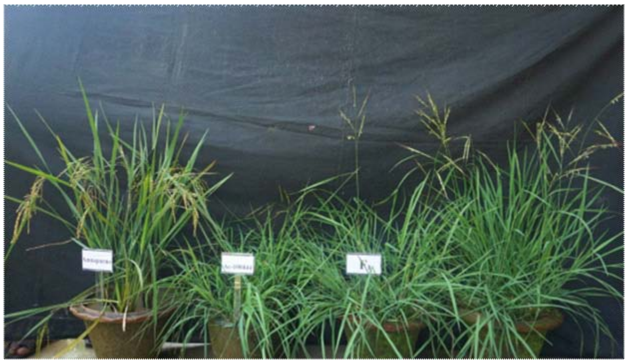


Fig. 1.6. Parents and interspecific hybrid of Annapurna x *O. rufipogon* (AC 100444)

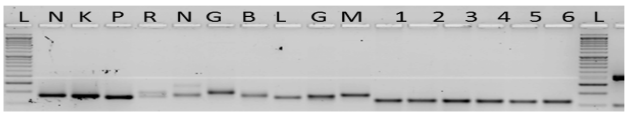


Fig. 1.7. Marker profiling involving members of *O. sativa complex* and *O. coarctata L. Marker, N-Nipponbare , K-Kasalath, P- Pokkali R- O. rufipogon, N- O. nivara, Gl-O. glaberrima, B- O. barthii, G- O. glumaepatula , M- O. meridionalis; 1-6: O. coarctata* accessions.

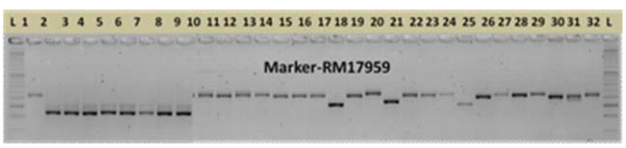


Fig. 1.8. Marker profiling involving salinity susceptible and resistant genotypes of *O. sativa* and *O. coarctata.* 1-NIPPONBARE, 2-9 (O. coarctata accessions) 2-C-1(2271), 3-C-2(2273), 4-C-3(2275), 5-C-4(2277), 6- 6-C-5(2278), 7-C-6(2279), 8-C-7(2280), 9 -C-8(2280), 10-Raspahnjar, 11-Nonabokra, 12-Luna Suvarna, 13-Talamagara, 14-Pokkali, 15-Bhalukai, 16-Luna Barial, 17- FL-478, 18-Pantara, 19- SR-26 B, 20- Pokkali EA, 21-Kamini, 22- IR-8, 23-Gayatri, 24-Pusa 44, 25-Kasalath, 26- IR 20, 27-Jaya, 28-Naveen, 29- IR 29, 30-IR 64, 31-Sahbhagidhan, 32-Swarna *Sub1*.

Generation advancement and selection of promising materials having good grain yield and bacterial blight resistance

Out of 100 improved lines developed for bacterial blight resistance involving popular rice varieties of north east India (CAU-R1, Shahsarang, Lampnah, Ranjit, PD 10 and VL 82) and Odisha (Naveen and Pooja) from eight cross combinations, sixteen promising lines performing better than the recurrent/donor parent were identified. Some of these lines have been nominated for AICRIP testing under DSN during 2019.

Genetic improvement of rice for enhancing input use efficiency

Identification of QTLs for seedling vigour under low N condition

A mapping panel consisting of 288 rice landraces and improved lines from upland/direct seeded ecology were used to identify QTLs for seedling vigour under low nitrogen. They were raised during *rabi* 2018 and *kharif* 2018 under dry direct aerobic condition with two replications. Several traits related to early seedling vigour were observed and growth rate (absolute, crop and relative) was estimated between two intervals. The observed data on different traits were subjected to GWAS with SNP of 288 lines. Two major candidate genes were identified related to nitrogen and root parameters. The most significant SNP id24666944 with probability of P=0.00000002656371504, on chromosome 2 was identified. The id24666944 is found to be associated with locus LOC_Os02g40710 and LOC_Os02g40730 of ammonium transporter protein, which is having the minimum allele frequency (MAF) of 0.07308. Absolute growth rate of shoots is presented in the Manhattan plot (Fig. 1.9). Similarly, GWAS was performed for absolute growth rate of root. GRAS transcription factor was identified at LOC_Os01g45860 on chromosome 1, involved in root branching having response to gibberellin.

Identification of candidate genes for root traits under low P and moisture deficiency condition

Another mapping panel of 260 lines were screened under low P (11.5 kg/ha) under acidic pH 5.3. A strong association (r= > 0.8) was found between root

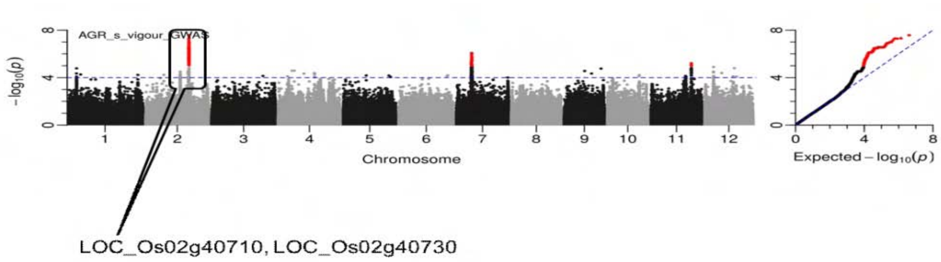


Fig. 1.9. Manhattan and QQ plot from GWA mapping of absolute growth rate of shoot

dry weight and shoot dry weight. Among the genotypes studied, Jhona349 and CN2-175-5-31 were found to have better root system than Dular at low P. GWAS was executed for root length; total root length and root dry weight. Several important locus like phosphatase (LOC_Os03g17940), NB-ARC domain (LOC_Os08g14830), AMP-binding domain (LOC_Os08g14760) and aquaporin proteins (LOC_Os04g47220) were identified and found to be significant (-log10(0.0001).

Deep root has great role on improving water use efficiency and survival rate under moisture deficient condition. Here, 260 rice landraces of upland and improved lines were screened in a contained environment during dry season 2018. One month after sowing, watering was withheld to increase the moisture deficient condition and to induce root elongation. Leaf rolling was observed in most genotypes at maximum stress (-65 kpa). Then the plants were uprooted and root traits were recorded. A strong relationship (r= > 0.8) was found between root dry weight, shoot length and number of roots at base. Further, GWAS was executed to identify candidate genes responsible for root elongation during moisture stress condition. The GWAS analysis has identified two transcription factors (LOC_Os08g36740 and LOC_Os08g36790), glycoprotein 3-alpha-L-fucosyltransferase A involved in cell wall synthesis (LOC_Os08g36840) and gibberellin receptor GID1L2 (LOC_Os08g37010.1, LOC_Os08g37030.1, LOC_Os08g37040.1, LOC_Os08g37050.1, LOC_Os08g37060.1) on chromosome 8 involved in root elongation without shoot elongation with probability of 0.00000009615803191 (Fig. 1.10).

Genetic improvement of rice for aroma, nutrition and grain quality

Development of aromatic, high yielding, disease resistant genotypes with short/long slender grains

Purification of *Gobindbhog*

Gobindbhog, a popular aromatic short grain (ASG) landrace of high commercial value of West Bengal was purified into four sorts following panicle progeny method. The purified sorts were characterized morphologically and using molecular markers which could establish their distinctness (Fig. 1.11).

Evaluation of aromatic breeding lines

Performance of advanced lines under station trial

Seventeen advanced breeding lines along with two aromatic check varieties were evaluated. CR 3662-12-

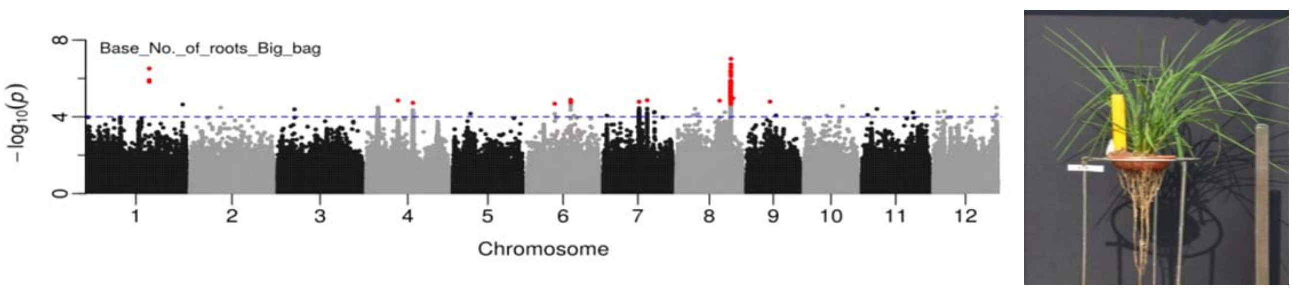
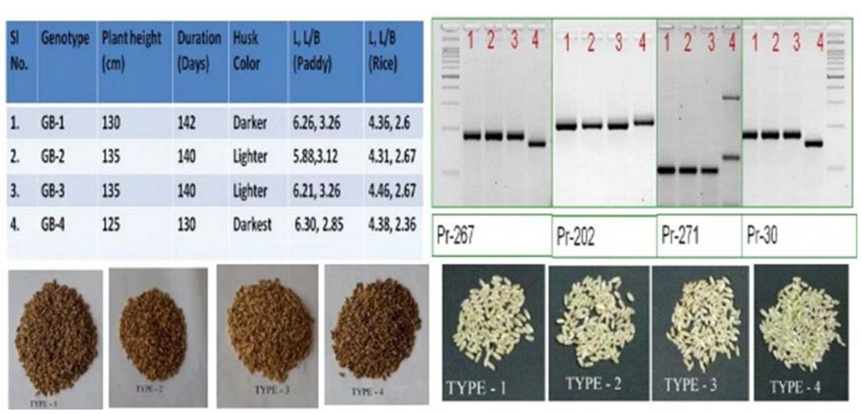


Fig. 1.10. Manhattan plot from GWAS mapping of no. of roots at base



Sl No.	Genotype	Plant height (cm)	Duration (Days)	Husk Color	L, L/B (Paddy)	L, L/B (Rice)
1.	GB-1	130	142	Darker	6.26, 3.26	4.36, 2.6
2.	GB-2	135	140	Lighter	5.88,3.12	4.31, 2.67
3.	GB-3	135	140	Lighter	6.21, 3.26	4.46, 2.67
4.	GB-4	125	130	Darkest	6.30, 2.85	4.38, 2.36

Fig. 1.11. Variation at morphological and molecular level in *Gobindbhog*

7-5 (Swarna/ Katrani) performed the best with an average yield of 5.45 t/ha over best check variety Sobhini (4.56 t/ha).

Nomination of cultures for national testing and evaluation under AICRIP trials

Four promising ASG cultures, CR 2981-16-2-6, CR 3663-261-8-4, CR 3715-119-18-9-2 and CR 2982-14-6-3 were nominated for IVT ASG trial and one culture, CR 2948-8-4-16 was nominated for IVT MS trial sunder AICRIP. One hundred and thirty-six nominations from different centers were evaluated under seven trials and performance was reported.

Seed multiplication of elite genotypes and demonstration of released varieties

The cultures nominated for AICRIP along with 10 NRRI developed ASG varieties were demonstrated and 125 ASG germplasm were multiplied for conservation in gene bank.

Development of high yielding genotypes with higher grain zinc and/ or protein content

Fifty breeding lines with higher nutrient content were developed following the bulk pedigree method.

Evaluation of breeding lines under AICRIP

Swarna derived breeding lines were evaluated under Biofortification programme of AICRIP-2018. CR2830-PLS-17 and CR2830-PLS-48 reported grain protein content (GPC) of 9.66% with an average yield of more than 5 t/ha. CR2830-PLS-17 was evaluated to be tolerant to stem borer and CR2830-PLS-48 showed a lower Glycemic index. Another line CR2830-PLS-30 reported 9.67% GPC with average yield of 5.4 t/ha and was found to be promising.

Evaluation of breeding lines in farmers' field

The performance of CR2830-PLS-17 was evaluated along with Swarna, Swarna *Sub1* and the high protein varieties, CR Dhan 310 & CR Dhan 311 in eight farmers' fields at six different locations of Odisha namely, Sankilo, Nischintkoili, Gopalpur, Chandol, Gaghaga and Baliantha. CR2830-PLS-17 consistently outperformed the other varieties giving yield advantage with higher protein.

Fig. 1.12. Field demonstration of CR Dhan 310 and CR Dhan 311

Popularization of nutrient-rich rice through Demonstration

The demonstration of high protein rice CR Dhan 310 and CR Dhan 311 was successfully conducted in farmers' field at Kendapara, Cuttack, Jagatsinghpur, Boudh, Bolangir and Kandamal of Odisha state (Fig. 1.12).

Variety in seed chain

Breeder seed indent was received from Jharkhand and Assam for 7.5q and 35q, respectively of CR Dhan 310 through their respective state departments. This is estimated to benefit more than 1.8 lakh farmers by 2020 by growing the high protein rice.

Breeding for specialty traits in rice grains with special emphasis on pigmentation

Screening the variability for antioxidants

A set of 277 rice genotypes were evaluated for total anthocyanin content, γ-oryzanols, total phenolic content, total flavonoids and 2,2-diphenyl 2-picrylhydrazyl (DPPH) antioxidant activity. Antioxidant content was found to be highly correlated with total flavonoids and phenolics content while anthocyanin content was highly correlated with γ-oryzanols. The genotypes, IRGC34996-1, IRGC29022-1, IRGC29315-1, IRGC12166-1 and DZ-78 were found promising for higher antioxidant content.

MoU signed for purification of Chakhao

One MoU was signed for purification of Chakhao, a pigmented landrace from Manipur being popularized by Green Foundation, Imphal.

Genetic studies on quality traits

QTLs for protein content

Three QTLs expressing stable across environments were identified in a BC_3F_4 mapping population developed from a biparental cross between ARC10075 and Naveen. Among the three QTLs identified, one is for grain protein content (*qGPC1.1*) and the other two for single grain protein content (*qSGPC2.1, qSGPC7.1*) that could explain 13%, 14%

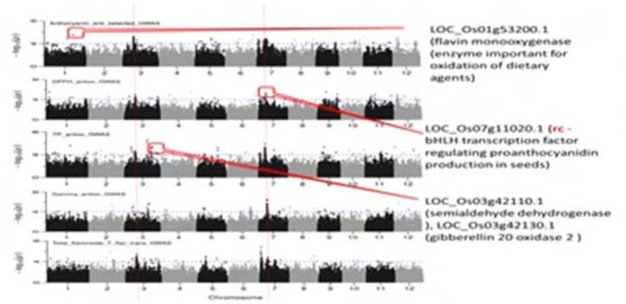


Fig. 1.13. Manhattan plots from GWA mapping of anthocyanin and related traits of coloured rice

and 7.8% of phenotypic variation for the trait, respectively.

QTLs for anthocyanin and related traits

Genome wide association study (GWAS) was undertaken using a panel of 288 genotypes representing variability. The study could identify LOC_Os07g11020.1 on chromosome 7 regulating proanthocyanidin and LOC_Os01g53200.1on chromosome1 to be associated with the synthesis of flavin monooxygenase (Fig. 1.13). The enzyme is found to play important role in oxidation of dietary agents and toxicants.

Breeding climate resilient genotypes for rainfed shallow lowland ecology

The climate-smart variety, CR Dhan 801 has been notified in the Gazette, Department of Agriculture and Co-operation, Ministry of Agriculture for cultivation in Odisha, West Bengal, Telengana, Andhra Pradesh and Uttar Pradesh. Another climate-smart variety, Subhas (CR Dhan 802; IET 25673; CR3925-22-7) has also been notified for cultivation in Bihar and Madhya Pradesh for rainfed shallow lowland ecology. Both CR Dhan 801 and Subhas are developed in the background of 'Swarna' variety possessing abiotic stress tolerance traits like submergence and drought and biotic stresses like stem borer (both dead heart and white ear heads), leaf folder, plant hopper and case worm while moderately resistant to bacterial blight, sheath rot and rice tungro virus. CR Dhan 801 and CR Dhan 802 are short bold grains, have good hulling, milling and head rice recovery like the recipient parent. Besides, they also contain intermediate amylose content and other desirable grain quality parameters.

CR3825-1-2-1-2-1-1 (IET-26952) nominated in the year 2017 to AICRIP trial was promoted to 3rd year of testing under late trial. Another entry in semi-deep trial was also promoted to 3rd year of testing showing promise in the region III of the country. CR 2667-5-1-2-1-1 (IET-25912) was promoted to AVT1 late trial. Three shallow lowland entries, CR4041-1-2-1-1-1 (IET 26696), CR3985-3-2-1-1(IET 26726) and CR3825-1-2-1-2-1-1 (IET-26952) were promoted to 2nd year of testing. Another 15 entries showing more than 6 t/ha under station trial were nominated to AICRIP trial for 1st year trial under lowland ecology.

For breeding climate smart varieties, stacking of gene/QTLs viz., *Sub1*+Xa21+xa13+xa5+qDTY1.1+ qDTY2.1+qDTY3.1 in Swarna background was initiated during 2017-18. During 2018, molecular screening was performed for confirmation of presence of homozygous gene combination in Swarna derived lines containing submergence tolerance and bacterial blight resistance. The derived lines *viz.*, CR4050-121-28-13-1, CR4050-121-28-13-2, CR4050-121-28-13-3, CR4050-121-28-13-4 and CR4050-121-28-13-5 (*Sub1*+Xa21+xa13+xa5) were screened for Xa21, xa13, Xa5 using primers pTA248, Xa13NF (prom), RM122, Xa5 (multiplex) while for *Sub1* using A203, RM8300, *Sub1*BC2 and *Sub1*C173. Two lines were hybridized with CR Dhan 801 and F_1 generation seeds were generated containing *Sub1* + DTY1.1 + qDTY2.1 + qDTY3.1 + Xa21 + xa13 + xa5 genes/QTLs. Through classical breeding approach, 135 single plant progenies from 31 cross combinations were selected and advanced to F_6 generation.

Genetic improvement of rice for multiple stress tolerance in unfavourable rainfed ecology

Selection of breeding materials suitable for semi-deep water conditions and evaluation of elite lines

Two hundred and seventy-two single plant selections were made on the basis of plant and panicle characters from 294 single plant progenies (F_4-F_8) derived from 29 crosses. Among 40 improved genotypes including five check varieties; CR 2582-3-35-2-1-1-2 performed best with an average yield of 5.51 t/ha followed by CR 2582-3-35-2-1-1-1 (5.48 t/ha), CR 2582-3-35-2-1-1-3 (5.36 t/ha) against the best check variety Jalamani (4.20 t/ha). Two AICRIP trials, IVT-SDW and AVT 1-SDW were conducted. Entry No. 607 performed best with an average yield of 3.90 t/ha followed by Entry No. 605 with 3.74 t/ha in IVT and Entry No. 501 performed best with an average grain yield of 3.59 t/ha followed by Entry No. 506 with 3.45 t/ha in AVT. CR Dhan 511 (IET 23906) was notified for cultivation in semi-deep water ecology in West Bengal and Andhra Pradesh. One entry, IET 25912 (CR 2667-5-1-2-1-1) was promoted to AVT-2 and two entries (IET 27574 and IET 27578) were promoted to AVT-1 SDW. Another 10 entries were nominated in AICRIP trial for 2019.

Development of mapping population for identification of 21 days submergence tolerant gene (s) and anaerobic germination (AG) ability

Three weeks submergence tolerant rice germplasm 'AC 20431B' was used to develop RIL population (F_6) and one backcross derived mapping population (BC_2F_2) from Swarna-*Sub1*/AC 20431B cross. With the aim of developing anaerobic germination tolerance in the background of Swarna *Sub1*, it was crossed with anaerobic germination donor BCP-59 and AC 1303-B and F_3s were evaluated in Rabi 2019.

Characterization of *Sub1*loci in 21 days submergence tolerant rice genotype, AC20431B and cloning of *Sub1* gene specific guide RNA for CRISPR/Cas9 mediated gene editing

To edit the *Sub1A* gene in AC 20431B, sequence of *Sub1A* gene was retrieved from Rice genome annotation database and BLASTP analysis which showed 100% similarity with a protein against rice reference protein database. CRISPR/Cas9 genome editing tool was used for the designing of primers for *Sub1A* editing. Hence, the guide RNA specific for *Sub1A* gene was designed for editing the *Sub1A* tolerant allele in AC 20431B through CRISPR/Cas9 approach. The secondary PCR confirmed the amplification of 650 bp guide RNA specific for the *Sub1A* gene and cloned in pGEMT easy vector followed by binary vector for Agrobacterium mediated transformation of AC 20431B. Simultaneously, the callus culture of AC 20431B showed high callus percentage (90%) with Azucena (100%) callus induction.

Advancement of mapping population for salt and water logging tolerance and identification and validation of QTLs and linked markers

Mapping population (RIL) from crosses Swarna/Rahspunjar and Savitri/Pokkali (AC 39416a) were developed. Rahspunjar and AC 39416a and Luna Suvarna are tolerant to salinity, water logging and germination stress oxygen deficiency. Phenotyping under control and water logging condition (50 cm depth) of RIL population derived from Savitri/AC 39416a revealed normal distribution of component traits. To detect robust QTLs across environments and background identification of introgression lines, backcross derived (BC_1F_4) mapping population were developed. The donors were used for developing BC_1F_1 seeds from seven cross combinations. CSR 27, AC 41585, Binadhan 10, Patnai are tolerant to moderately tolerant to salinity stress at reproductive stage. They were used to harvest BC_1F_1 seeds for developing seven backcross derived mapping population for multi-environment and multi-background QTL detection.

Development and evaluation of elite lines with abiotic stress tolerance for coastal saline areas

Populations derived from crosses involving salt, submergence, water logging and salinity tolerance donors are in F_3- F_5 generation. Evaluation of 25 such lines was conducted under normal condition (NRRI, Cuttack) and coastal saline (Ersama, Jagatsingpur, Chilika and Khorda) condition in *kharif* 2018. The salinity level (EC) at Ersama was from 4.33 to 7.57 dSm-1 and water depth was from 5 to 40 cm, whereas at Chilika EC was from 3.5 to 7.2 dSm-1 and water depth was from 10 to 30 cm. The lines performed well as compared to checks, Luna Suvarna and Rahspunjar under normal (4.2- 7.5 t/ha) and saline stress situation (3.0- 4.6 t/ha) were IET 27841, IET 27852, IET 27051, IET 27060 and CR-2856-S-1-1-3-21-1-2. Three AICRIP Trials, CSTVT- IVT, CSTVT-AVT-1 and CSTVT-AVT-NIL were conducted in *kharif* 2018 at coastal saline area at Ersama. The highest yielding entries were Entry no. 2332 with yield of 3117 kg/ha in IVT, entry number 2203 with yield of 1586 kg/ha in AVT and Entry no. 4712 with yield of 3002 kg/ha in AVT- NIL-CSTVT. Two lines, IET 27851 (CR 3903-161-1-3-2) and IET 27852 (CR 2851-S-1-6-2B-4-1) were promoted to AVT-1 CSTVT for the second year of testing in AICRIP. IET 27051 (CR 2851-S-1-B-4-1-4-1-1) had the highest average grain yield (4.5 t/ha) in AVT-1 trial and would be repeated. A total of thirty-two disomic wide cross derivatives of *O. brachyantha* (AC 100499), *O. rufipogon* (AC 100166) and *O. longistaminata* (AC 110404) were evaluated in saline and water logging condition at Ersama. The promising entries were CR3993-12-4, CR3993-17-5, CR3993-12-2-1, CR 4211-4, etc. Among evaluated lines, IR 84649-81-4-B-B-CR 3397-S-4B-1-5 (IET 27045) yielded 2.05 t/ha at Srikakulam in Andhra Pradesh under multiple stresses condition and was found to be the best. An experiment was conducted in the farmer's field with moderate salinity (EC= 4 dSm-1) at Ersama during the wet season. Two salt tolerant rice varieties (Luna Barial and Luna Suvarna), three cultures, one susceptible check (Gayatri) and two local varieties (Rahspunjar and Pauli) were tested for their yield potential under recommended management practices. Results revealed that CR 3900-1-135-8-5-4 and CR 3879-3-1-6-1-3-1 exhibited highest grain yield of 3.45 and 3.40 t/ha, respectively which were significantly higher than Gayatri and local checks.

Harnessing heterosis for enhancing yield and quality of rice

Source nursery

Altogether 1127 diverse parental genotypes were maintained, out of which 226 were screened for presence of restorer (*Rf*) genes and were utilized in crossing programme.

Identification of maintainer, restorer and new hybrid combinations

A total 1034 test crosses involving 11 CMS (CRMS 31A, CRMS 32A, PMS 17A, APMS 6A, PUSA 5A, PUSA 6A, IR 79156A, IR 58025A, IR 80555A, APMS 6A, RTN 12A) were evaluated and 23 genotypes were identified as promising maintainers and 24 as effective and good restorers (> 85% fertility restoration). Besides, 372 new test crosses were generated which will be evaluated in Rabi, 2019.

Development of new CMS lines

CRMS 56A (Kalinga-1), a medium-late duration CMS developed under nucleus background of DH 79 (CRMS32B/RTN12B) having large dual stigma exertion and >40% out-crossing might be useful in development of late duration hybrids with substantial seed producibility.

Table 1.4. Morphological data of CMS lines evaluated during *kharif*, 2018

CMS Line	DFF	Ht (cm)	PN	PE%	GT	PS%	OC%
CRMS31A	100	85	9	65	LS	100	32
CRMS32A	103	88	12	62	LS	100	30
PMS 17A	108	89	18	66	LS	100	26
CRMS 56A*	110	95	8.5	68	LS	100	45

DFF=Days to 50% flowering, HT= plant height; PN=Panicle number; PE=Panicle exsertion; GT= grain type; PS=pollen sterility; OC=Out-crossing; *= promising CMS lines Besides, sixty-two (BC_2-BC_9, and 6 new crosses) sterile crosses were advanced in backcross generation, some of those with stable sterility and enhanced out-crossing are listed in Table 1.5.

Table 1.5. Promising sterile back-crosses advanced during 2018-19

Sl. No.	BCN No.	Recurrent parent	Source of cytoplasm	Remarks
1	BCN9199A	CR2234-1020 (WA)	WA	Good floret opening
2	BCN9200A	CR2234-1020	Kalinga-I	Good floret opening
3	BCN799A	A-180-12-1(87)	WA	Short duration, drought tolerant
4	BCN9180A	CR 2234-834(WA)	WA	Good floret opening and stigma exsertion
5	BCN7140A	IR 68301-11-64-3-6-6	Kalinga-I	Complete panicle emergence
6	BCN6853A	CR 25B-244B-440	WA	Floret opening and purple stigma exsertion
7	BCN6862A	31B-GP-18	WA	CRMS 31B Gene pyramid with 4 BLB genes
8	BCN5863A	32B-GP- 39	Kalinga-I	CRMS 32B Gene pyramid with 4 BLB genes
9	BCN4275A	CRMP1-07-1010	WA	Good floret opening, mid late

10	BCN4276A	CRMP1-07-1010	Kalinga-I	Good floret opening, mid late
11	BCN4278A	Kuderat-2	WA	Medium duration
12	BCN4279A	Kuderat-2	Kalinga-I	Medium duration
13	BCN4346A	CR-172	WA	Late duration
14	BCN3121A	CRRP 1	WA	One time more floret opening
15	BCN2118A	CRHR-330-1	WA	Complete panicle emergence
16	BCN2582A	CR 25B-32B-337	WA	Floret opening and stigma exsertion
17	BCN3583A	CR 25B-32B-337	Kalinga-I	Floret opening and stigma exsertion
18	BCN3591A	CR 1071-C18-1840	WA	Floret opening and stigma exsertion
19	BCN3592A	CR 1071-C18-1840	Kalinga-I	Floret opening and stigma exsertion

Parental Line Improvement

Trait development in CMS and restorer lines

In order to make hybrids more substantial and sustainable, MABC based trait development strategies for grain yield, quality besides biotic and abiotic stresses have been adopted. Pyramiding of BB resistant genes (*Xa4*, *xa5*, *xa13* and *Xa21*) in CRL 22R are advanced to BC_2F_1; salinity and submergence tolerance in restorer of Ajay and Rajalaxmi were advanced to BC_2F_1. Introgression of *Wx* gene in CRMS 32B, IR 42266-29-3R were advanced to BC_1F_1. Crosses of CR2711-76 (BPH donor) and improved-IR42266-29-3R have been advanced to BC_1F_1.

The super rice genotype, TR-128 (Gn1a, SCM2; based on Gn1a Indel 3 and SCM 39K pro) was used as donor for the introgression of grain yield attributing traits into male parent of Rajalaxmi. Besides, stigma exsertion trait in CRMS 31A and CRMS 32A from *O. longistaminata* was advanced to BC_3F_2. Partial restorers, Akshaydhan, Azucena (BC_3F_3), INH 10001 and NP 801(BC_2F_4) were bio-fortified with fertility restorer genes, *Rf3* and *Rf4*.

Restorer and maintainer breeding

Total 2715 single plant progenies (F_3 to F_{11} generations) from 114 crosses (AxR, RxR and BxB) were evaluated in pedigree nursery, out of these 22 were selected for station trials and 10 lines were used in crossing programme. Besides, four random mating maintainer populations and two restorer populations (each with 5 parental components) were advanced to 8^{th} random mating generations and two *inter-subspecific* MAGIC populations (B and R; each with 10 parental genotypes).

Development of Iso-cytorestorer

A total of 121 iso-cytorestorers of 8 hybrids were developed and utilized in crossing programme. Nine out of 35 test-crosses out yielded (1.67 to 15.18 % heterosis) CRHR32 whereas CRMS 32A/MP351 (33.08 g/plant) followed by CRMS 31A/MP351 (32.4 g/per plant) recorded 15.18% and 12.81%, respectively, yield superiority over hybrid CRHR 32 (28.72g/plant).

Seed production of hybrids

Truthfully labeled (TL) seeds of twenty-four hybrids including three released, Rajalaxmi (70.0 kg), Ajay (95.0 kg) and CR Dhan 701 (67.0 kg) was produced besides, breeder seeds of CMS, CRMS 31A (117.0 kg) and CRMS 32A (55.0 kg); and nucleus seeds of parents of three hybrids.

New promising hybrid combinations

One late duration hybrid, CRHR 113 (IET 26976) was promoted to AVT-1Late trials. Notably, nine new hybrids, CRHR 111 (IVT-L), CRHR 112 (IVT-L), CRHR 143 (IVT-L); CRHR 119 (IHRT-MS), CRHR 145 (IHRT-MS); CRHR 123 (IHRT-ME), CRHR 124 (IHRT-ME); CRHR 126 (IHRT-M), CRHR 127 (IHRT-M) were nominated to AICRP, 2018.

DNA fingerprinting of parent/hybrid

DNA fingerprints of 4 CMS (CRMS 53A, CRMS54A, CRMS55A and CRMS 56A) and 2 hybrids, CRHR102 and CRHR 103 were developed utilizing 36 hyper-variable STMS markers.

Evaluation of AICRIP trials

Three hybrid rice trials, 34 test entries under IHRT-ME were conducted., IHRT-ME-20 (PHI-18107) recorded highest yield of 6715.00 kg/ha followed by entry IHRT-M-27 (PHI 18105) with 6698.00 kg/ha. IHRT-M was constituted with 22 test entries where PHI-18103 recorded highest yield of 7040.00 kg/ha followed by entry US 364 with 6703.00 kg/ha. In IHRT-MS, total16 test entries were tested where RRX-502 recorded highest yield of 6641.0 kg/ha followed by WGL-14 (NCV-1) with 6624.0 kg/ha.

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

Release of CR Dhan 602

The elite line CR 3724-1 (IET 25692) was identified by VIC for release in *boro* situation of Assam and Tripura as CR Dhan 602**.** The average yield is 5.79 t/ha and potential yield of 9.4 t/ha. The maturity duration is 154-163 days with semi-dwarf plant type (101-104.5cm). It is non-lodging type and possesses long slender grains besides having moderately resistance to leaf blast and other insect pests.

Similarly, three entries were promoted to AVT 2, *viz.*, CR4113-3-2-1 (IET 27263), CR3969-24-1-2-1-10-1-5 (IET 26418) and CR3856-44-22-2-1-10-1-5 (IET 26420) in mid duration group; three to AVT 1, *viz.*, CR 3856-44-22-2-1-9-1(IET 27267) (IME), IET 27267 (IET 27640) (Late), CR-3938-6-2-1-1-1-1-2 (IET 27623) (Late) in national level testing of AICRIP.

Fig. 1.14. CR Dhan 602 in dough stage

Evaluation of elite cultures for NGR related to grain yield

New Generation Rice (NGR) targets breaking yield ceiling mostly in favourable ecology. About 500 genotypes including released varieties and land races were evaluated for yield and yield attributing traits. Some of the genotypes were performed exceedingly well for the key agronomic traits as below:

a. Panicle length (>30.0cm): Nua Dhusara, Sonnamani, Basmati-564, Pusa Sugandha-3, Ranbir Basmati, Pravathi

b. Tiller number (>15): Dhanalaxmi, Ratnagiri-73, Karjat 4, Ratnagiri-5, Bhagirathi, Gayatri, PR114, Savitri, Pusa Bas.1121, CO-41, CO-43

c. Panicle weight (>5.0g): R-mahasuri, Mahalaxmi, Matangini, Golak, Jogen, Purnendu, Uphar, Pusa Sugandh -5, Mandakini, Dandi,Padmanath

d. Grain number (> 300): Kanchan, R-Mahsuri, RTN-24, Pavitra, WGL-32100, Mahanadi

Similarly, several genotypes were identified resistant for major diseases and pests at molecular level (SNP genotyping). Variety PR 123 was having Xa4, xa5, xa13, Xa21 genes along with good plant type and non-lodging character. Similarly, others with Xa4, xa5, Xa21 and some with Pita, Pi 54, Non- chalky type 5 along with high grain No. (>300) were identified.

Genetic improvement of rice with novel NGR for grain quality and biotic stress tolerance

About 168 fixed lines in PYT, 92 in AYT1 and 16 in AYT2 were tested under station trial along with checks *viz.*, Swarna, Naveen, MTU 1010 and IR 64. Out of those 15, 4 and 10 genotypes performed well compared to checks in respective trials. Few genotypes with superior NGR component traits were found fixed in advance generation selection. Most of the NGR cultures were having shy tillering and broad and droopy leaves, whereas these plant types were more towards ideal plant traits with high leaf density and stiff straw and lodging resistant along with moderately high tiller (7.4-12.0), very high grain yield per plant (Table 1.6)

Targeted trait improvement in available NGR cultures

One NGR genotype previously identified as superior CR 3856-44-22-2-1-11-5 (SR 1-3-1) was tested for multi locational trial (MLT) in 6 different districts of Odisha in 2017 and repeated in 2018. It gave maximum of

Table 1.6. NGR Advanced lines

Genotype	Per Plant Yield(g)	Tiller	Grain wt/ Panicle (g)	No of Grains	No of Chaffs	1000 grain wt(g)
SRB 2-1	79.75	8.5	4.68	146	62	29.45
SRB 5-2	60.86	8	4.29	147	65	21.77
SRB 7-2	66.53	8.5	7.83	182	27	18.54
SRB 7-1	64.94	9.1	5.24	131	46	26.59
SRB 5-1	61.24	9.6	4.39	167	39	18.27
SRB 5-2	60.87	8.5	4.825	167	60	21.77
SRB 5-8	60.84	10.1	4.27	155	57	20.79
SRB 2-4	60.62	7.4	6.06	201	55	25.1
SRB 2-3	57.23	12	4.77	165	42	21.91
SRB 1-1	57.11	9.2	6.21	129	48	24.12

SRB symbolizes for Designation CR 3856-44-22-2-1-11-4

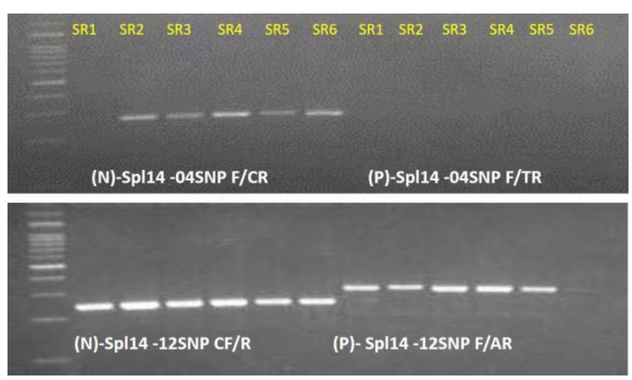
63.9% higher productivity. It could yield 48.8-80.6 q/ha, with potential grain yield of 80 q/ha. This culture was introgressed with BLB resistance (*Xa21*, *xa13* and *xa5*) and submergence tolerance (*Sub1*). The back crosses with different gene combinations were found to be submergence tolerant in large plot phenotyping.

Favourable Upland

A PYT was conducted under rainfed DSR and transplanting conditions involving 36 advanced breeding lines of 2 crosses (CR Dhan 40 x CG425 and CR Dhan 40 x NPT PSR 12) and 4 check varieties *viz.*, Abhishek, Sadabahar, Sahbhagidhan and IR 64 Drt in alpha lattice design with 3 replications at Hazaribagh. Under DSR, CRR789-22 produced significantly higher yield (1.03 t/ha) than the check Abhishek (0.57 t/ha). Altogether, 8 entries (CR Dhan 40 x NPT PSR 12) were recorded with higher yield > 0.57 t/ha. Under transplanting, Sahbhagidhan produced the highest yield (4.08 t/ha). However, 6 entries produced higher yield than the rest of the checks (>3.5 t/ha).

Screening of functional *OsSPL14* gene in NGR

Six highly promising NGR lines i.e. SR18-7-1, SR14-5-1, SR6-1-1, SR1-5-1, SR 395-3-2-1 and SR1-3-1 were screened for functional *OsSPL14* gene associated positively with the panicle branching and negatively with the number of tillers. Two functional SNP markers are reported for this gene; one in the promoter region (Slp14-04SNP F/CR) and the other in the coding region (SPL14-12SNP A/C). The analysis revealed the presence of inferior allele at promoter region; Slp14-04SNP (C) and both inferior and superior alleles in the coding region; SPL14-12SNP (A/C) (Fig. 1.16 & 1.17). Slp14-04SNP (C) is considered inferior as this locus facilitates methylation of the promoter region, thereby either partially or completely silencing the SPL14 gene.



NGR Genotypes
SR1: SR18-7-1
SR2: SR14-5-1
SR3: SR6-1-1
SR4: SR1-5-1
SR5: SR 395-3-2-1
SR6: SR1-3-1

Fig. 1.15. Genotyping for *OsSPL14* gene in NGR Genotypes

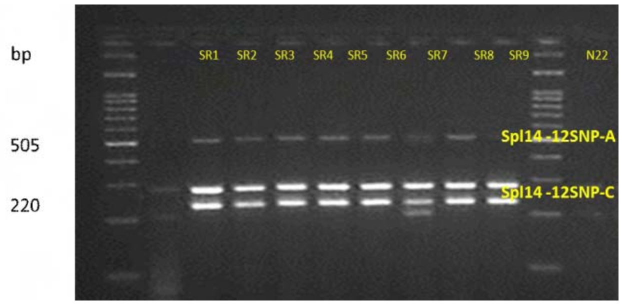


Fig. 1.16. CAPS marker analysis of SPL14-12SNP locus in NGR Genotypes

Biotechnological Strategies for genetic Improvement of Rice

Increasing the androgenic potential in hybrids by manipulation of chemical factors

Attempt was made to enhance the callus response for androgenesis by manipulating the chemical factors from which histone deacetylase inhibitors along with growth hormones were found potent in increasing callus response upto ~ 80% in rice hybrids such as Arize Tez Gold and Rajalaxmi (Fig. 1.17).

Performances of Double Haploids

Upon agronomic evaluation of 50 DHs derived from F1s of Chakhao x IR20, 3 DHs (MBR5, MBR7 and MBR8) were identified showing IR20 type phenotype with black pigmented grains (Fig. 1.18, Table 1.7).

Normal medium HDA inhibitor added medium

Fig. 1.17. Callusing response of anther culture in Arize Tez Gold rice hybrid

Evaluation of DH lines

Under preliminary evaluation, 92 out of 315 DHs (developed from 27P63) were identified based on morpho-agronomic characters; out of which, 12 promising DHs were evaluated in replicated trial. The highest yield (7080.0 kg/ha) was recorded in M-104 followed by M-41-2 (5790.0 kg/ha) and M-104-2 (5680.0 kg/ha) against the parent hybrid, 27P63 (7100.0 kg/ha).

Table 1.7. Agronomic characteristics of DH lines

DHs	Plant Height (cm)	No. of Tillers	Panicle Length (cm)	No. of Grains	Spikelet Fertility (%)	Test Weight (g)
MBR5	128	28	25.9	187	56.68	21.1
MBR7	130	27	25.0	131	69.46	23.8
MBR8	127	26	26.5	120	68.33	24.5

Fig. 1.18. Androgenesis to agronomic characters of DHs from Chakhao x IR20

Besides, ten medium duration doubled haploid lines of CRHR 32 (Y-2-5, Y-2-1, Y-3-2, Y-1-1, Y-6-1, Y-9-1) and BS 6444G (PA80-2, PA139-4, PA27-1, PA66-3) were also evaluated. Highest yield was recorded in Y-2-5 (7010.0kg/ha) followed by Y-2-1 (6370.0kg/ha) and the derivatives of BS6444G, PA 139-4, PA27-1 showed the yield of 6080.0 kg/ha and 6330.0kg/ha, respectively.

Evaluation of *in vitro* raised mutants from Shaktiman for glyphosate tolerance

The efficiency of the *in vitro* mutation approach was studied using variety, Shaktiman for development of glyphosate tolerance in rice. The 45 days and 60 days old M1 mutants were sprayed with 2, 4, 6 ml/l glyphosate from which 45 days old plants were found comparatively more tolerant as against of 60 days old ones; the control plants were killed after seven days of glyphosate treatment (Fig. 1.19).

Estimation of protein content in selected DH lines

A total of 73 DH lines derived from a quality rice hybrid 27P63, were evaluated for protein content which ranged from 7.16% to 12.01%. The highest protein content (12.01%) was found in M-129-1 while lowest (7.16%) was in M-113-3 (Fig. 1.20).

Identification of Differentially Expressed Genes (DEGs) for sheath blight resistance using RNA-Seq data

A set of differentially expressed genes (DEGs) for sheath blight resistance has been identified using public domain RNA-seq data. Details of DEGs are depicted in fig 1.22. A candidate blast resistance gene, Os04g0303900 (chr01:38310587-38313631) was selected from rice line Tetep for functional analysis of sheath blight resistance.

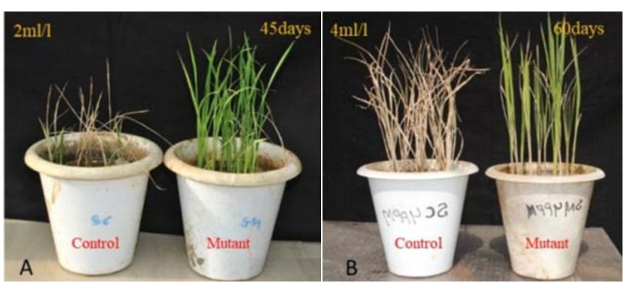


Fig. 1.19. Glyphosate treated 45 and 60 days old *in vitro* raised mutants derived from Shaktiman showing tolerance

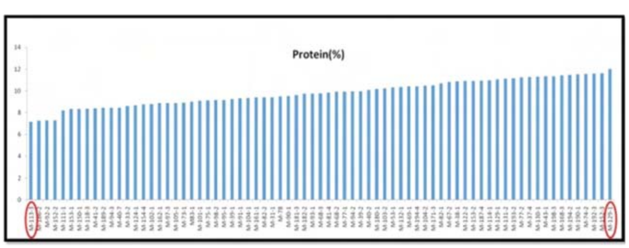


Fig. 1.20. Protein content in 73 DH lines derived from rice hybrid 27P63

CRSIPR-Cas9 based editing of *IPA1*, *Sc* gene and identification of efficient *indica* cultivar (HKR-127) for higher transformation frequency

Guide RNA targeting third exon the IPA1 (Ideal Plant Architecture 1) regulating number of spikelets and first exon of Sc gene regulating hybrid fertility in *indica* and *japonica* hybrids was cloned and mobilized into binary vector by golden gate assay. Then, IPA1-gRNA-Cas9 and Sc-gRNA-Cas9 vector were mobilized into callus via Agrobacterium in cultivars HKR-127, N22 and CRMS32B, respectively. Further, hygromycin selected calli of HKR-127 for *IPA1* showed green shoot regeneration of putative transformants. Additionally, genotypic variation in transformation efficiency was tested where *indica* cultivar, HKR-127 showed higher transformation efficiency of about 80-90% as compared to other tested rice varieties such as N22, Naveen, Swarna, and HKR-127 (Table 1.8, Fig. 1.22).

Development of Genomic Resources for Rice Improvement

Fine mapping of QTLs associated with BPH resistance Salkathi

Mapping population consisting 300 F_3 lines developed from the cross TN1 and Salkathi (BPH resistant) were screened and corresponding F_2 lines were genotyped with flanking SNP markers for QTLs associated with BPH resistance in Salkathi. Linkage analysis confirmed the presence of 3 QTLs. Insilco analysis led to the identification of 15 candidate genes associated with BPH resistance. Further expression analysis is being undertaken to confirm the candidate genes.

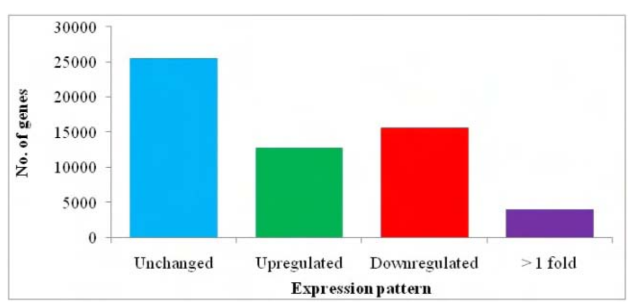


Fig. 1.21. Identification of differentially expressed genes (DEGs) during rice- ShB interaction

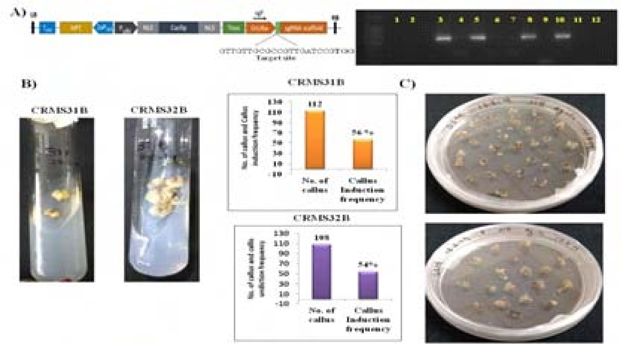


Fig. 1.22.a: Sc gene transformation in CRMS31B and CRMS32B. A) Cloning of Sc specific Cas9 vector using golden gate assay and colony PCR, B) Callus induction frequency of CRMS31B and CRMS32B, C) Selection of transformed calli of 31B in hygromycin selection medium

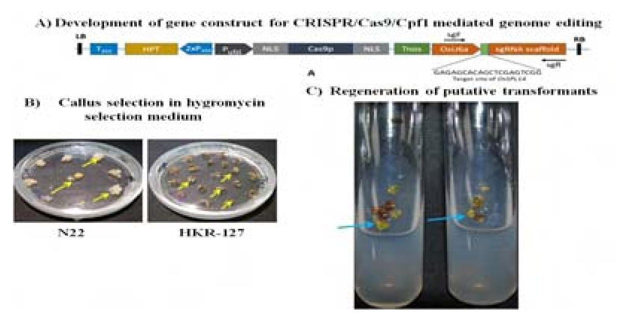


Fig.1.22. b: IPA1-gRNA-Cas9 for improving number of spikelets per panicle in N22 and HKR-127. A) Cloning of IPA1-gRNA-Cas9 vector for transformation, B) Selection of callus in hygromycin containing medium for the cultivars N22 and HKR-127, C) Regeneration of hygromycin resistant callus in regeneration medium

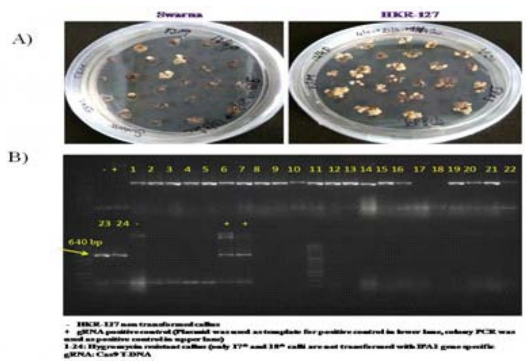


Fig. 1.22.c: Response of indica cultivars to Agrobacterium mediated transformation. A) Hygromycin resistant calli of Swarna and HKR-127, B) PCR analysis of hygromycin resistant calli using guide RNA specific Pps-Pgs primers

Cultivar	No. of seeds inoculated	Callus induction %	No. of microcalli	No. of hygromy-cin resistant calli
Swarna	220	209 (95%)	225	25
HKR-127	220	215 (98%)	280	213

Table 1.8. Hygromycin resistant callus observed in the transformation experiments

Fig 1.22. CRISPR-Cas9 based gene editing in *IPA1* and Sc genes

Association mapping to identify genes/ QTLs associated with seedling vigour

A mini core diversity panel consisting of 96 genotypes were evaluated for different seedling vigour traits including biochemical traits at 6 days, 14 days and 28 days after germination (Table 1.9, Table 1.10). Based on the performances over three seasons *viz.*, wet season 2017, dry season 2018, wet season 2018, three best genotypes, ARC6101, IR 93341:13-B-2-21-21-1RGA-2RGA-1-B-B and IR 93351:9-B-6-5-10-1RGA-2RGA-1-B-B were identified for development of biparental mapping population. Subsequently, the association mapping panel will be genotyped with early seedling vigour linked SSR and SNP markers to identify the QTLs associated with seedling vigour.

Gene prospecting and allele mining for tolerance to heat stress

Favourable allele validation for heat stress tolerance

Seventy-nine rice varieties were genotyped with 9 markers associated with heat stress tolerance. Association analysis indicated that RM242 could reduce the spikelet sterility significantly by 6%. Further, 36 rice varieties showed heat susceptibility index. The validated marker RM242 can be effectively used for improving the genetic tolerance of rice varieties to heat stress.

Allele mining of *PIF4*

Phytochrome Interacting Factor 4 (*PIF4*) plays a central role in regulating the temperature, photoperiod and abiotic stress response in rice. 11 non-synonymous substitutions and 121 SNPs were identified in the coding region of the *PIF4* gene in different rice ecotypes. Allele mining of *PIF4* gene using sequence data of 3K genotypes led to the identification of 12 haplotypes. Two *aus* specific haplotypes were identified which may be responsible for heat tolerance and needs validation.

Allelic pattern of selected RILs of the cross NDR359 x N22 for five heat stress QTLs

Table 1.9. Performance of mini core collection for early seedling vigour under direct seeded condition at 14 and 28 days after germination

Genotypes	14 DAS			28 DAS				RGR (g/g/day)	AGR (cm/day)	CGR (m2)
	Shoot length	Leaf no.	Shoot wt(g)	Shoot length	Leaf no.	Tiller no.	Shoot wt(g)			
Tapaswini x Dular (68)	13.79	2.50	0.012	33.53	5.95	1.35	0.150	0.178	1.410	0.328
Tapaswini x Dular (4)	9.56	2.47	0.009	25.02	6.42	1.30	0.134	0.195	1.104	0.299
Tapaswini x Dular (21)	10.71	2.35	0.011	20.87	7.71	1.90	0.129	0.175	0.725	0.279
ARC6101	10.69	2.10	0.011	28.88	5.35	1.35	0.124	0.173	1.299	0.269
Tapaswini x Dular (43)	12.59	2.45	0.012	28.58	5.65	1.30	0.123	0.168	1.142	0.266
IR 93341:13-B-2-21-21-1RGA-2RGA-1-B-B	5.83	1.83	0.004	24.70	4.00	1.00	0.113	0.232	1.348	0.259
IR 93351:9-B-6-5-10-1RGA-2RGA-1-B-B	7.34	2.40	0.007	22.00	7.00	1.30	0.109	0.198	1.048	0.242
ARC11566	9.24	2.20	0.007	28.62	5.40	1.25	0.106	0.191	1.385	0.236
Tapaswini x Dular (37)	10.83	2.55	0.008	23.14	5.47	1.25	0.106	0.184	0.879	0.232
ARC11211	10.37	2.25	0.008	28.51	5.00	1.05	0.103	0.182	1.296	0.226
Mean	**10.09**	**2.31**	**0.009**	**26.38**	**5.79**	**1.31**	**0.120**	**0.134**	**0.663**	**0.127**
SD	**2.31**	**0.22**	**0.003**	**3.89**	**1.05**	**0.24**	**0.015**	**0.038**	**0.327**	**0.070**
CD5%	**0.45**	**0.04**	**0.001**	**0.77**	**0.21**	**0.05**	**0.003**	**0.007**	**0.064**	**0.014**

The recombinant inbred line populations of the cross NDR359 and N22 were evaluated for the allelic pattern for five reported heat stress tolerance QTLs, qHTSF*1.1*, *qSSIY 3.1*, *qHTSF4.1*, *qSSIY5.1* and *qSTIPSS9.1*. Three lines were identified consisting of N22 alleles either in homozygous/heterozygous condition for the heat stress QTLs. RILs with N22 allele for *qHTSF4.1* reduced the spikelet sterility by 5% as compared to the NDR359 allele. However, the N22 allele of *qSSIY 3.1* reduced around 27 spikelets per panicle without altering the spikelet sterility response.

Table 1.10. Range of distribution for seedling vigor and biochemical traits at 6 days after germination under in vivo condition in 96 genotypes

Traits	Min	Max	Mean	SD	Variance	Skewness	Kurtosis
Seedling vigour traits							
Shoot length(cm)	1.59	7.85	4.37	1.19	1.41	0.20	0.65
Root length(cm)	0.49	8.87	3.42	1.57	2.47	0.56	0.67
Fresh weight(mg) (S+R)	0.00	408.60	172.79	71.30	5083.13	0.51	0.57
Dry weight(mg)(S+R)	9.90	98.50	39.78	16.63	276.45	1.16	1.74
Biochemical traits							
Total Amylase Activity (soluble starch mg/10 min)	0.10	0.33	0.18	0.06	0.00	0.48	-0.42
Alpha Amylase Activity (mg/20 min.)	0.19	0.59	0.36	0.10	0.01	0.19	-1.04
Reducing sugar(mg)	0.28	1.71	0.82	0.35	0.13	0.32	-0.84

PROGRAMME : 2

Enhancing Productivity, Sustainability and Resilience of Rice Based Production System

Enhancing the sustainability of rice production depends upon resource use efficiency which is based on three major components such as technical, allocative and environmental efficiencies. Though, India achieved a record rice production in last couple of years, however, resource use efficiency is still low down. Sustainability, productivity and profitability of rice system related to environment are the budding issues which need to be tackled. In order to deal with the above mentioned issues, a planned programme was made with the aim to develop, validate and disseminate environment friendly technologies to enhance productivity, profitability and sustainability of rice production system.

The main objectives of the programme are to (i) enhance nutrient and water use efficiency in rice by technological intervention (ii) increase productivity and profitability of rice based cropping and farming system with site specific weed management (iii) economic or environmental friendly utilization of soil, water, nutrient and rice residues by resource conservation technologies and microbial intervention (iv) develop, refine and validate small scale farm implements for small and marginal farmers, and (v) harness microbial resources for alleviating abiotic and biotic stresses in improving soil health.

Nutrient management for enhancing productivity and nutrient use efficiency in rice

Critical nitrogen dilution curve (Nc) cultivars under different agro-ecological situations

Critical N (Nc) dilution curves of rice variety Naveen and IR 64 were developed for Cuttack and Hazaribagh locations using a power function equation according to Greenwood *et al*. (1990): $Nc = aW^{-b}$, where, W is above ground plant biomass (t ha^{-1}), Nc is N concentration (%) in above ground plant, a is positive constant i.e. N concentration in the leaf when W = 1 t ha^{-1} and b is the statistical parameter (slope of the relationship) (Table 2.1). The Nc curves can be used to calculate NNI (Nitrogen nutrition index) for determining N deficiency/sufficiency during the growth period.

Source-sink relationship in contrasting N responsive varieties

Six rice varieties of contrasting N efficiency (Naveen, Indira, Ratna, Surendra, Birupa and Daya) were grown with graded dose of N (0, 40, 60, 80, 100, and 150 kg ha^{-1}) to compare N use efficiency, N uptake and distribution pattern. The yield response to applied N was fitted to quadratic equation $y=-ax^2+bx+c$, where y is yield (t ha^{-1}) and x is N applied in kg ha^{-1}, intercept (c) and slopes of curve at different N level (Table 2.2). According to N response, varieties can be grouped as efficient at low N (Naveen, Birupa), responder to high N (Indira) and efficient at low N & responder to high N (Surendra).

Effect of ZnO NP (Zinc oxide nano particle) on rice

Effect of ZnO NP on growth, uptake of Zinc and productivity of rice was studied in a pot culture experiment with IR 36 and Ratna. ZnO NP showed significant positive effect on chlorophyll content and root length. The highest grain yield (24.50 g pot^{-1}) was recorded when ZnO NP was applied at recommended dose (5 kg Zn ha^{-1}).

Effect of seed priming and nutrient management on anaerobic germination of rice

Submergence at germination stage (standing water depth of 8 cm till 28 days) was experimented with two contrasting cultivars (IR64 and IR64-AG) in combination of treatments for seed priming (Pr0: control, Pr1: 1% $CaCl_2$, Pr2:1.5% KH_2PO_4) and nutrient management (N0: RDF and N1: RDF+Ca). It was found that priming with 1.5% KH_2PO_4 and RDF+Ca improved anaerobic germination potential under prolonged submergence stress at germination stage, which was evident from enhanced germination percentage, germination rate and hypocotyl elongation and reduced mean germination time, particularly in non-AG genotype. Priming improved periodic availability of non-structural carbohydrates as a result of increased α-amylase activity in both AG and non-AG cultivars (Fig. 2.1).

Evaluation of rice varieties for phosphorus use efficiency

The experiment was conducted with four graded doses of P (P0: control; P1: 20 kg P ha^{-1}; P2: 40 kg P ha^{-1}and P3: 60 kg P ha^{-1}) and 12 varieties, namely IR-64, Gayatri, Pooja, Sarala, Padmini, CR-1014 (*kharif* 2017); CR Dhan 310, Abhishek, Rajalaxmi, Sahbhagidhan (*kharif* 2018); IR-36, Kasalath. Increase in application of P significantly increased the number of tillers and panicles, grain/panicle, length of the panicle in P3 compared to P0, which has significantly contributing towards increase in yield. Agronomic and recovery efficiency was found higher in Gayatri, while physiological efficiency was higher in Sarala.

Nutrient management for enhancing temperature stress tolerance

Experiment was conducted with rice cultivars Naveen and Lalat to evaluate the effect of nutrient management packages on high temperature stress tolerance with three dates of sowing (S1 - 30.12.2017; S2 - 09.01.2018; and S3 - 19.01.2018) in main plots and seven nutrient management treatments (T1 - Control with RDF; T2 - RDF + Boron (B); T3 - RDF + Silicon (Si); T4 - RDF + B + Si; T5 - RDF +25% additional K; T6: RDF + 25% additional K + B; T7: RDF + 25% additional K + B + Si) in sub plots design with three replications. The results revealed that grain yield of rice decreased by 8.5% and 14.8% with the late date of sowings S2 and S3, respectively as compared to S1. Combination of B+Si+K (T7) and B+K (T6) resulted in significantly higher grain yield than other treatments.

Agronomic practices for CR Dhan 311

Experiment was conducted in high protein rice variety CR Dhan 311 with three dates of planting (D1-15 days before normal transplanting, D2- normal transplanting and D3-15 days after normal transplanting) and four fertilizer levels i.e. F1- 100 % RDF + $ZnSO_4$ @25 kg ha^{-1} (N in 3 splits @ 1/3+1/3+1/3), F2- 100 % RFD of the location (N in 3 splits @ 1/2+1/4+1/4), F3-150 % of RFD of the location (N in 3 splits @ 1/3+1/3+1/3) , F4- 150 % of RFD +$ZnSO_4$ @ 25 kg ha^{-1} (N in 3 splits @1/2+1/4+1/4), F5- absolute control (no fertilizer). Results revealed that late planting date exhibited significantly highest grain yield over earlier planting dates. Among the nutrient management options the treatment F4- 150 % of RFD + Zn of the location (1/2+1/4+1/4) contributed significantly highest grain yield (5.14 t ha^{-1}) over all the other treatments. Performance of high protein rice variety CR Dhan 310 under different irrigation and nitrogen levels was also studied. Higher grain yield was observed with irrigation at saturated ± 5 cm (standing water) as compared to irrigation at hair line crack i.e., -40 K pascal. 100 kg N ha^{-1} gave significantly higher yield of 6.22 t ha^{-1} over 0, 60 and 150 kg N ha^{-1} but was at par with 80 and 120 kg N ha^{-1}.

Abundance of fluorescent pseudomonas, phoD and soxB under LTFE soil

The abundance of fluorescent pseudomonas, alkaline phosphatase (*phoD*) and sulfur oxidation (*soxB*) were analyzed under long-term fertilizer experiment though Illumina MiSeq and q-PCR. HPLC-based concentration of phloroglucinol (a specialized functional component of fluorescent pseudomonas) in LTFE soils was also observed to validate the abundance of fluorescent pseudomonas. Results indicated that continuous application of nitrogen alone over 49 years decreased the *Pseudomonas* OTUs, copy no. of fluorescent pseudomonas and phlorglucinol concentration compared to control, CONPK and C1NPK. Significantly higher copy no. *phoD* and *soxB* were observed in treatment NK with and without combination of FYM compared to other treatments.

Table 2.1. Parameters of critical N dilution curve ($N_c = aW^{-b}$) developed for Naveen and IR-64 at Cuttack and Hazaribagh

Parameters	Cuttack		Hazaribagh	
	Naveen	IR 64	Naveen	IR 64
a	1.67	2.21	1.77	1.74
b	0.233	0.27	1.18	1.19
r2	0.78	0.70	0.58	0.58

Table 2.2. Intercept and slopes of yield-N response curve ($y = -ax^2 + bx + c$) for different varieties

Varieties	Y Intercept (c)	Slope 1 (0- 60)	Slope 2 (60-90)	Slope 3 (90- 120)
Naveen	3	11.5	1.9	-7.7
Indira	2.3	18.2	9.4	0.6
Ratna	2.5	15.5	7.3	-0.9
Surendra	2.9	16.9	10.4	3.8
Birupa	3	17.2	7.3	-2.6
Daya	2.4	15	6.1	-2.9

Assessing energy and water footprints and increasing water productivity in rice based systems

Water vapour flux in tropical lowland rice at NRRI

An experiment was carried out to study the water vapour flux (FH_2O) in tropical low land rice-rice system using eddy covariance (EC) system installed at NRRI. FH_2O was measured using open-path infrared gas analyzer. Results showed that the FH_2O increased with advancement of crop growth and the highest value was recorded during maturity and the lowest during the vegetative stage (Fig. 2.2a). Variables minimum temperature (MiT), air temperature (Ta), soil temperature (Tg), evaporation (E), latent heat of vaporization (LE), FH2O, maximum temperature (MaT), net radiation (NR), photosynthatically active radiation (PAR), shortwave downwell radiation (SD) and shortwave upwell radiation (SU) were far from the centre. Hence, these factors were closely related (r close to 1). FH_2O was very close to LE, which indicated they were significantly and positively correlated. The variables long wave upwell (LU) and sensible heat (HS) are on the opposite side of the centre, therefore, they were significantly negatively correlated (r close to -1) (Fig. 2.2b).

Estimation of energy balance components over Mahanadi delta region

Moderate Resolution Imaging Spectroradiometer (MODIS) calibrated L1B product (MOD021KM) and its corresponding geolocation product MOD03 were used for estimating Land Surface Temperature (LST), total atmospheric water vapour content (W) and Normalised Difference Vegetation Index (NDVI) over the districts covering Mahanadi delta region in Odisha using Surface Energy Balance System (SEBS) Model. MODIS Bands 1, 2, 3, 4, 5, 6, 7, 17, 18, 19, 31 and 32 were used. The pixel data was aggregated for the

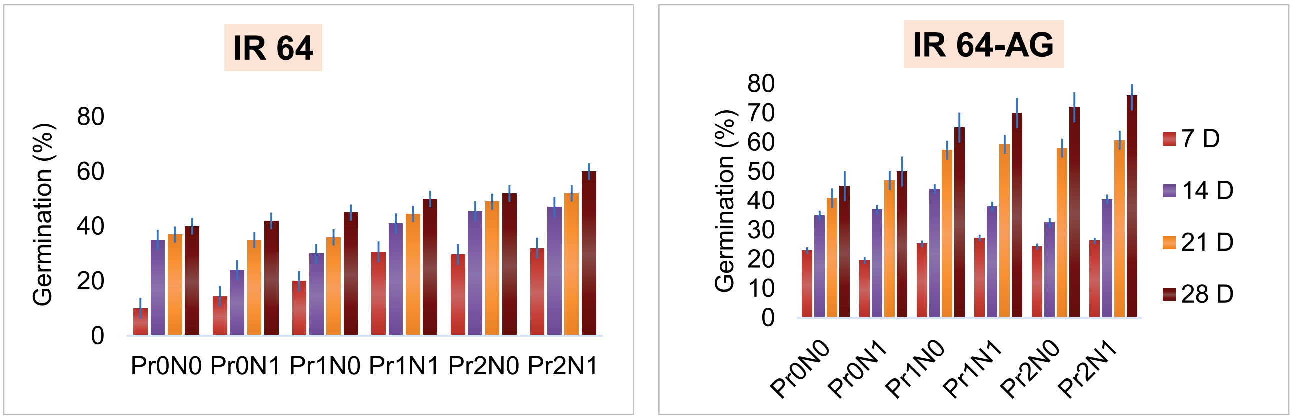


Fig. 2.1. Germination ability of AG and non-AG cultivars with effect of priming and nutrient treatments under prolonged submergence at germination stage

whole Mahanadi delta region and results showed that the maximum atmospheric water vapor content was 7.62 g cm^{-2}, whereas the minimum was 4.40 g cm^{-2} during 2017. Atmospheric water vapor content varied during different months of the year. NDVI also varied during different stages of the crop growing period in the study area and reached to a maximum of 0.66 during peak vegetative growth stage in *kharif* season (Fig. 2.3).

Ground Water Table Depth and flow direction of NRRI research farm

Piezometers and observation wells were installed at 150 m x 150 m grids locations in NRRI campus to observe the Ground Water Table Depth (GWTD) and Ground Water Flow Direction (GWFD). The contour map and flow pattern were prepared using Inverse Distance Weighted (IDW) interpolation and eight direction pour point formula (8DPPF) respectively. During beginning of January, only 5 % of the total observation points were showing groundwater table depth within 1 m from ground surface (GS), whereas 55% observation points were showing GTD between 1.1-1.5 m, 30 % observation points were having groundwater table depth between 1.51-2.0 m and 10% observation points were showing groundwater table depth >2 m, respectively from GS. The contour map of the GWTD from soil surface and the GWFD map for the month of January are shown in Fig. 2.4 and Fig. 2.5.

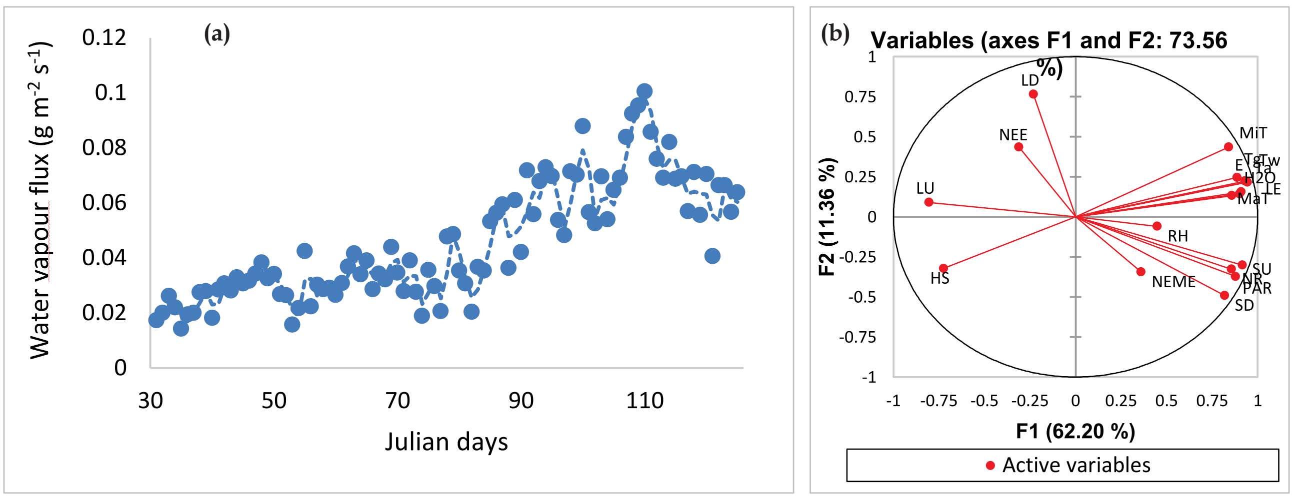


Fig. 2.2. Temporal variation of H_2O vapour flux of paddy field during dry season (a) variable factor map showing the relationship of water vapour flux with other variable (b)

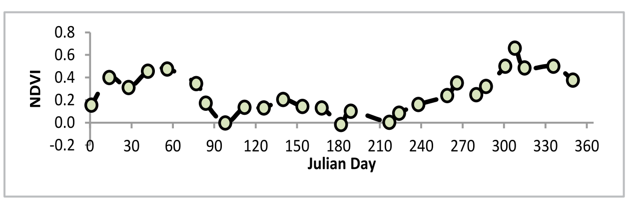


Fig. 2.3. Variation of Normalised Difference Vegetation Index (NDVI) during the year 2017 over Mahanadi delta region

Soil water potential based deficit irrigation in rice

A field experiment with split plot design with four rice varieties (Satyabhama, Annada, Ankit and Naveen) as sub plot and five irrigation schedules (main plot) was conducted based on tensiometric measurement of soil water potential (SWP). The irrigation treatments were (a) continuous flooded (Control); (b) alternate wet and drying (field capacity); (c) Water Deficit Stress (WDS) at active tillering stage; (d) WDS at heading stage; (e) WDS at grain filling stage. There was a decrease in total water input by 36-45% as compared to flooded condition (control). WDS during the reproductive stages did cause significant lowering of yield as compared to WDS at vegetative stage for all the varieties; however the yield decline was more for variety Naveen. Yield reduction for varieties like Satyabhama, Ankit and Annada under active tillering stress ranged from 9 to 14%, whereas under heading stage stress it ranged from 20-25% and under grain filling it was 25-29%. WDS at reproductive stage was not recoverable and care was taken to avoid such a situation. The decrease in grain yield was linked with the decrease in % spikelet fertility for different varieties under different WDS conditions (Fig. 2.6).

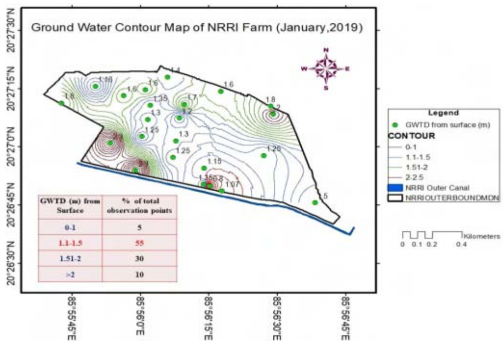


Fig. 2.4. Contour map of ground within water table depth in NRRI for January, 2019

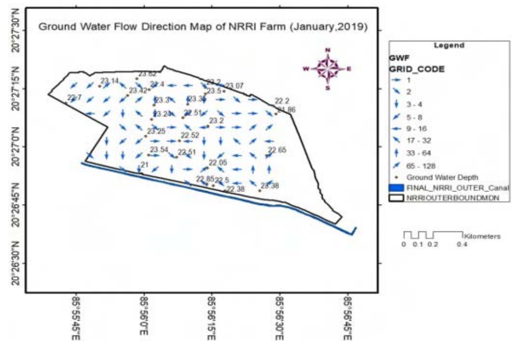


Fig 2.5. Ground water flow pattern NRRI campus for January, 2019

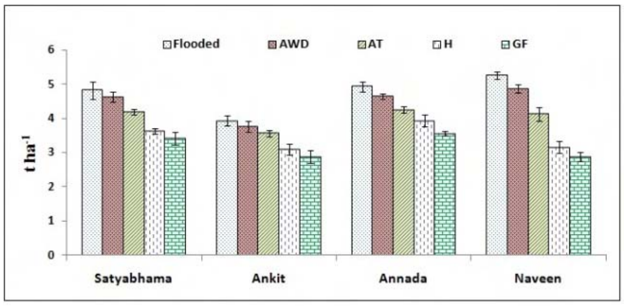


Fig. 2.6. Grain yield of different rice varieties exposed to water deficit stress at different growth stages. (AWD: alternate wet and dry, AT: active tillering, H: heading, GF: grain filling)

Climate projection for coastal Odisha plains using CMIP5 models

Temporal and spatial variations of maximum temperature (MaxT), minimum temperature (MinT) and precipitation (P) were projected over coastal districts of Odisha using Coupled Model Inter-comparison Project (CMIP5) models under Representative Concentration Pathways (RCP) 4.5 and 8.5 emission scenarios for the 21st century. The projections were made for three time slices (near-2011 to 2039, mid-2040-2069, late-2070-2099) compared to the baseline years (1980–2010). The annual mean P of Odisha coastal plains is projected to change by -1 to 1.5%, -3.3 to -0.6%, -3.8 to 0.1% (RCP4.5) and -1% to 4%, -1% to 2%, 3% to 12% (RCP 8.5) during near, mid and late century. Under RCP4.5 the MinT and MaxT is expected to increase by 0.6-0.7, 0.7-0.8, 1.2-1.4 °C and 0.5-0.6, 0.6-0.7, 1.3-1.5 °C, respectively during near, mid and late century. Similarly, under RCP8.5 the MinT and MaxT is expected to increase by 1.7-2.2, 1.6-2.0, 3.1-3.8°C and 1.7-1.9, 1.7-2.1, 3.0-3.4°C, respectively during near, mid and late century.

Agroecology-based intensification of rice based cropping system for enhancing productivity and profitability

Nutrient balance and carbon fractions in zero tilled rice – maize cropping system

A field experiment was carried out to study the effect of different nutrient management options on the rice-maize cropping system under conventional and zero tillage situations to develop conservation agriculture based nutrient management. It was laid out in a split-split plot design with two tillage systems i.e. conventional and zero tillage in main plots and three residue management system i.e. RDF + no residue, RDF + residue mulching (3 t ha^{-1}) and RDF + residue mulching (6 t ha^{-1}) to maize in subplots and two N levels to rice i.e. LCC based (75% RDN) and LCC based (100% RDN) replicated thrice. The variety Pooja (rice) and Super 36 (maize) were used in the experiment. The results indicated significantly lower grain yield (8.40 %) in zero tillage compared to conventional tillage but was at par in maize. Mulching with rice straw in maize significantly increased the maize yield and the residual effect increased the rice grain yield with rice straw mulching in maize. Maize and rice grain yield was increased by 10.8 and 16.2%, respectively with application of rice residue @ 6 t ha^{-1} as mulch in maize. System productivity in terms of rice equivalent yield of conservation tillage system was on par with that of conventional tillage in rice-maize cropping system but significantly higher with application of rice residue as mulch to maize and recommended dose of nitrogen to rice.

The partial factor productivity (PFP) of potassium was significantly higher in conventional tillage compared to zero tillage and increased with increase in quantity of residue and nitrogen levels in rice but did not differ significantly with tillage system in maize in rice - maize cropping system. Partial nutrient balance (PNB) of potassium decreased with increase in residue quantity applied as mulch but did not differ significantly with respect to tillage and nitrogen levels. PNB of potassium in the rice-maize cropping system decreased but PFP increased with residue quantity but did not differ with tillage and nitrogen levels. Zero tillage improved the total organic carbon as well as the labile carbon fractions of soil compared to conventional tillage after four cycles of rice-maize cropping system. Residue mulching in maize increased the carbon content of soil but nitrogen levels did not affect the carbon content of soil except MBC in soil after four cycles rice-maize cropping system. Seasonal variation in soil organic carbon content was observed in rice - maize cropping system. Zero tillage increased the labile and very labile carbon by 13.3 and 12.1% respectively, compared to conventional tillage but did not affect the less labile and non labile carbon fraction in the soil. Rice residue mulching in maize increased all the labile carbon fractions. Addition of 6 t of rice residue as mulch in maize increased the very labile, labile and less labile carbon fractions by 14.5%, 21.4% and 16.8%, respectively compared to no mulching.

Evaluation of intensive rice based cropping systems

Effect of crop diversification and intensification in rice-based cropping system was studied. The experiment was laid in randomized block design and replicated thrice. The treatments consisted of T_1: Rice - Rice, T_2: Rice - Groundnut, T_3: Rice -Blackgram - Sesamum, T_4: Rice - Blackgram + Toria - Cowpea, T_5: Rice - Maize, T_6: Rice – Maize - Cowpea, T_7: Rice - Maize + Blackgram -Cowpea, T_8: Rice- Maize + Cowpea - Sesamum, T_9: Rice - Maize + Blackgram - Sesamum. Results revealed that horizontal intensification of rice - maize cropping system with introduction of cowpea during summer season registered 18.06% increase in rice equivalent yield as compared to rice-maize only. Further vertical intensification of rice-maize-cowpea cropping system with inclusion of blackgram as an inter crop in maize recorded 32.5% increase in rice equivalent yield as compared to rice-maize system. Among the cropping systems tested, rice -maize + black gram - cowpea gave highest rice equivalent yield (12.55 t ha^{-1}), net return (Rs. 80330) and B: C ratio (1.70) and the system recorded 19.8 % increase in rice equivalent yield as compared to conventional rice-rice cropping system (Table 2.3).

Table 2.3. System yield and economics of different rice-based cropping systems

Cropping system	System yield (REY t/ha)	Gross return (Rs.)	Cost of cultivation (Rs.)	Net return (Rs.)	B:C
Rice-Rice	10.48	162500	100800	61700	1.61
Rice-Groundnut	9.54	147600	89960	57640	1.64
Rice-Blackgram-Sesamum	9.04	140380	90800	49580	1.54
Rice-Blackgram +Toria-Cowpea	10.04	156020	97620	58400	1.60
Rice-Maize	9.47	146790	91150	55640	1.61
Rice-Maize-Cowpea	11.18	173200	106760	66510	1.62
Rice-Maize + Blackgram-Cowpea	12.55	194530	114200	80330	1.70
Rice-Maize+Cowpea-Sesamum	12.13	188020	114400	73620	1.64
Rice-Maize + Blackgram-Sesamum	12.06	186950	114800	72140	1.63
CD (p=0.05)	0.48	-	-	-	-

Integrated rice based farming systems for enhancing climate resilience and profitability in eastern India

Evaluation of existing rice-based IFS under irrigated and deep water areas

Multi-tier rice-fish-horticulture based integrated farming system with components of various crops and livestock was taken up in deepwater ecology. The grain yield of wet season rice Jayanti Dhan, Pradhan Dhan and Luna Suvarna were sown in Tier III during the first week of June in rainfed medium-deep water (up to 50 cm water depth) in the upper part of the field yielded (t ha^{-1}) 5.87 , 5.32 and 5.18 respectively. In the Tier IV under deepwater situation with more than 50 cm water depth at lower end of the field, the grain yield (t ha^{-1}) in newly released varieties CR Dhan 500, CR Dhan 505, CR Dhan 506, CR Dhan 508 and Varshadhan were 4.78, 5.28 t, 6.01 , 6.76 and 6.57 respectively. Among the varieties, CR Dhan 505 and CR Dhan 508 were found to be most suitable for inclusion of fish and duck for the tall and stiff straw. A total of 20 components (rice, green gram, ground nut, tuber crops, vegetables, fruit crops and animal components such as fish , duck) were identified in the rice based integrated farming system and their stability in terms of yield and economic value based Rice Grain Equivalent Yield (RGEY) were studied. Among the components, the horticultural crops viz., sweet potato, elephant foot yam and tomato provided higher stability with respect to both yield and RGEY. The fruit crops (banana, papaya), taro, okra, radish and ridge gourd occupied the higher ranks in RGEY, while duck, green gram, ground nut, French bean and cowpea were better in yield stability, but poorer in RGEY. Both, rice and fish closely provided yield stability in the system, while fish component provided second to highest RGEY due to higher price compared to rice. The average total productivity of the system was 13.67t ha^{-1}, which is about 10 times higher than traditional rice farming in India. This integrated farming system thus, can be an option for higher and stable productivity in deepwater areas of India, and in South and Southeast Asia.

Evaluation of rice plant as a periphytic substrate in rice –fish system

A field experiment was conducted for the second year with the objective to evaluate the rice plant as a periphytic substrate under integrated rice-fish system. Five treatments T1- (rice alone), T2 (rice + rohu), T3 (rice + catla), T4 (rice + mrigal) and T5 (rice + polyculture) were taken in randomized block design with four replications (Table 2.4). The high Dry Matter (DM) , ash content, and low Ash Free Dry Matter (AFDM) content in T1, T3 and T4 were corroborated to the shading effect as because of none grazing of peri-phyton. The high AFDM and low ash content in T2 and T5 was due to grazing of peri-phyton by rohu- a potential grazer.

Table 2.4. Effect of presence and absence of fish on the rice plant as a periphytic substrate in rice-fish system

Treatments	Rice	Rice + Rohu	Rice + Catla	Rice + Mrigal	Rice + CRM
	T1	T2	T3	T4	T5
Survival (%)	-	92-94.6 (92.4±2.9)	88.2-94.2 (91.6±2.7)	84.6-96.2 (88.4±4)	84-88.8 86.2±3.4)
SGR (%BW d-1)	-	3.12-3.32 (3.22±0.15)	2.78-3.01 (2.69±0.08)	3.98-4.13 (4.01±0.08)	-
NBW(kg ha-1 80 d-1)	-	398-485 (439±52)	469-495 (486±31)	323-396 (375±15)	337-398 (367±18)
DM(mg m-2)	47-65 (58±5	51-60 (57±5)	53-65 (61±6)	53-64 (59±4)	52-59 (55±6)
AFDM (mg m-2)	22-34 (28±5)	38-52 (43±8)	34-39 31±5)	29-38 (34±2)	34-43 (38±3)
Ash (%)	48-55 (51±2)	12.8-48.75 (32±11)	42-51 (47±4)	42-58 (45±8)	28-48 (37±8)

*SGR-Specific Growth Rate; NBW-Net Body Weight; DM- Dry Matter; AFDM- Ash Free Dry Matter.

Evaluation of rice based integrated farming systems for coastal saline areas

Rice based integrated farming system was developed successfully and validated at Village: Gadakujanga, Block: Ersama, District Jagatsinghpur. Farmer (Sri Kunjo Mullick) converted his 4 acres of land into rice-fish with duck system. Components were rice, fish, ducks, poultry, vegetables and horticultural crops on the bunds. Farmer got net income of Rs.1,05,200 ha^{-1} $year^{-1}$ from high yielding rice variety (4.56 t ha^{-1}), fish (820 kg ha^{-1}), poultry (250 kg 80 $chicks^{-1}$ $cycle^{-1}$), duckery (Egg and 110 kg $meat^{-1}$ 50 $ducklings^{-1}$ $year^{-1}$) fruits and vegetables on the bund during the second year. Soil was collected and analyzed for pH, organic carbon, phosphorus, available nitrogen and phosphorus. Result showed that with the increase with soil depth there was a decrease in nutrient content except soil pH. Nutrient status of pond refuge was recorded to be high with SOC (1.60), pH(6.56) and total N (0.09) where fish were bred throughout the year along with the duck movement whereas all the soil chemical properties were found to be significantly lower in case of the homestead land where vegetable enterprise was extensively cultivated by the farmer.

Bacterial biodiversity and ecosystem services in rice-based farming systems

Comparison of soil fertility and quality under different rice-based farming systems, conventional system (CS), integrated farming system (IFS) and IFS water stagnant system area (IFSw) in terms of various physico-chemical, bacterial diversity structure and composition was studied and correlated with rice productivity. Results indicated significantly ($p<0.05$) higher values of soil organic carbon (SOC), total nitrogen (TN), available N (AN), phosphorous (AP) and potassium (AK) in IFSw followed by IFS and CS (IFSw>IFS>CS). Microbial biomass (MBC) and soil dehydrogenase activity (DHA) were significantly ($p<0.05$) higher at high productive site (IFS and IFSw) as compared to the CS. In rice-rice system, the agronomic characteristics of rice and total productivity as rice equivalent yields (REY) was higher in IFS (IFS REY = 20.33 ± 0.59 t ha^{-1}; CS REY =8.72 ± 0.22 t ha^{-1}, $p< 0.05$). Higher relative abundance of operational taxonomic units (OTUs in %) of Proteobacteria, Actinobacteria and Firmicutes were found in CS compared to IFS and IFSw, whereas OTUs (%) of Chloroflexi, Acidobacteria, Nitrospirae and Cyanobacteria were higher in IFS, however, IFSw had higher abundance of OTUs (%) of Euryarchaeota, Crenarchaeota, Bacteroidetes and Chlorobi. The relative abundance of taxonomic groups in respect of different farming systems (CS, IFS and IFSw) indicated distinct diversities and bacterial community compositions. The multiple regression analysis among the soil quality indicators of SOC, TN, AK, MBC, MBP and DHA indicated positive correlation with productivity; however, Firmcute and Acidobacteria (OTU) with REY showed negative regression correlation. Overall, the present study indicated that adoption of rice based integrated farming leads to soil health improvements and enhancement of productivity through augmentation in nutrient cycling and diversities in bacterial community composition.

Increasing productivity and input-use efficiency in rice-based production systems with resource conserving technologies (RCTs)

Soil quality index in rice-green gram system under different RCTs

Soil quality assessment was done for five resource conservation technologies along with conventional control with and without application of nitrogen under direct seeded and transplanted conditions in a rice-green gram system. Using principal component analysis (PCA) and multiple regressions, minimum data sets comprising of DTPA_Zn, pH, bulk density, clay dispersion index and alkaline P for transplanted condition (Fig. 2.7a) and soil organic carbon, available N, electrical conductivity, alkaline P and pH for direct seeded condition (Fig. 2.7b) were identified for rice-green gram system. Application of green manure and zero tillage treatment significantly improved soil quality and sustainability of the rice-green gram cropping system both under direct seeded and transplanted system of rice.

Root behaviour under different RCTs

Root growth parameters of rice were evaluated under different resource conservation technologies (RCTs) for transplanted and direct seeded condition and it was observed that zero tillage treatment both under transplanted and direct seeded condition recorded highest root growth parameter values. Root length density and root weight densities for all the RCT treatments, increased significantly compared to the control and conventional practice; and maximum values were recorded under zero tillage treatment. Similarly, the root growth parameters under green

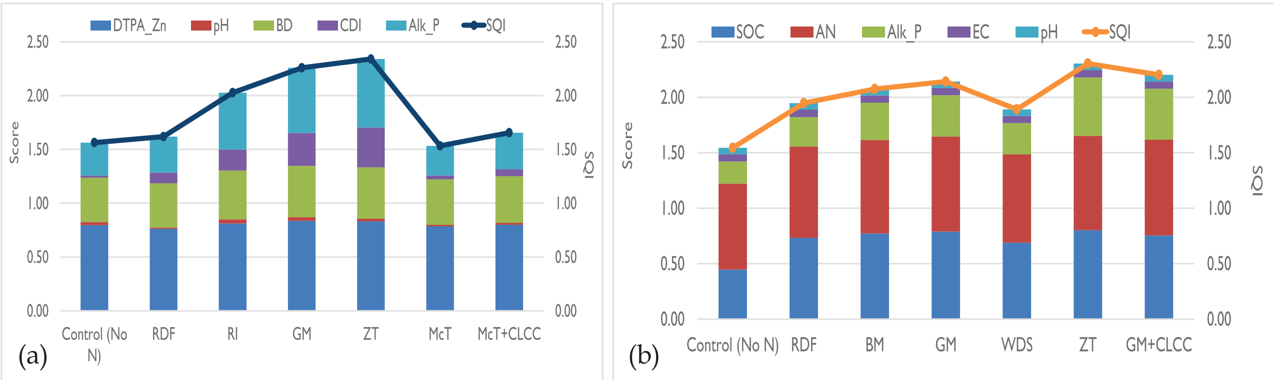


Fig. 2.7. Non-linear scoring results on soil quality index in rice-green gram system under different RCTs for a) transplanted rice b) direct seeded rice. RDF – Recommended dose of fertilizer; RI - Residue incorporation; GM – Green manuring; ZT – Zero tillage; McT – Mechanical transplanting; CLCC – Customized leaf color chart; BM – Brown manuring; WDS – Wet drum seeder.

manuring treatment also increased significantly as compared to the control and conventional practice.

Evaluation of components of conservation agriculture (CA) for rice based system

A field experiment was conducted in *rabi* and *kharif*, 2018 to study the impact of different components of conservation (minimum soil disturbance/reduce tillage (T), permanent soil cover through crop residues or cover crops (R), and crop rotations (D)) in alone and in combination. The treatments were control, R, T, D, RT, TD, RD and RTD replicated thrice in randomized block design (RBD). In *rabi*, Sahbhagi dhan and IPM 2-3 of Moong were grown, while in *kharif* Pooja were grown. Highest yield of rice (Pooja) was recorded in RD which is at par with D, TD and RTD. Harvest index of rice is also higher in TD, RD and RTD. There is enhancement of rice yield by 1-14% in *kharif* over control. However, when Moong was grown in the diversification component, the rice equivalent yield (REY) was much lower than the rice as a sole crop (-34 to -55% lower over control).

Cyanobacterial structural diversity under long-term RCTs

Cyanobacterial structural diversity as influenced by the long-term resource conservation technologies under rice-green gram cropping system was studied and population diversity of cyanobacteria was done through q-PCR technique. The cyanobacterial gene copy number varied from 6.37 x10^5 to1.42 x10^6 amongst transplanted conditions and showed highest in 100% RDF-N. On the other hand, under direct seeded condition, it varied from 8.28 x10^5 to 1.54 x10^6 and highest abundance was observed in green manuring treatment.

Assessing weed dynamics, management for improving productivity and production of rice

Weed distribution pattern in coastal Odisha

Field survey was conducted in three districts of Odisha *viz.* Cuttack, Jajpur and Puri during the wet season, 2018 to detect the dominant weeds in transplanted rice by quantitative survey method. The weed samples were collected at 30-45 days after transplanting for computing relative frequency (RF), relative density (RD), relative abundance (RA) and importance value index. There was a dominance of broad leaved weeds (42.7%) and sedges (37.8%) in rainfed lowland transplanted rice fields. Among the weed species, *Ludwigia octovalvis* was the most dominant with highest RF, RD, RA and IVI. Among the sedges, *Cyperus iria* was most dominant in Cuttack and Puri district where as *Fimbristylis miliacea* was dominant in Jajpur district (Table 2.5).

Evaluation of rice germplasm for weed competitiveness

Field experiment was conducted during wet season, 2018 to evaluate rice germplasm for their weed competitiveness under direct-sown condition. A total no. of 120 rice germplasm was evaluated. Plant and weed canopy height during 45 DAS, tiller number/ plant and yield were recorded. IR 93329, IR 93346, IR 93354, TA103 and TD 67 were found to be weed competitive (Fig. 2.8).

Development of weed control technology in direct-sown rice

Field experiments were conducted by integrating chemical and mechanical methods in wet direct-sown rice (W-DSR) during dry season, 2018 with cv. CR Dhan 203 and dry direct-sown rice (D-DSR) in wet season, 2018 with cv. CR Dhan 304. Treatments

Table 2.5. The relative density, relative abundance and importance value index of different weed species in transplanted rice fields in Cuttack, Jajpur and Puri

Species	Relative density (%)			Importance Value Index (IVI)			Importance Value Index (IVI)		
	Cuttack	Jajpur	Puri	Cuttack	Jajpur	Puri	Cuttack	Jajpur	Puri
Broadleaved weeds	**49.0**	**38.0**	**41.0**	**45.4**	**36.0**	**42.0**			
Ludwigia octovalvis	29.5	22.2	24.0	10.4	8.6	9.5	60.0	44.7	48.4
Sphenoclea zeylanica	2.0	1.9	2.5	3.7	2.7	3.0	8.1	8.4	10.5
Marsilia quadrifolia	3.4	3.5	1.0	2.8	4.9	3.6	11.9	12.2	6.3
Alternanthera sessilis	2.3	1.0	3.2	2.8	3.2	3.7	10.0	5.9	11.9
Ludwigia adscendens	1.8	1.2	2.7	3.4	3.1	4.7	7.6	6.5	10.7
Other weeds	10.0	8.2	7.6	18.0	13.5	17.5	45.1	36.6	37.3
Sedges	**30.3**	**40.0**	**45.0**	**28.4**	**28.0**	**40.0**			
Cyperus iria	10.8	13.0	17.0	6.1	6.2	11.0	25.0	30.5	37.1
Cyperus difformis	2.2	1.6	9.3	4.1	3.5	8.8	8.7	7.6	24.4
Cyperus haspan	3.4	3.6	0.5	3.5	5.1	3.6	11.4	12.4	4.9
Fimbristylis miliacea	5.8	20.5	13.8	4.1	8.2	7.0	16.3	42.2	32.3
Other weeds	8.1	1.3	4.4	10.6	5.0	9.6	24.7	9.3	17.9
Grasses	**20.7**	**22.0**	**14.0**	**26.2**	**36.0**	**18.0**			
Echinochloa crus-galli	4.1	4.7	4.5	5.9	6.4	5.9	16.6	19.1	19.2
Panicum repens	6.6	5.7	5.6	6.7	5.2	4.4	17.8	16.8	17.4
Leptochloa chinensis	2.2	1.1	1.3	3.5	2.7	3.1	8.5	5.8	7.0
Cynodon dactylon	4.6	5.5	2.5	5.7	8.7	3.7	14.0	17.6	10.6
Other weeds	3.2	5.0	0.1	4.4	13.0	0.9	14.0	24.4	1.4

Fig. 2.8. Weed competitiveness of rice germplasm

included mechanical weed control twice by two row motorized weeder at 20 and 40 days after emergence (DAE), chemical weed control by pendimethalin (PENDI) *fb* bispyribac sodium (BPS) (750 and 30 g ha^{-1} at 3 and 25 DAE), PENDI at 3 DAE *fb* mechanical weed control at 30 DAE, BPS at 10 DAE *fb* mechanical weed control at 30 DAE, manual weeding (DAE) at 25 cm row spacing, manual weeding (30 DAE) at 20 cm row spacing, weed free at 25 cm row spacing, weed free at 20 cm row spacing, weedy at 25 cm row spacing and weedy at 20 cm row spacing.

The highest grain yield was recorded with weed free check at 20 cm spacing, which was on par with weed free check at 25 cm spacing. Early post emergence application of BPS 30 g ha^{-1} (10 DAE) *fb* mechanical weeding with two row motorized weeder at 25 cm spacing registered significantly higher grain yield (4.00 t ha^{-1}), net return (Rs 37430/ha) and B:C ratio (2.29), it was on par with sequential application of PENDI (750 g ha^{-1}) *fb* BPS (25 g ha^{-1}) at 25 cm spacing during dry season, 2018. BPS 30 g ha^{-1} (10 DAE) *fb* mechanical weeding by two row motorized weeder (30 DAE) at 25 cm row spacing recorded highest grain yield (5.41 t ha^{-1}), net return (Rs 49,910/ha) and B:C ratio (2.43) during wet season, 2018.

Evaluation of herbicide-based weed control in direct-sown rice

Field experiment was conducted in the wet season, 2018 to study the efficacy of sequential herbicide application and herbicide mixtures in W-DSR (cv. Naveen). The treatments included bispyribac sodium (BPS) *fb* ethoxysulfuron (ETHOX) (25 & 15 g ha^{-1} at 7 and 21 DAS), cyhalofop butyl (CHB) *fb* ETHOX (100 & 15 g ha^{-1} at 10 and 21 DAS), flucetosulfuron (FLUCETO) *fb* ETHOX (25 & 15 g ha^{-1} at 7 and 21 DAS), XR 848 benzyl ester (XR 848) + CHB (150 g ha^{-1} at 15 DAS), penoxsulam+CHB (130 g ha^{-1} at 15 DAS) and BPS+ETHOX (25 + 15 g ha^{-1} at 15 DAS) with recommended BPS (30 g ha^{-1} at 10 DAS) and herbicide mixture bensulfuron methyl (BSM) + pretilachlor (PRET) (60+600 g ha^{-1} at 7 DAS). Control of weed flora in BPS *fb* ETHOX (WCE-91.0%) and XR 848+CHB (WCE 88.0%) was recorded at par. Sequential application of BPS *fb* ETHOX showed 16% and 13% yield advantage over BPS and BSM + PRET, respectively. The yield reduction due to weed competition in weedy plots was more than 50%.

Effect of different herbicides on soil microbes in rice field

Effect of herbicides on soil microbes was studied. Treatments were BPS+ azimsulfuron (25+22 g ha^{-1}), FLUCETO+BPS (25 +25 g ha^{-1}), penoxsulam + CHB (25+100 g ha^{-1}), fenoxaprop-p-ethyl+ETHOX (50+15 g ha^{-1}), BPS+ETHOX (25+15 g ha^{-1}), CHB+ETHOX (100+15 g ha^{-1}), XR 848+CHB (25 + 125 g ha^{-1}), FLUCETO + PRET (25+500 g ha^{-1}), BSM+PRET (60+600 g ha^{-1}). The population of bacteria, fungi and actinomycetes were temporarily affected by herbicide application, but there was no significant variation after 20-30 days. Similar trend was observed in MBC, FDA, DHA, urease, acid and alkaline phosphatase activities in rice soil.

Bio-efficacy of slow release herbicide formulation

Low cost adsorbents (FYM, Charcoal, Biochar) as carrier material of commercial herbicides were tested to evaluate their efficacy as slow release formulation. Controlled release formulation at different doses (CF 100% @ 30 g a.i. ha^{-1}, CF 75% @ 22.5 g a.i. ha^{-1}, CF 125% @ 37.5 g a.i. ha^{-1}) along with commercial formulation (BPS10SC @ 30g a.i. ha^{-1}) were tested against broadleaved and grassy weeds. No significant differences were observed among the developed formulation with respect to germination, fresh and dry weight of weeds (both broadleaved and grasses). Whereas, commercial formulation could effectively control the broadleaved weeds compared to developed formulation. Bispyribac sodium adsorbed so strongly into the adsorbent (FYM) that it could not release the herbicide at enough concentration to control the weeds.

Economic and environment friendly use of rice straw

Rice straw is one of the abundant lingo-cellulosic bio-resource in the world. However, nowadays, field burning of straw is a major practice followed to get rid of excess rice straw, but those cause air pollution leading to ill effect on human beings. Thus, there is growing interest in alternative eco-friendly uses of rice straw. As for example incorporation/ retention of straw in field itself, conversion of rice straw to bio-ethanol, biochar, and compost and use it as a substrate of mushroom production.

A field experiment was conducted at NRRI fields (B13, 14 ab block) during *kharif* season 2018 for *in situ* utilization of rice straw. The initial experimental soil samples had the pH, electrical conductivity (EC), moisture content, total organic carbon (TOC), readily mineralizable carbon (RMC) and microbial biomass carbon (MBC) of 6.8 ± 0.3, 0.6 ± 0.05 dSm^{-1}, 18.8 ± 2.9 %, 7.4 g kg^{-1}, 101.9 ± 14.1 µg C g^{-1} and 159.4 ± 21.1 µg C g^{-1}, respectively.

Eight treatments, viz., T1: Conventional harvesting (CH) and immediate incorporation in field by ploughing; T2: Conventional harvesting + Retention + Glyphosate + Zero Till Sowing; T3: Conventional harvesting + Spreading over field (Simulated as combined harvester + in situ-microbial decomposition; T4: Conventional harvesting + Retention + Zero Till Sowing + in situ-microbial decomposition; T5: Harvesting at Physiological

Fig. 2.9. Treatment imposition after physiological maturity and harvesting (a) Immediate incorporation of straw, (b) Straw retention + zero tillage, (c) Spreading of straw + in situ microbial inoculation, (d) Straw retention + inoculation + zero tillage

maturity (PH) and immediate incorporation in field by ploughing; T6: Harvesting at Physiological maturity (PH) + Retention + Glyphosate + Zero Till Sowing; T7: Harvesting at Physiological maturity (PH) + Spreading over field (Simulated as combined harvester + in situ-microbial decomposition; T8: Harvesting at Physiological maturity (PH) + Retention + Zero Till Sowing + in situ-microbial decomposition, were imposed after harvesting at physiological maturity (PH) and conventional harvesting (CH) of kharif crop (Fig. 2.9).

After treatment imposition soil carbon fractions (MBC, RMC), soil enzymatic activities (FDA, dehydrogenase, β-glucosidase, cellulase and xylanase) and greenhouse gases (CH_4, N_2O and CO_2) emission were estimated at 10, 20, 30 and 40 days intervals.

The readily mineralizable carbons (RMC) and microbial biomass carbons (MBC) were increased from 10 days of treatment imposition to 30 days then decreased at 40 days irrespective of treatments. In the treatment of spreading of straw with microbial inoculums, the labile carbon and soil enzymatic activities (β-glucosidase, cellulase and xylanase) were found higher. The methane emission was higher in delayed harvesting + spreading of straw + microbial inoculation treatment. The similar trend was observed at physiological maturity harvest and delayed harvesting. The CO_2 and CH_4 emissions were increased from 5 to 18 days of treatment imposition then decreased slowly. All the GHGs (CO_2, CH_4 and N_2O) emissions were relatively less in zero tillage (ZT).

Mechanization of rice-based cropping systems for higher productivity and energy use efficiency

Urea briquette applicator attachment in mechanical rice transplanter

The four row urea briquette applicator attachment was developed to apply urea briquettes between the rows of rice transplated by eight row mechanical transplanter (Fig. 2.10). During field evaluation at operating speed of 1.66 kmph the field capacity of the developed machine was 0.191 ha h^{-1} with field efficiency of 67.82%. For deep placement of urea briquettes manual applicator and hand placement required 8.6 and 10 times higher manpower as compared to developed applicator. The cost of operation by developed applicator is 90% to 92% less over manual applicator and hand placement methods.

Development and evaluation of power operated two row wet land weeder

Power operated two row wet land weeder for rice was developed and was evaluated in comparison to manual weed control implements and methods (Table 2.6). Operation cost of power weeder was found Rs 1239/ha, which was 55.55%, 28.91% and 82.22% less than finger weeder, star cono weeder and hand weeding, respectively. Cost of energy of power weeder was also better (Rs 2.49/MJ) that was 69.37%, 43.41% and 84.38% less than the cost of energy of Finger weeder, Star cono weeder and hand weeding respectively

Design and development of battery powered weeder

A single row battery powered weeder was developed for wetland rice crop. This weeder can be operated in 20 cm and above row spacing. The developed weeder equipped with 24 V DC motor which gives 0.33 HP power and torque of 22 NM. Cutting blade was designed to rotate at 250 RPM. Power transmission system is designed to transmit the power from battery to blade with the use of chain and sprocket. The developed weeder is light weight and low vibration as compared to engine operated weeder and will result drudgery reduction while operating in field.

Effect of parboiling treatment on the milling quality parameters of the selected rice varieties

Parboiling treatments were performed over five varieties (Agnibora, Swarna, CR-1014, BPT-5024 and Molbora) by hot soaking method following the standard procedure. The treated paddy samples were dried to a required moisture content of 12% before milling. The milling trials were done to obtain head rice, brokens, polished rice and bran. The milling parameters were studied and the results were compared with that of the control sample (raw rice) i.e., without any treatment (Table 2.7).

Fig. 2.10. Deep placement urea briquette applicator attachment for mechanical rice transplanter

Harnessing microbial resources for alleviating abiotic and biotic stresses for improving soil health

Morphological markers to identify different Azolla spp.

Morphological markers were identified to differentiate different strains of *Azolla* spp. Among 102 strains, 23 sporocarp producing *Azolla* were identified, however, only *A. microphylla* had shown sporocarp production under Euazolla section. Out of 23 sporocarp producing, one strain GSMI 1 belonged to *A. microphylla,* whereas other strains belonged to *A. pinnata* based on different morphological (shape and imbrications of plant body, shape of dorsal leaf lobe, colour of ventral leaf lobe, angle of dorsal and ventral leaf lobe and presence and absence of root hairs) features.

Table 2.6 . Comparative field performance evaluation of weeders

Implements	Actual field capacity (ha h^{-1})		Field efficiency (%)		Weeding efficiency (%)		Plant damage (%)	
	25 DAT	40 DAT	25 DAT	40 DAT	25 DAT	40 DAT	25 DAT	40 DAT
Finger weeder	0.010	0.012	69.82	72.34	78.67	84.77	1.6	1.4
Star cono weeder	0.015	0.016	61.32	64.7	64.77	66.22	2.6	2.8
Power weeder	0.076	0.075	78.14	77.49	67.22	68.48	2.94	2.99
Hand weeding	0.003	0.005	NA	NA	96.66	97.20	0.6	0.1

Table 2.7. Milling quality parameters of selected paddy varieties

S.No.	Variety	Hulling percentage (%)		Milled Rice Yield (%)		Head Rice Yield (%)		Brokens (%)		Milling degree (%)		Milling recovery (%)	
		Raw	Parboiled	Raw	Parboiled	Raw	Parboiled	Raw	Parboiled	Raw	Parboiled	Raw	Parboiled
1	Agnibora	76.9	72	66.3	45.7	71.4	68	2.9	3.7	89.2	63.4	66.3	45.7
2	Swarna	79.3	80	66.2	78	72.3	76	2.7	0.32	88.17	99.9	66.2	78
3	CR- 1014	78.5	72	63.6	72.5	65.4	80	7.0	1.8	87.9	94.1	63.6	72.5
4	BPT-5024	78.1	72	68.2	67.4	63.1	68	9.8	3.4	93.5	93.4	68.2	67.4
5	Molbora	76.5	76	66.7	70.2	58.6	62	16.9	0.48	88.5	93	66.8	70.2

Use of Azolla as livestock feed and microbial growth medium

Azolla is a fresh water fern and gets decomposed very fast in absence of water, hence an attempt was made to prepare value added products such as *Azolla* pellet for livestock feed and microbial growth medium from *Azolla* extracts to preserve its value. *Azolla* pellet (15 g each) was prepared containing considerable amount of protein, antioxidants, major and minor nutrients (Fig. 2.11a). *Azolla* based microbial growth medium was developed and compared with existing commercial media (Fig. 2.11b). Result indicated that *Azolla* medium was 32.7% and 62.7% cheaper compared to nutrient agar and Jensen agar media, respectively. Growth of bacteria, fungi and their functional traits were *at par* on *Azolla* medium compared to commercial media.

Performance of Azotobacter chroococuum Avi2 under drought stress

A pot experiment was conducted to analyze the role of antioxidant (ascorbic acid) and *Azotobacter chroococcum* AVi2 under moisture stress in two droughts susceptible (IR 64 & Naveen) and tolerant (Satyabhama & Ankit) rice cultivars. Result indicated that *A. chroococcum* (AVi2) along with ascorbic acid enhanced the plant-growth promotion (PGP) in all cultivars under drought compared to moisture stress alone. Thus, a simple formulation of *A. chroococcum* was made to alleviate moisture stress *vis-a-vis* enhancing the PGP efficacy in rice (Fig. 2.11c). Overall, the findings of this experiment will help to enhance the performance of beneficial microbes under moisture stress condition.

Fig. 2.11. (a) *Azolla* feed pellets; (b) NRRI *Azolla* medium for microbial growth; (c) Bacterial liquid formulation for alleviating drought stress.

q-PCR calibration of different microbial genes

Various methodologies *viz.*, spectrophotometers and PCR-based techniques are available to quantify the structural and functional microbial genes in agricultural soils; however q-PCR-based methodology has not been systematically standardized. Therefore, a simple q-PCR-based methodology has been standardized by us for absolute quantification of methanogen (*mcrA*), methanotrophs (*pmoA*), alkaline phosphatase (*phoD*), sulfur oxidation (*soxB*), cyanobacteria (*cya*) and Pseudomonas (*ps*).

Evaluation of NRRI microbial consortium for ex-situ decomposition of paddy straw

Decomposing microbial consortium was developed using efficient lignocellulolytic microbes comprising *Aspergillus* sp., *Trichoderma*, *Streptomyces* sp. and *Bacillus* sp. and its decomposing potential of rice straw was evaluated under *ex-situ* condition. Following five treatments viz., T1-NRRI consortium (2%) + Cowdung (1%) + Urea (0.5%) + Pipe for aeration, T2-Commercial consortium (as per their recommendation : 200 lit t^{-1}), T3-NRRI consortium (2%) + Cowdung (1%) + Urea (0.5%) + No Pipe , T4-Cowdung (1%) + Urea (0.5%) and T5- Only paddy straw were evaluated with four replication. In each treatment, 100 kg (dry weight basis) paddy straw was used and moisture content was maintained around 55-60% throughout experiment. Among the treatments, NRRI microbial consortium either with pipe (for aeration) or without pipe was found efficient than other treatments, which decomposed paddy straw within 50 days without turning.

Evaluation of Skermanella sp. *and B. thuringiensis against rice leaf folder*

In this experiment, liquid formulation was prepared using *Skermanella* sp. and *B.thuringiensis* (three strains BT1, BT2 and BT3) strains separately and then these four formulations were evaluated (at the rate of 2.0 lit of inoculums (2.3-3.1x10^9 CFU/ml per acre) against rice leaf folder under field condition in Lalat during *kharif*, 2018. Un-inoculated control and chemical spray were maintained for comparison of efficacy of microbial strains. Among the treatments, *Skermanella* sp. and BT3 application recorded significantly lower leaf folder incidence (5.2-6.4%) compared to other strains (BT1 and BT2). There was 4.2 and 13.2% leaf folder incidence in chemical spray and un-inoculated control, respectively.

AM fungal diversity in paddy soil

The analysis of AMF diversity through Illumina-MiSeq® sequencing technique in flooded paddy soils exposed to eight years eCO_2 drastically reduced Glomerales but encouraged the population belonging to order Diversisporales. This study also finds the suitability of AML1/AML2 primer pair for analyzing AMF diversity using next- generation sequencing technique.


PB

PROGRAMME : 3

Rice Insect-Pest and Diseases : Emerging Problems and their Management

It is reported that about 1/3rd of the crop get damaged due to different stresses and major damage is done by biotic stresses which include insects, diseases, nematodes, virus etc. The damage is not only done in the standing crop but also in the stored grains. The recent climatic scenario has also brought changes in biotic stress management. Many minor diseases and insects have become major threat to rice cultivation. Environment need to be protected for the next generation hence it is necessary to manage the crop in sustainable way to be eco-friendly. So emphasis has been given on identification of new sources for resistance against different biotic stresses, use of modern technologies like nanotechnology and biotechnology to manage the rice pests. Special focus is on using ecological engineering, biocontrol agents to manage the crop pests.

Exploration of new sources of resistance for insect-pests and diseases of rice

Resistant donor identification against BPH & WBPH

Out of 153 rice genotypes screened against BPH and WBPH during 2018, 12 landraces *viz.,* Bhalum-1, Megha rice -3, IMP-Sabarmati, GR 7, Karjat-3, MTU-1061, MTU-1075, RTN-3, R-Suhasini, Pravata, Santephal, BD 102 and two accessions *viz.,* AC 44845 & AC 44846 were found resistant (score 3) to BPH while only four genotypes *viz.,* Pathara, Pratap, Tejaswini, Santephal were found resistant (score 3) to WBPH.

Study on antibiosis and tolerance basis of resistant from Manipur rice accessions against BPH

Only six accessions (AC 9019, AC 9053, AC 9060, AC 9080) out of 102 Manipur rice accession (MRA) were identified as resistant to BPH. These resistant and few moderately resistant genotypes along with standard checks TN1, Salkathi and Ptb33 were selected to study brown plant hopper resistance based on antibiosis and tolerance like honey dew excretion response and the amount of phloem sucked up by the BPH; fecundity of BPH; functional Plant Loss Index (FPLI) due to BPH infestation and plant dry weight loss per mg of insect dry weight. Least honeydew area was recorded in AC 9053(A), followed by AC 9080, AC 9074(A) and AC 9060. AC 9074(A) (152) registered lowest egg laying followed by AC 9060 (165.33) and AC 9080(178). 9074(A) (23.52) had lowest FPLI followed by AC 9063 (33.21) and AC 9060 (33.99). The plant dry weight loss per mg of insect dry weight produced was lower in Ptb33 (12.51mg) and Salkathi (21.05mg) followed by resistant genotypes 9074(A) (22.70mg) and AC-9060(32.07mg).

Biochar mediated defence induction in rice to Asian rice gall midge *Orseolia oryzae* (Biotype-2) paddy

Biochar amendments to soils had shown significant effects on gall midge development. Silver shoot formation was lower at the higher levels of biochar (40- 60 g kg^{-1}) application than lower levels (10-30 g kg^{-1}) as well as control (Table 3.1). Similarly, significant and higher levels expression of defence enzymes [POD ($P < 0.0001$), PPO ($P < 0.0001$) and CAT ($P < 0.0001$)] indicating higher defence against gall midge. Thus, application of biochar @ 40-60 g kg^{-1} to soils had significant effect on *O. oryzae.*

Effect of elicitor spray on rice plants and dead heart damage caused by yellow stem borer

Elicitor (Potassium silica) sprayed plants showed better recovery from dead heart damage (1- 47.03 and 88.37%, 5- 53.68 and 91.45%) compared to untreated control (8.43 and 34.55%) plants at both post-treatment one and two counts respectively. It was also observed at seven days after treatment that mean silica content was increased (4.7 to 6.1) in leaves of different dose of elicitor sprayed plants compared to untreated control (4.2%) whereas in stem (4.17 to 5.09%) compared to untreated control (4.02%). Increased level in chlorophyll content, tiller numbers/plant, effective tiller numbers, filled grain numbers and weight/panicle whereas reduced larval weight of yellow stem borer larva were observed in the silica sprayed plants. Increased activity of defence enzymes (catalase & peroxidase) and more expression of proteins in the range of 12-15 Kda were observed in elicitor sprayed plants.

Table 3.1. Activity of defense enzymes and other bio-chemicals in comparison to silver shoot formation

Sl. No.	Biochar (g kg^{-1} of soil)	POD (IU g^{-1} FW)	PPO (IU g^{-1} FW)	CAT (µmol min^{-1} mg^{-1} protein)	TSS (µg per g of FW)	Total phenol (µg per g of FW)	Silver shoot infestation (%)
1	10	0.40± 0.03 ^{de}	0.27±0.06 ^{cd}	4.55±0.57^{c}	0.24±0.03 ^{bc}	40.63±1.89 ^{e}	29.91±5.92 ^{b}
2	20	0.55±0.08 ^{cd}	0.20±0.10 ^{d}	5.12±0.12 c	0.33±0.04 ^{bc}	56.16±1.70 ^{d}	15.70±4.45 ^{bc}
3	30	0.93± 0.08 ^{c}	1.47±0.31 ^{bc}	5.07±0.16 ^{c}	0.44±0.03 ^{b}	71.98±1.53 ^{c}	13.59±3.11 ^{bc}
4	40	1.69± 0.21 ^{b}	1.50±0.53^{b}	6.41±0.27 ^{b}	1.18±0.14 ^{a}	82.05±1.28 ^{b}	6.33±5.20^{c}
5	50	2.55± 0.24 ^{a}	3.97±0.42^{a}	7.40±0.37 ^{a}	1.21±0.20^{a}	87.55±1.94 ^{a}	5.56±1.93^{c}
6	60	1.77± 0.13 ^{b}	4.33±0.86^{a}	7.44±0.29^{a}	1.24±0.05^{a}	87.46±0.98^{a}	11.18±2.12 ^{c}
7	Control	0.11± 0.04 ^{e}	0.17±0.12^{d}	2.45±0.30 ^{d}	0.17±0.03 ^{c}	31.59±2.84 ^{f}	73.61±13.06^{a}
P value		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Screening of rice varieties against Angoumois grain moth (*Sitotroga cerealella*)

Twenty rice varieties were screened for their reaction against the important stored grain pest *Angoumois* grain moth, *Sitotroga cerealella* under laboratory conditions. Moth emergence data were recorded after 30 days of releasing five pairs of freshly emerged moths. Based on Dobies Susceptibility Index (DSI), Bina Dhan-8 showed resistant reaction (DSI=0.0) and Durga, Kalajeera and CR Dhan 310 were moderately resistant (DSI 4.82, 3.24, 1.99) and the remaining varieties were susceptible to highly susceptible (DSI ⩾5.05).

Screening of donor resistant to leaf folder of paddy *Cnaphalocrosis medinalis*

Out of 30 Assam rice collection (ARC) germplasm screened against leaf folder under greenhouse condition and petri-plate method following the damage area count method, 28 germplasms were observed as moderately resistant.

Screening of resistant donor to different pathogen causing rice diseases

Bacterial blight

Out of 1383 genotypes screened for bacterial blight resistance, only two entries showed score 1 while 105 exhibited score 3. Chakaakhi, Sumit, Savitri, Kalashree, Reeta, CR-2983-4, SB-1, SB-61, UP-13, UP-15, UP-20, UP-59, MN-7, MN-97 were some of the entries which belong to score 3.

Brown spot

In order to find out resistant donor to rice brown spot pathogen *Bipolaris oryzae,* around 154 aerobic rice, 27 Kerala pokkali and 66 Karnataka rice lines were screened and among these, 11 from aerobic rice, four from Kerala pokkali and 11 from Karnataka lines were identified as moderately resistant.

Sheath blight

A total of 2151 entries including AICRIP entries were evaluated for identifying resistant donor against sheath blight pathogen under artificial inoculation. Out of 290 farmer's varieties, 85 released varieties, 60 next generation rice lines, 281 ARC and 25 double haploid lines evaluated 9, 8, 5, 7 and 3 entries, respectively were observed as moderately resistant to sheath blight pathogen. Altogether 1310 AICRIP entries 16 NSN1, 21 NSN2, 5 NHSN and 5 DSN entries were observed as moderately resistant. Some promising accessions are as follows: Kandhamala-Jhalaka, Biradia Bankoi, Champei Siali-D, Dubaraj-S Ganjam Gedi, Koraput-Kundra-Haldichudi, Kendrapara-Haladigundi, Boudh-Jholi Puagi , Ngrh-Baigana Manji, Chandan, Naveen, Hanseswari, CR 1014, Chndrama, CR Dhan 601, Sahbhagidhan, Durga, ARC 5944, 6097, 6173, 7050, 7089, 7107 and 7410.

False smut and Sheath rot

Seven hundred and thirty four accessions comprising 108 DSN, 129 NHSN, 398 NSN1 and 99 ARC were grown for screening against false smut (*Ustilaginoidea virens*) and sheath rot (*Sarocladium oryzae*) pathogen under natural infection condition. Incidence of false smut was very low, thus none of the entries were considered as resistant. Thirty five ARC, 49 DSN, 96 NSN1 and 46 NHSN entries were found non-infected to the false smut disease and will be evaluated in next season. Location severity index for sheath rot disease was moderately high to low (6.5 to 2.21). 13 ARC, 60 DSN, 52 NSN1 and 58 NHSN were observed as resistant to sheath rot disease. Some of the promising entries resistant to both false smut and sheath rot are as follows: ARC- 5940, 6023, 6040, 6060, 6102, 6117, 6147, 6183 and DSN- 2, 7, 10, 12, 15, 28, 60, 63, 69, 78 and 91.

Morphological diversity among the false smut pathogens

A wide morphological diversity was observed among the 80 isolates of *U. virens* collected from different parts of eastern and north-eastern India. Diversity was based on sporulation period, changes of colour, size and texture after 7, 14, 21 and 28 days of the culture. Diversity among the isolates is >60%. Intra-state diversity of Odisha and West Bengal isolates is 63% and 60%. All the 80 isolates were grouped into two major clusters. Cluster II was having only one isolate while cluster I subdivided into two subclusters. There was no grouping based on geographical distance but grouping was mainly based on sporulation period and changes of colour after certain period.

Bakanae

One hundred and twenty three varieties were screened for bakanae disease resistance. Among them, eight (6.5%) were found as highly resistant (HR) and seven (5.7%) resistant, 31 (25.2%) moderately resistant and remaining 77 (62.6%) were in susceptible group. Some of the promising genotypes resistant to bakanae disease are as follows: Luna Sankhi, Improved Tapaswini, Sarasa, Sadabahar, CR Dhan 311, Khira, Wifa-10, Binadhan-8.

Phenotypic and genotypic evaluation of bakanae resistant paddy varieties using SSRs

Twelve microsatellite or SSR markers were used to characterize and assess genetic diversity among the 123 varieties. All 12 primers showed polymorphism and polymorphism information content (PIC) ranged from 0.031 (RM-10153) to 0.374 (RM-3698) with a mean value of 0.264. The lowest PIC value of markers RM-10153 and highest PIC value of RM-3698 represented the formativeness for genetic diversity analysis. The results of this analysis demonstrated maximum percentage of variation present among individuals within groups (95%) while minimum variance existed among populations (5%). The F_{IS} and F_{IT} value for four markers loci were observed to be 1.0 and F_{ST} was found to be 0.033 at P>0.001. The un-weighted neighbour joining tree was constructed using DAR win software to evaluate genetic diversity among 123 varieties. The genetic distance was assessed to construct a dendrogram by using the 12 gene specific markers data led to the clustering of 123 NRVs into three major clusters, I, II and III. Major cluster I consisted of 19 varieties, of which 8 (42.10%) are moderately resistant. Major Cluster II consist of 41 varieties having four (9.75%) highly resistant (HR) genotypes. Similarly, Major cluster III found to be the largest cluster which possessed 61 varieties and consisted only four (6.55%) HR genotypes. All the genotypes possessing highly resistant reaction were distributed in cluster II and III. But, resistant and moderately genotypes were distributed in all the three clusters including susceptible and highly susceptible genotypes.

Phenotypic and genotypic evaluation of brown spot disease resistance of rice

Out of 121 NRRI released varieties (NRVs), 18 (14.8%) showed moderately resistance, 58 moderately susceptible (48.4%) while remaining 45 (37.7%) susceptible reaction to brown spot disease. Out of twelve markers, only two markers, RM3919 and RM6534 were found to be significantly associated with the brown spot disease resistance explaining phenotypic variance from 1.3 to 1.7%. The population structure analysis and PCoA divided the entire 121 NRVs into two sub-groups. Analysis of molecular variance showed maximum (97%) diversity within populations and least (3%) diversity between populations. The cluster analysis grouped the 121 released varieties into two major clusters.

Evaluation of NRRI released rice varieties and few other collections against rice root knot nematode, *Meloidogyne graminicola* under pot culture condition

Altogether 110 entries of paddy were evaluated against rice root knot nematode, *Meloidogyne graminicola* following Taylor and Sasser (1978) scale and only two entries *viz.,* CR Dhan 303, Reeta were observed as moderately resistant and remaining all were susceptible.

Bio-ecology of rice insect pests and diseases for climate smart protection strategies

Rice harvest cutting height and ratoon crop effects on diapausing rice stem borer infestation

Rice harvested leaving stubbles in the field until the following growing season harbors stem borer larvae and or pupae. A field study was carried out in five experimental blocks i.e., A, B, C, D and U of NRRI farm from December 2018 to February 2019 to ascertain the main crop harvest cutting height and the production of a ratoon crop on the level of infestations of the rice stem borers. About 18,328 rice stubbles were uprooted and examined by dissecting the stem on daily basis. Plant dissections showed that three predominant stem borer larvae infesting rice were Yellow stem borer (YSB), (*Scirpophaga incertulus*), Striped stem borer (SSB), (*Chilo supressalis*) and Pink stem borer (PSB), (*Sesamia inference*) diapaused in the rice crop residues during the period of investigation. The relative abundance of the diapausing stem borers revealed that irrespective of blocks YSB was most predominant followed by PSB and SSB that compared to YSB larvae and pupae, relatively more SSB, PSB are located high in rice plants (>10 cm from the base of the culm) (Fig 3.1). The occurrence of stem borer species was correlated with the height of the stubbles. This study showed that lowering paddy cutting height during harvesting can suppress late season PSB and SSB populations. Furthermore, rice stubble under favorable conditions represents a substantial overwintering habitat, thus warranting evaluation of pest management tactics targeting overwintering populations. Based on the results obtained, efficient control of borers on rice can be achieved by leaving short stubbles during harvesting followed by rotary tillage.

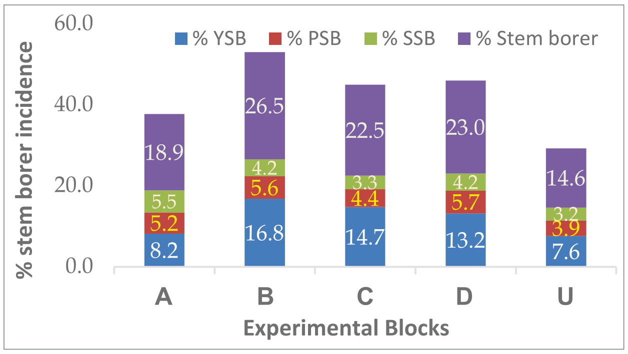


Fig. 3.1. Relative abundance of rice stem borers in rice stubbles (Dec 2018 to Feb 2019)

Pest management through ecological engineering

An experiment was laid in the NRRI farm in lowland rice ecosystem during *rabi* 2019 where the rice field had one-meter bunds in three sides and around three meters bund in one side. The rice crop (cv. Naveen) was raised in recommended agronomic practices. The bamboos tied with straw bundle in the top and charged with 5-6 spiders and yellow sticky traps were placed in the field to monitor the flying insects. Three vegetable crops namely bitter gourd, ladyfinger and pumpkin were grown in the wider bund measuring 67.2 m^2. Roving survey was conducted to know the insect pest incidence and natural enemies in rice field as well as vegetables. Observation on natural enemies were undertaken fortnightly starting from seedling stage to ripening stage.

About 13.5 kg of bitter gourd, 33.8 kg of lady finger and 59.2 kg of pumpkin were harvested from the bund. The patches attracted large number of pollinators and were used as perches and foraging sites for insectivorous birds. Weekly sweep net method collection in rice fields revealed that the insect pests' population remain below economic threshold level in ecological engineering-based pest management plots compared to conventional pest management plots. The harbored natural enemies were predators like, spiders, coccinellids and hymenopterans parasitoids. The insect pests *viz.*, YSB, Brown plant hopper (BPH) and Green leaf hopper (GLH), Gundhi bug (GB), SSB, Leaf folder (LF), Grass hopper (GH) population were lower in the rice crop grown as per ecological engineering based pest management practices where in vegetables grown as bund crop (Fig. 3.2).

Faunal diversity in coastal rice ecosystem

Insect fauna in upland rainfed coastal ecology in Naira, Srikakulam, AP revealed presence of 24 insect pest species belonging to nine families and five orders. Among beneficial insects, the population of coccinellid beetles was observed to be the highest (38.1±2.01 per sq meter) during *kharif* 2018. Higher biodiversity indicates higher ecosystem functioning, predation, parasitism, decomposition making the pest populations in lower levels (Fig. 3.3).

Biology and morphometric studies of different life stages of rice weevil *Sitophilus oryzae*

Comparative biology of *Sitophilus oryzae* (Curculionidae: Coleoptera) was studied inside the

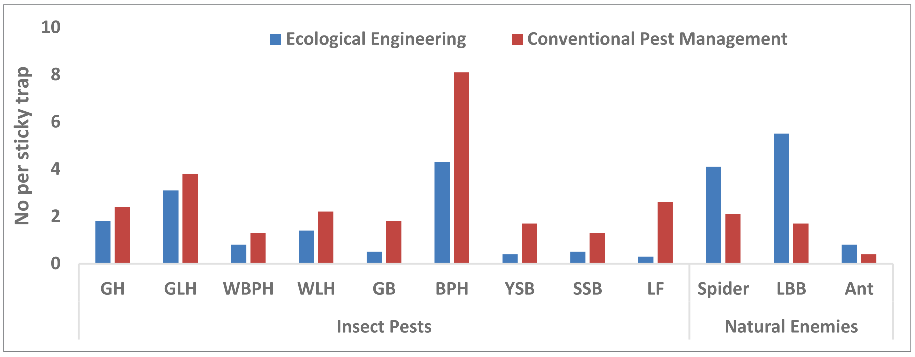


Fig. 3.2. Sticky trap catches in ecological engineering and conventional pest management regimes

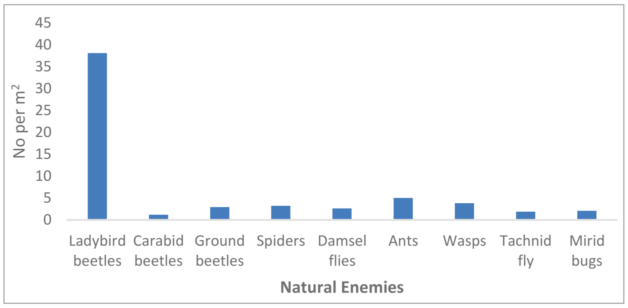


Fig. 3.3. The pest populations in lower levels

laboratory under two different situations *i.e.* with and without food. The ability of adult *S. oryzae* to live in the presence or absence of food was determined by enclosing male and female adults obtained from the culture maintained separately in plastic boxes. The results indicated that total life cycle from egg to egg stage for female was 129.67 and 48.67 days under with and without food situations, respectively. Total larval period lasted for 25-30 days. The larvae after complete growth pupated inside the rice grain. Pupal period lasted for 6-9 days with a mean of 7.33 ± 1.53 days. The males had comparatively short life than the females.

Morphometric studies of different life stages of *S.oryz*ae indicated that the average length of egg was 0.36±0.02 mm. The average length of the larva and pupae was 2.42 ±0.04 mm and 2.80 ±0.06 mm respectively. Similarly, the average length of the adult male and female weevil was 3.11 ± 0.07 mm and 3.49 ±0.08 mm, respectively.

Population structure of rice pathogens in different rice ecologies

Bacterial blight

Bacterial blight (BB) caused by *Xanthomonas oryzae* pv. *oryzae (Xoo)* is a major threat to production and quality produce. The bacterial blight pathogen has evolved a diverse population with development of new racial structures due to climate change and faulty crop cultural practices. Hence, samples of BB were collected from Eastern India *viz.,* Odisha, West Bengal, Bihar, Assam, Tripura along with Telengana (reference isolate) to assess the changes in genetic diversity in Xoo. The pathogen was isolated and pathogenicity was confirmed by inoculation to a susceptible check Taichung Native-1 and then we used different ISSR primers were used to study the genetic diversity among different Xoo populations (Fig. 3.4).

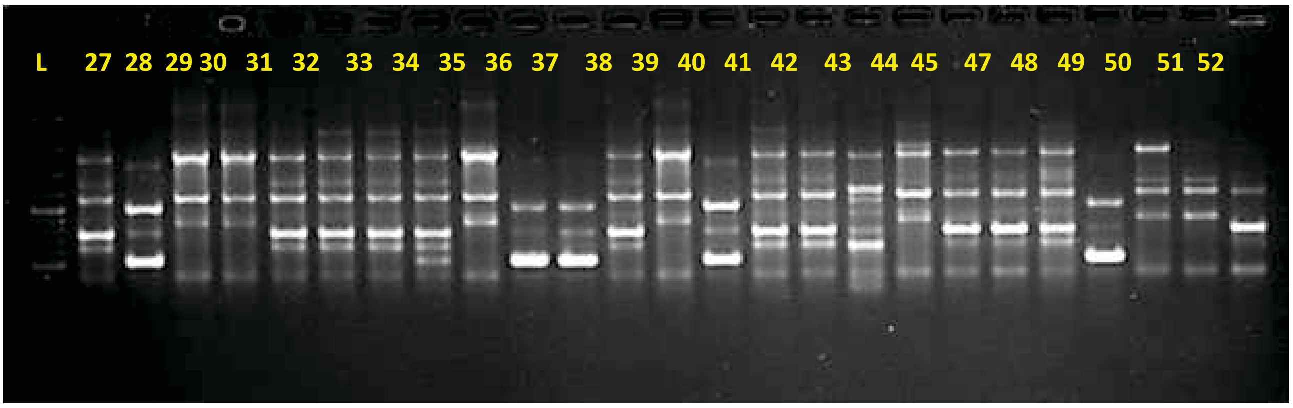


Fig. 3.4. The figure illustrates DNA fingerprinting of *Xoo* isolates based on an ISSR primer. 27-52 are the different isolates. L: 100 bp plus DNA ladder

Morphological and genetic characterization *Fusarium* isolates

Morphological and genetic diversity of 65 isolates of *Fusarium* spp. was studied. The results revealed that, morphologically three types of pigmentation (pink, yellow and purple) were observed. Fourty isolates produced pink pigmentation, 14 isolates produced yellow and 11 isolates produced purple pigmentation. Isolates with pink pigmentation were fast growing, yellow pigmentations were moderate growing and purple pigmentation were slow growing. The pathogenicity analysis was carried out on a highly susceptible variety Pooja which revealed that, 60.93% isolates were highly virulent, 21.87% were moderately virulent and 17.18% isolates were less virulent. These isolates did not produce any chlamydospore. Genetic diversity analysis using TEF-1α primers (F-5 'GTTAAGAGGCGCGGTGTCGGTGG3', R-5 'GGAAGTACCAGTGA TCATGTT3') amplified a amplicon size of 750 bp. Sequence homology and phylogenetic analysis showed diversity among the isolates forming three major clusters. All the isolates were distributed in sub-clusters. The sequences have been deposited to NCBI database and accession numbers were received.

Development of a Loop-Mediated Isothermal Amplification (LAMP) assay to setect *Fusarium* spp.

An effort was made to detect the *Fusarium* spp. associated with bakanae disease from infected plants, seeds and soil samples. The loop primers were designed for *Fusarium fujikuroi*, *F. verticilloides* and *F. proliferatum* using TEF 1α sequences using Primer3 software. These primers were screened for quick and sensitive detection of *Fusarium* spp. The LAMP assays efficiently amplified target genes in 70 min at 60 °C. A color change from purple to sky blue was observed in the presence of the DNA of targeted pathogens only, by adding hydroxynapthol blue to the reaction system prior to amplification. Further analysis for confirmation on minimum genomic DNA needed in the assays is under standardization. LAMP assay can successfully and rapidly diagnose the probable infected paddyplant and seed samples from fields for bakanae disease.

Life cycle of rice root knot nematode *M. graminicola* at two different temperature

The study revealed that at higher temperature range nematode completes its life cycle faster (5 days) than that of the lower temperature range. It resulted in a greater number of generations at higher temperature. This study is helpful to study the impact of global warming on nematode population structure (Table 3.2).

Bio-intensive approaches for pest management in rice

It was observed that combined application of different treatments *viz.*, seed treatment + seedling root dip + soil application resulted in the effective reduction of nematodes. Among the different *Trichoderma* strains tested, CRRI T-1 was recorded to be the most effective and among the different *Bacillus* strains tested, RB 31 was adjudged as the most effective in reducing the nematode population.

Collection and isolation of pheromone compounds for stinkbugs

Gundhi bug *Leptocorisa oratorius* pheromone compounds (alarm and defense secretions), E-2-octenal, n-octyl acetate, hexyl acetate, 3-octenal, 1-Octenol, (Z)-3-octenyl acetate were tested against adult and nymphal populations, and specific behavioral responses were not detected, except alerting and alarm defensive function. These compounds were present in abdominal meta thoracic scent glands. Ventral abdominal glands of male *Leptocoriza acuta*, produce 2-phenyl ethanol, which is

Table 3.2. Effect of temperature on the life cycle of root knot nematode *M. graminicola*

Sl. No.	Temperature (^{0}C)		J2 (days)	J3 (days)	J4 (days)	Adult female (days)	Adult female with egg mass (days)	Second stage J2 (days)
	Night	Day						
1.	15	29	1-4	5-7	8-12	13-14	15-25	26
2.	22	35	1-3	4-6	7-9	10-11	12-20	21

similar to smell of rose, but its functional activity could not be established because of non-availability of enough number of insect species.

Effect of *Cleistanthus collinus* botanical treatment on gut histology of yellow stem borer larva (YSB)

The botanical *Cleistanthus collinus* was extracted through soxhlet apparatus using three solvents *viz.,* hexane, ethyl acetate and methanol and the crude extract yield after evaporation in rotary evaporator was 2.84, 5.36 and 10.92 g per 40 g of leaf powder of *C. collinus,* respectively. The crude extract of each solvent at concentration 0.05 and 0.10% were subjected to cut stem bioassay against third instar larvae of rice yellow stem borer and found extracts of hexane and ethyl acetate showing more mortality (46.67%) where in untreated control nil mortality was observed. Further the gut histology study was undertaken to see the possible effect of *C. collinus* on gut of YSB larvae and observed disrupted basement membrane (Fig. 3.5a), disruption in epithelial cell layer and disturbed, collapsed columnar epithelial cells (Fig. 3.5b and 3.5c) in larvae fed with *C. collinus* extract treated paddy cut stems whereas no disruption observed in gut of larvae fed with water treated paddy stems (Fig. 3.5d).

Characterization of bacterial diversity associated with brown planthopper, *Nilaparvata lugens*(stål) and their role in insecticide resistance

Characterization of the bacterial communities associated with field collected populations of BPH from six different locations were undertaken. the bacteria were characterized by different morphological (colony colure, shape, appearance, size, pigmentation, etc), biochemical (starch hydrolysis, gelatin liquefaction, gram reaction, catalase and H_2S production) and molecular (16SrRNA) parameters.

On the basis of varied morphological, biochemical and molecular characterization the bacterial community were identified to belong to *Bacillus* spp, *Enterobacter* spp., *Aceneto bacter* spp. *Ochrobactrum pseudogrignonense*, *Micrococcus* spp. *Pseudomonas* spp., *Staphylococcus sciuri*, *Pantoea* spp. *Exiguobacterium enclense* which are associated with different life stages of BPH.

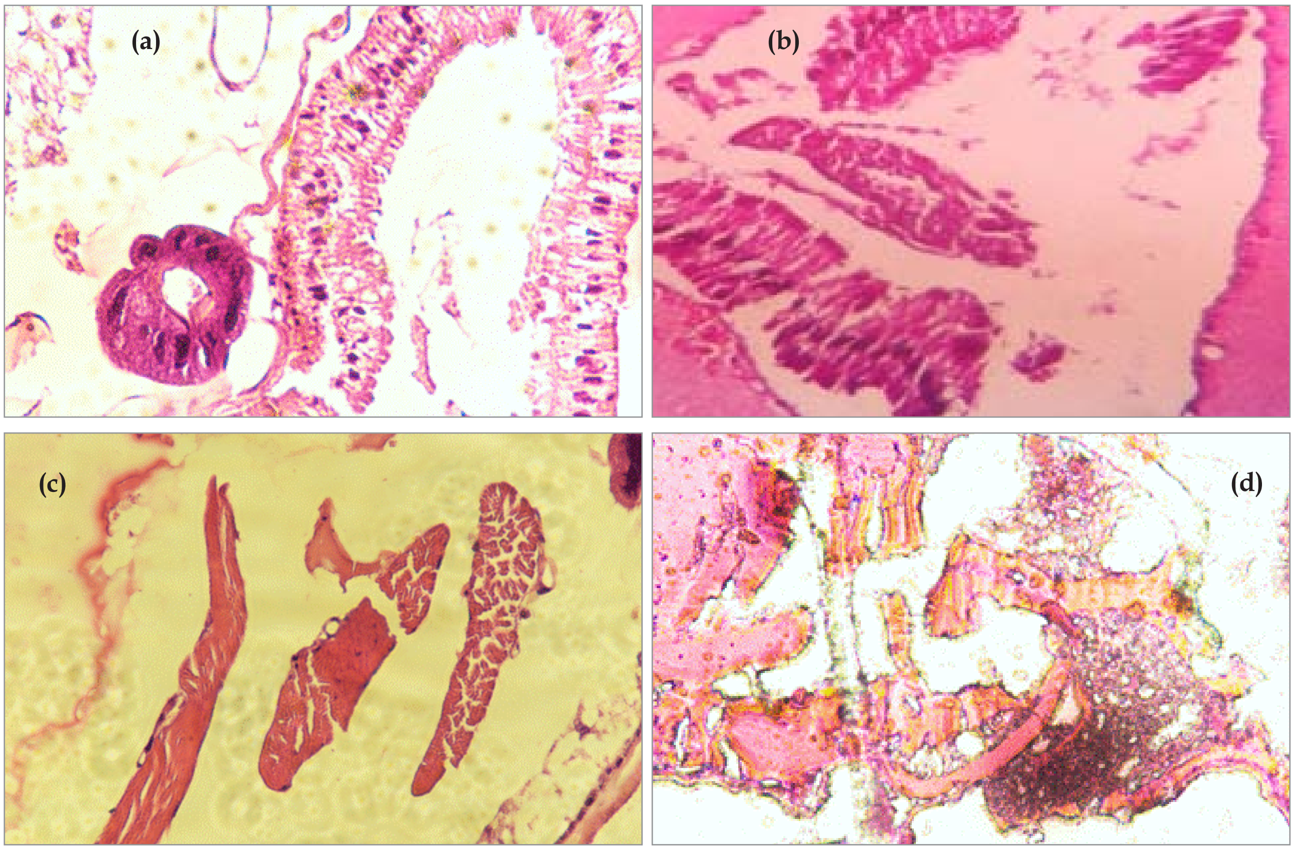


Fig. 3.5. Gut histology of YSB larvae fed with *C. collinus* treated rice stems (a-c) and untreated stems (d)

Nano-emulsion of eucalyptus oil: An alternative to synthetic pesticides against two major storage insects (*Sitophilus oryzae* and *Tribolium castaneum*) of rice

In search of an alternative and ecofriendly management of storage insects of rice an experiment was conducted to prepare nano-emulsion of eucalyptus oil of different concentrations *viz.*, 6%, 8% and 10% and tween 80 as emulsifier and water as solvent. Different ratios of eucalyptus oil and tween 80 (1:0.5 to 3.33:1) were mixed with water and the mixtures were homogenized at high rotation speed to obtain nano-emulsion (Fig. 3.6). Among all the combinations 1:2 and 1:2.5 (eucalyptus oil: tween 80) of 6% eucalyptus oil concentration in final emulsion were found to be more stable based on centrifugation, thermodynamic stability, heating and cooling, freezing and thawing. For these two combinations, the droplet sizes of nano-emulsion were 4.041 nm and 2.271 nm and poly dispersity index (PDI) were 0.372 and 0.769, respectively. The Zeta potential of these two emulsions were 6.20 mV and 7.69 mV, respectively. The bio-efficacy test against *Sitophilus oryzae* and *Tribolium castaneum* revealed that the formulated nano-emulsions were superior over original macro eucalyptus oil emulsion. The LC_{50} of 1:2 and 1:2.5 formulated nano-emulsion eucalyptus oil against *Sitophilus oryzae* were 0.563 and 0.455 µl cm^{-2}, respectively. Against *Tribolium castaneum,* LC_{50} were 1.114 and 0.899 µl cm^{-2} for 1:2 and 1:2.5 formulated nano-emulsion, respectively. Whereas, LC_{50} of bulk emulsion of eucalyptus oil (BEEO) were 0.795 and 4.178 µl cm^{-2} against *Sitophilus oryzae, Tribolium castaneum*, respectively. The formulated nano-emulsions were superior over original bulk eucalyptus oil emulsion and have great potential to be used as alternative to harmful chemical pesticides.

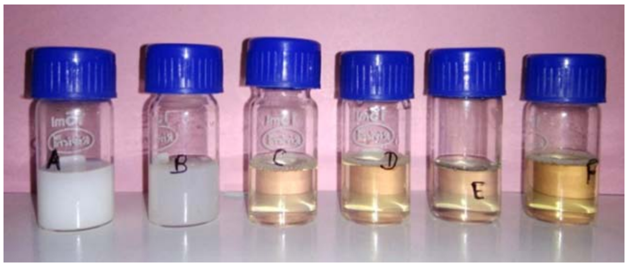


Fig. 3.6. Emulsions of eucalyptus oil prepared with different combinations of EO: Emulsifier (A-1:0.5, B-1:1, C-1:1.5, D-1:2, E-1:2.5, F-1:3)

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

Validation and promotion of IPM module in farmer's fields under shallow low land ecosystem in the farmer's fields were undertaken in the village Bodhpur of Cuttack Sadar involving 24 farmers during *kharif*, 2018 with Swarna and Pooja. In IPM practice, seed treatment was performed with carbendazim 50 WP @ 2.0 g kg^{-1} seed before sowing in nursery bed. Need based application of pesticides were undertaken by the farmers in the affected areas only. The fungicide carbendazim 50 WP @ 1.0 g $litre^{-1}$ against brown spot, sheath blight, sheath rot diseases. Cartap hydrochloride @ 1 kg ai ha^{-1} against YSB, leaf folder, BPH and need based foliar application of another insecticide chlorpyriphos 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 formulations were provided to the demonstrated farmers. Periodical monitoring and recording of disease incidences along with grain/straw yield parameters were undertaken in the presence of the participating farmers. In need based IPM practice in variety Swarna, less infestation of YSB, LF & Gundhi bug was observed as compared to scheduled based IPM practice and farmer's practice of pest management in variety Swarna. Similar observation was also observed in variety Pooja in farmer's field.

In case of treatment with Swarna IPM (Need based), least incidences of brown spot-3.92%, sheath blight-5.22%, sheath rot-3.66%, false smut-3.74% with maximum grain yield of 6.7 t ha^{-1}, straw yield of 5.2 t ha^{-1}, B:C ratio-2.2 were found followed by Swarna IPM (Schedule based) over Swarna (Farmer's practice). Treatment with Pooja IPM (Need based), least incidences of 3.76% brown spot, 4.8% sheath blight, 3.08% sheath rot, 4.57% false smut with maximum grain yield- 6.1 t ha^{-1}, straw yield- 5.5 t ha^{-1}. The B:C ratio for Swarna variety under need based IPM practice was 2.4 and Pooja 2.2 and in scheduled based IPM practice the B.C ratio, for Swarna was 2.0 and Pooja 1.7. In farmers' practice, B:C ratio for Swarna was 1.7 and Pooja 1.6. In one hectare the net return of Rs. 77250/- was obtained in Swarna need based IPM practice followed by Rs. 58750/- in Swarna schedule based practice and Rs 36750/- in Swarna farmers' practice. In case of Pooja variety these values were Rs. 67,500/-, Rs. 46,750/- and Rs. 31,250/-, respectively.

Trichoderma for rice health management

Germination and early vigour

Notable differences in mean germination time and vigour indices were observed among the treatments. Mean germination time, Vigour index-I and Vigour index-II of different *Trichoderma* treated seeds ranged from 2.13 to 4.13 days, 2166.67 to 3413.33 and 11.00 to 18.33, respectively in variety Shatabdi. Similarly, Vigour index-I and Vigour index-II notably differed among the treatments. In Annapurna highest vigour indices was observed with CRRIT-15 treatment followed by CRRIT-2.

Estimation of chlorophyll content

Sound variations were observed in chlorophyll a and chlorophyll b content, total chlorophyll content, and chlorophyll a/b ratio among the treatments in both the varieties. Total chlorophyll content ranged from 4.61 mg g^{-1} to 18.78 mg g^{-1} in Annapurna rice variety. CRRIT-2 treated plants of Annapurna exhibited highest total chlorophyll content. Total chlorophyll content in variety Shatabdi ranged from 1.39 mg g^{-1} to 25.96 mg g^{-1}. Seeds inoculated with T. hebeiensis (CRRIT-15), T. parareesei (CRRIT-16), T. erinaceaum (CRRIT-2), Trichoderma longibrachiatum (CRRIT-22) exhibited comparatively higher effects on chlorophyll content as compared to other isolates described in the present investigation.

Growth promotion as indicated by agronomical parameters

Most of the *Trichoderma* strains controlled the plant growth and yield parameters. Root and shoot length, dry and fresh weight was significantly improved in both the varieties. No. of tillers/hill varied notably among the treatments. Yield of Annapurna ranged from 19.59 to 31.14 g/hill, here the highest value was recorded from CRRIT-15 (31.14g/hill) followed by CRRIT-16 (30.54 g/hill) and CRRIT-3 (29.23 g/hill). Similarly, significant difference was observed in yield of Shatabdi and CRRIT-15 treatment exhibited the highest yield (43.53 g/hill) followed by CRRIT-16 (40.80g/hill) and CRRIT-27 (40.38 g/hill). As an overall study all the isolates performed better than the control one. (Fig. 3.7 (a) and (b))

Expression of stress related enzymes

Significantly higher expression of the stress related enzymes was observed in *Trichoderma* treated plants as compared to untreated plants against both the rice varieties. Similarly, CRRIT-15 and CRRIT-2 treated root and shoots of rice variety Annapurna and Shatabdi had notably higher SOD activity compared to other treatments. Whereas, catalase activity was drastically higher in CRRIT-15 and CRRIT-2 treatment in both root and shoot. The same trends were observed in the expression of peroxidase in root and shoot samples of both the varieties.

Use of *Trichoderma* based formulation 'Rice Vit' as a Biostimulant promoting growth in hybrid rice "Ajay"

NRRI *Trichoderma* based formulation 'Rice Vit' was used for seed treatment in the hybrid rice Ajay in the farmers field of Chandol, Kendrapada. This formulation enhanced root and shoot length, fresh and dry weight and also number of effective panicles /hill significantly (Fig. 3.8). Yield of control was 46.58g/hill and *Trichoderma* treated one was 65.51g/hill.

Optimization of chemical pesticide-use for management of rice pests in different eco-systems

In long term pesticide trial (*rabi* and *kharif* 2018), the

Shatabdi (a) Annapurna (b)

Fig. 3.7. Effect of *Trichoderma spp.* Seed dressing on seedlings of rice variety Shatabdi and Annapurna (T0=control, T1, T2, T3, T15, T16, T22 & T27 are different spp. of *Trichoderma*)

Fig. 3.8. Effect of *Trichoderma* based 'Rice Vit' seed treatment in Ajay

grain yield of insecticide Cartap were 6.1 t ha^{-1} and 4.9 t ha^{-1} followed by Chlorpyriphos were 5.7 t ha^{-1} and 4.7 t ha^{-1} and Carbendazim (4.9 t ha^{-1} and 3.9 t ha^{-1}), Pretilachlor (4.7 t ha^{-1} and 3.8 t ha^{-1}), whereas in control 4.1 t ha^{-1} and 3.2 t ha^{-1}, respectively.

During *kharif* 2018, out of 8 treatments, the pesticide combinations DPX-RAB 55+ Contaf@ (0.48+2.0) ml l^{-1} and DPX-RAB 55 + Baan @ (0.48+0.6) ml l^{-1} recorded highest grain yield (4.4 t ha^{-1}) followed by Engage+ Baan @ (0.75+0.6) ml l^{-1} recorded 4.3 t ha^{-1}, Engage +Contaf @(0.75+2.0) ml l^{-1} recorded 4.2 t ha^{-1}. These pesticide combinations were found very effective against stem borer, leaf folder, gundhi bug and blast disease.

During *rabi* 2018, out of eight treatments, the pesticides combination Chlorantraniprole 20% + Carbendazim+Mancozeb 50% (Coragen+CM75) was recorded highest grain yield (6.1 t ha^{-1}) followed by Chlorantraniprole 20%+ Validamycin 3% (Coragen +V3) (6.0 t ha^{-1}) and Dinotefuran 20% + Carbendazim+Mancozeb 50%) (Token + CM75) (5.9 t ha^{-1}). These pesticides combinations are found very effective against stem borer, leaf folder, gundhi bug and blast disease.

Eleven different chemicals were screened against *Xanthomonas oryzae* pv. *oryzae in-vitro*. Out of which, chloramphenicol was recorded to be the best and 6 other chemicals exhibited growth inhibition. Two chemicals were superior to streptocycline. For further determination of dose, *in vivo* studies are being conducted.

Evaluating the *in vivo* efficacy of new combination fungicides against sheath blight disease in rice, caused by *Rhizoctonia solani* Kuhn

Field experiment was conducted in R.B.D design at NRRI farm during *kharif*, 2018 with 9 treatments and four replications. The treatments taken during the experimentation were T1- flusilazole 12.5% + carbendazim 25%SC @ 1.0 ml l^{-1}, T2-azoxystrobin 18.2%w/w + difenoconazole 11.4% w/w SC @1.0 ml l^{-1}, T3- azoxystrobin 11% + tebuconazole 18.3% w/w SC @ 1.5 ml l^{-1}, T4- tricyclazole 18% + mancozeb 62% WP @ 2.5 g l^{-1}, T5- zineb 68% + hexaconazole 4% WP @ 2.5 g l^{-1}, T6- trifloxystrobin 25% + tebuconazole 50% WG @ 0.4 g l^{-1}, T7- mancozeb 50% + carbendazim 25%WS @ 2.5 g l^{-1}, T8- fluxapyroxad 62.5 g l^{-1} + epoxiconazole 62.5 g l^{-1} EC @1.5ml/litre and T9-Control. From the critical observations and computed analysis, best treatment was T3- azoxystrobin 11%+ tebuconazole 18.3% w/w SC @ 1.5 ml l^{-1} showing 15.8% disease severity, 78.8% reduction in disease severity over control; 20.6% disease incidence, 73.7% reduction in disease incidence; grain yield- 5.67 t ha^{-1} & 68.2% increase in grain yield over control. Second significant treatment was T2- azoxystrobin 18.2%w/w + difenoconazole 11.4% w/w SC @ 1.0 ml l^{-1} which showed 16.4% disease severity, 77.9% reduction in disease severity over control; 23.4% disease incidence, 70.1% reduction in disease incidence; grain yield-5.33 t ha^{-1} & 58.2% increase in grain yield over control.

***In vitro* efficacy of two proven effective fungicides, azoxystrobin 23% SC and validamycin 3% L each in six concentrations of 50ppm, 100ppm, 200ppm, 500ppm, 750ppm, 1000ppm *w.r.t* inhibition of per cent mycelial growth and sclerotial formation**

An *in vitro* (lab works) study was conducted to evaluate the relative efficacy of two proven efficient fungicides azoxystrobin 23% SC and validamycin 3% L each in above six concentrations where critical observations on inhibition of percent mycelial growth and sclerotial formation were recorded, where the fungicide validamycin 3% L was found relatively more effective than azoxystrobin 23% SC at 750ppm and 1000ppm concentrations.

Sensitivity study of false smut pathogen (*Usilaginoidea virens*) to different fungicides

Four systemic fungicides (technical grade) of different mode of action, *viz.*, azoxystrobin (strobilurin group -mitochondrial respiration inhibitor) and propiconazole & tebuconazole (Triazole group -a sterol demethylation inhibitor) and carbendazim (benzimidazole group - interfering with spindle formation during mitosis of cell) were assayed against the *U. virens* culture of native isolate following poisoned food technique under ideal laboratory condition. LD50 values for azoxystrobin (Az), propiconazole (Prop), tebuconazole (Tebu) and Carbendazim inhibiting mycelial growth of the *U. virens* (Isolate NRRI-FS-1) were calculated as 0.08, 0.05, 0.035 and 0.5 µg ml^{-1} respectively.

Evaluation of new molecules against false smut pathogen: Eight new combination fungicides were tested against false smut pathogen under field condition during *kharif 2018* following standard evaluation method. Fungicides Fluxapyroxad 62.5% + Epoxyconazole 62.5% (1.5 ml l^{-1}) followed by Azoxystrobin 11% + Tebuconazole 18.3% (1.5 ml l^{-1}) was found best based on percent panicle and percent spikelet infection for controlloing false smut disease (Fig. 3.9).

Understanding the effects of abiotic factors on chlorantraniliprole degradation

Chlorantraniliprole (CAP) is widely used insecticide in rice ecosystem for insect management. Laboratory studies were conducted to investigate the dissipation behaviour of CAP insecticide in two common Indian soil (Alluvial and Red soil). The physico-chemical properties of alluvial soil were pH 5.68, EC 0.67 dS m^{-1}, organic carbon 0.7% and total nitrogen 0.07%, whereas, red soil had pH 5.57, 0.53 dS m^{-1} EC, 0.41% organic carbon and 0.05% total N. CAP when applied at recommended dose (RD) (@ 40g a.i. ha^{-1}) and double recommended dose (DRD) could not be recovered from both the soils after 60 days post application. Dissipation half-lives of CAP from alluvial soil was 43.31 days in both the doses. Whereas, dissipation half-lives of CAP from red soil were 36.47 and 43.31 days for RD and DRD treatments, respectively. Higher clay content in alluvial soil led to higher half-life of CAP compared to red soil. Another experiment was conducted to study the effect of different water Ph (4, 7 and 9.2) solutions on insecticide degradation. The results showed that degradation of chlorantraniliprole in water followed first-order kinetics. The result revealed that CAP was considerably stable at pH 4 and 7 but degrades at faster rate at pH 9. Among different available formulations, CAP slowly released in the water from Ferterra (0.4 GR) as compared to Coragen (18.5 SC).

Degradation of mixture of pesticides from indigenously developed biobed systems

Conventional Swedish biobed concept is a mixture of top soil, manure/peat and straw at the ratio of 1:1:2. Several cost-effective materials can be used as biobed mixture. In this experiment we tried to develop a biobed system using FYM, straw, soil and vermicompost at different ratio as follows: A)

	Treatment	Dose
T1	Flusilazole 12.5% + Carbendazim 25%	1.0 ml/l
T2	Azoxystrobin 18.2% + Difenconazole 11.4%	1.0 ml/l
T3	Azoxystrobin 11% + Tebuconazole 18.3%	1.5ml/l
T4	Tricyclazole 18% + Mancozeb 62%	2.5g/l
T5	Zineb 68% + Hexaconazole 4%	2.5g/l
T6	Trifloxystrobin 25%+ Tebuconazole 50%	0.4g/l
T7	Mancozeb 50% + Carbendazim 25%	2.5g/l
T8	Fluxapyroxad 62.5% + Epoxyconazole 62.5%	1.5ml/l
T9	Control	

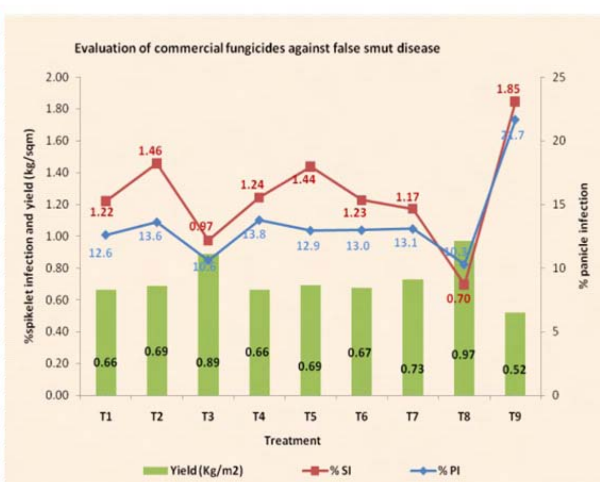


Fig. 3.9. Evaluation of new combination fungicides

Straw:Soil:FYM::33:33:33 B) Straw: Soil: Vermicompost :: 33:33:33, C) Straw:Soil: Vermicompost: FYM:: 25:25:25:25 D) Straw: Soil:FYM::50:25:25 E) Straw:Soil:Vermicompost:: 50:25:25. Threepesticides, i.e. 1 ml of imidacloprid (17.8 SL), 1 g of carbendazim (50 WP) and 1 ml of bispyribac sodium salt (10 SC) were mixed to 100 ml of water and sprayed over the top of the biobed column. Higher rate of degradation of imidacloprid during the first 30 days was observed in the biobed column with Straw: Soil: FYM::50:25:25, whereas lowest degradation occurred in column"E" (Fig. 3.10). The highest amount of bispyribac sodium degraded on column "D". The dissipation rate of carbendazim was highest in the column "A"as compared to other biobed columns. Biobeds were effective to reduce the pesticide concentration less than one percent of the initial amount loaded after 90 days. Among all the biobed mixtures, Straw:Soil: FYM::50:25:25 found to be the best.

Phosphine bioassay studies against important stored grain pests of rice

Laboratory bioassays were conducted to enumerate LC_{50} values for phosphine against different stages of important stored grain pests of rice *viz.*, lesser grain borer, *Rhyzopertha dominica*, rice weevil, *Sitophilus oryzae* rust-red flour beetle, *Tribolium casteneum* and grubs of Khapra beetle, *Trogoderma granarium* as per protocol mentioned in FAO Method No. 16 (FAO Plant Protection Bulletin 23). The results of probit analysis against different test insects indicated that at 24 hours after treatment (HAT) *S. oryzae* and *R. dominica* strain of Cuttack location were most susceptible to phosphine with LC_{50}values of 2.88 and 4.32 ppm. However, *T. granarium* larvae were comparatively tolerant to Phosphine by registering LC_{50} of 461.52 ppm similarly, *T. castenium* was found to be tolerant to Phosphine at all the life stages tested. Eggs were found to be resistant to Phosphine

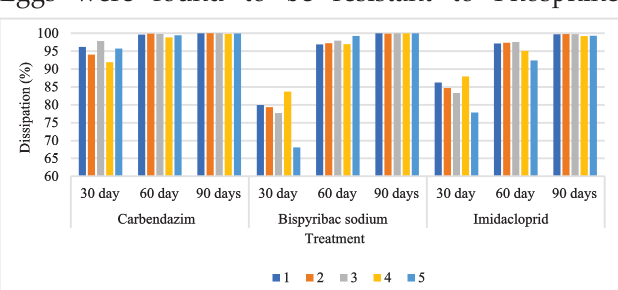


Fig 3.10. Dissipation of three pesticides from biobed mixtures

followed by adults/larvae registering LC_{50}values of 1091.52 and 309 ppm, respectively that may be attributed to rate of respiration, which was found to be least in egg stage compared to adult/larval stage.

Study the efficacy of Dinotefuran against five population of BPH

Field populations of *N. lugens* were collected from various rice growing areas of India, *viz.*, Odisha, Haryana, Kerala, Chhattisgarh and Punjab between March to December, 2017. Laboratory reared and field collected BPH populations were subjected to toxicological bioassays (rice-stem dipping method) to assess their resistance levels to commonly used insecticides in the sampled areas, Dinotefuran. The mortality data from the insecticide bioassays were subjected to probit analysis for the determination of lethal concentration values (LC_{50}). Karnal and Punjab BPH populations were found to have lesser susceptibility against Dinotefuran compared to Bargarh, Kerala and Raipur population. Resistance factors (RF) were estimated at the LC_{50} level as RF = LC_{50} of field population / LC_{50} of laboratory reared susceptible population. The classification of resistance levels was done based on the RF as RF value <10- fold as low resistance, RF = 10–40-folds as moderate resistance, RF = 40–160-folds as high resistance and >160-fold as extremely high resistance. The field populations were found to exhibit low to moderate levels of resistance against Dinotefuran.

Efficacy of different chemicals against rice root knot nematode, *M. graminicola* under pot culture condition

The experiment was carried out in one kg pot containing sterilized soil and with 15 days old rice seedling at the rate of one seedling / pot. These chemicals were given through soil drenching at the recommended doses. Nematodes were inoculated 24 h after the application of the chemicals at the rate of one J_2/g soil. Each treatment was replicated thrice in RBD. Experiment was terminated 30 days after inoculation of juveniles and observations were recorded on the root population of the nematodes. Among the different treatments, carbofuran recorded least number of galls, females and eggs in the root system when compared to other treatments. Highest nematode population was recorded in untreated control.

PROGRAMME : 4

Biochemistry and Plant Physiology of Rice for Grain Quality, Abiotic Stress Tolerance and Improving Photosynthetic Efficiency

Rice being staple food for most of the population, exhibits relatively high glycemic index (GI) value compared to other carbohydrate rich foods, which may lead to obesity and type-II diabetes. Grown under diverse ecosystems under changing climatic conditions it gets exposed to different environmental stresses reducing grain yield and quality. To address the problems, this programme is developed with three objectives to study about low GI and high protein rice; to identify donors and understand physiological and molecular mechanism of abiotic stress tolerance; to enhance photosynthetic efficiency by introduction of C4 pathway and minimizing photorespiration. In the present study, rice varieties released by the institute were evaluated and large variations were observed in the GI values (57.5-76.4) and resistant starch (RS) content (0.28-2.94%). Further, the effect of drought stress on RS and GI showed that Kamesh, ZHU-1-26, IR 20 and Annada have lower reduction in amylose content and RS resulting in significant change in GI values. N-metabolism pattern in contrasting grain protein varieties for N-uptake enzymes were also studied at different growth stages. Free fatty acid content was determined in 15 rice varieties at every three-month interval for 15 months to establish a correlation between free fatty acid formation and ageing of rice.

Under abiotic stress physiology, six ARC accessions and five released high yielding varieties consistently performed as drought tolerant donors with SES score '1' in two consecutive years. Genotypes N-22 and Annapurna had high translocation of non-structural carbohydrates from source to sink tissue leading more grain yield stability under high temperature stress. Relative gene expression of Sedoheptulose 1-7 bisphosphate of Taraori Basmati under different light intensities had maximum expression showing its photosynthetic adaptability to low light stress. Drought tolerant lines AC 3577, IC 516009, Parijat, PAU 9, Mahulata and Rameswari showed 65-80% survival under two weeks of complete submergence imposed at early vegetative stage, further AC 1303 and AC39416A showed tolerance to combined stress of submergence with saline water indicating their multiple stress tolerance ability. Genotypes like AC 42088, AC 42087 and AC 1303, were found to withstand 3-weeks of complete submergence. Pokkali (AC 41585), a good Na+-excluder managed to sequester higher Na+ load in the roots with little upward transport while, moderately salt-tolerant Lunidhan found to have less selectivity in Na+-transport, but possessed higher capacity to Na+-sequestration in leaves.

For enhancing photosynthetic efficiency, introduction of C4 *Sorghum bicolor* Carbonic anhydrase (CA) enzyme in rice was done. The cassette (CaMV35S-SbCA-nos) was subcloned in the binary vector to produce pCAMBIA1301-CaMV35S-SbCA-nos construct and was confirmed by restriction digestion. Study in the *SbCA* gene expression showed enhanced expression levels in the transgenic than the control and vector control plant. Approximate 2-5 fold higher CA enzyme activity and increased net photosynthetic rate was observed in *SbCA* transgenic over control and vector control plants.

Rice grain quality in relation to glycemic index, mineral bio-availability and protein content

Screening of rice germplasm for high Resistant starch (RS), amylose content (AC) with low glycemic index (GI) using *in vitro* enzymatic method

Biochemical analysis was done to determine the GI and RS in 100 NRRI rice varieties. Large variation in the value of GI (57.50-76.40) and RS (0.28-2.94%) was observed. Among the genotypes studied, Shaktiman showed lowest GI (57.50) with relatively high RS (2.11%). Gayatri had the highest RS content (2.94%) with relatively low GI (60.31). The highest value for GI (76.40) was found for Hue with lowest RS (0.28%). A significant negative correlation was observed between GI and RS. (Fig. 4.1. a, b)

Thirty drought tolerant genotypes were studied for the effect of stress on GI and AC in the grains. Rice genotypes ZHU-1-26, IR-20, Ananda, Kamesh exhibiting lower reduction (<1) in GI values along with Swarnaprava (1.34), APO, Anjali (1.75) while wide variation was observed for rest of the genotypes (Fig. 4.2).

Ghee and soybean oil resulted in maximum GI lowering effect compared with other cooking oils. Pigeon pea resulted in maximum GI lowering effect compared with other pulses. Fenugreek seed, leaf and cauliflower showed maximum GI lowering effect compared with other vegetables.

Understanding the biochemical changes in rice during storage

To establish the correlation between free fatty acid (FFA) generation with ageing, FFA estimation was done in 15 different rice genotypes (grouped in pigmented, non-pigmented and scented) at every three months interval for 15 months. Observation showed that in all varieties FFA production increased till 12 months of aging then it decreased. FFA value ranged from 0.283% to 0.412% in pigmented varieties, 0.286 to 0.538% in non-pigmented varieties and 0.474 to 0.483% in scented varieties after 15 months of ageing (Fig. 4.3.a, b, c). Level of FFA production was found to be less (15-20%) in pigmented varieties as compared to non-pigmented varieties.

Estimation of nitrate reductase (NR) and nitrite reductase (NiR) in the three varieties viz. Naveen, Heera and CR Dhan 310 for understanding the nitrogen assimilation pattern

To understand the nitrogen assimilation pattern, estimation of Nitrate reductase (NR) and Nitrite reductase (NiR) activity was conducted at different plant growth stages in three varieties *viz.,* Naveen (Low grain protein content), Heera (High grain protein content) and CR Dhan 310 (NRRI released high grain protein content). It was found that both NR and NiR activity for Heera and CR Dhan 310 were higher than that of Naveen. Interestingly, the activities of the nitrate uptake enzymes in Heera and CR Dhan 310 were found to be at par (Fig. 4.4. a & b).

Physiology of rice for individual and multiple abiotic stress tolerance

Evaluation of rice genotype for vegetative stage drought tolerance

Out of 402 ARC accessions and 503 released high yielding rice varieties screened for vegetative stage drought tolerance under field condition during dry season 2018, 06 ARC accessions (ARC 7336, ARC 7343, ARC 10260, ARC 10304, ARC 10314 and ARC 11124) and 05 released high yielding varieties (Kalyani-2, IR 64 MAS, Kalinga II, CSR 18 and Krishnahamsa) were consistently identified as drought tolerant donors with SES score '1' and 03 ARC accessions as susceptible donors with SES score '9' in two consecutive years. Nine double haploid lines out of 100 and 05 pigmented lines out of 119 also showed high tolerance in the first year of screening (Fig. 4.5).

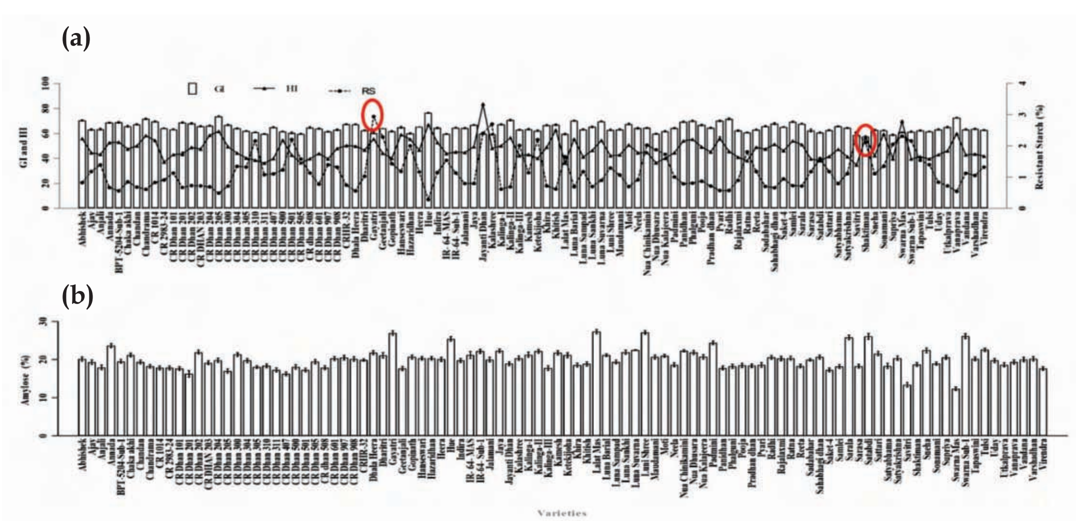


Fig. 4.1. (a & b). GI, RS and AC values of 100 NRRI rice varieties

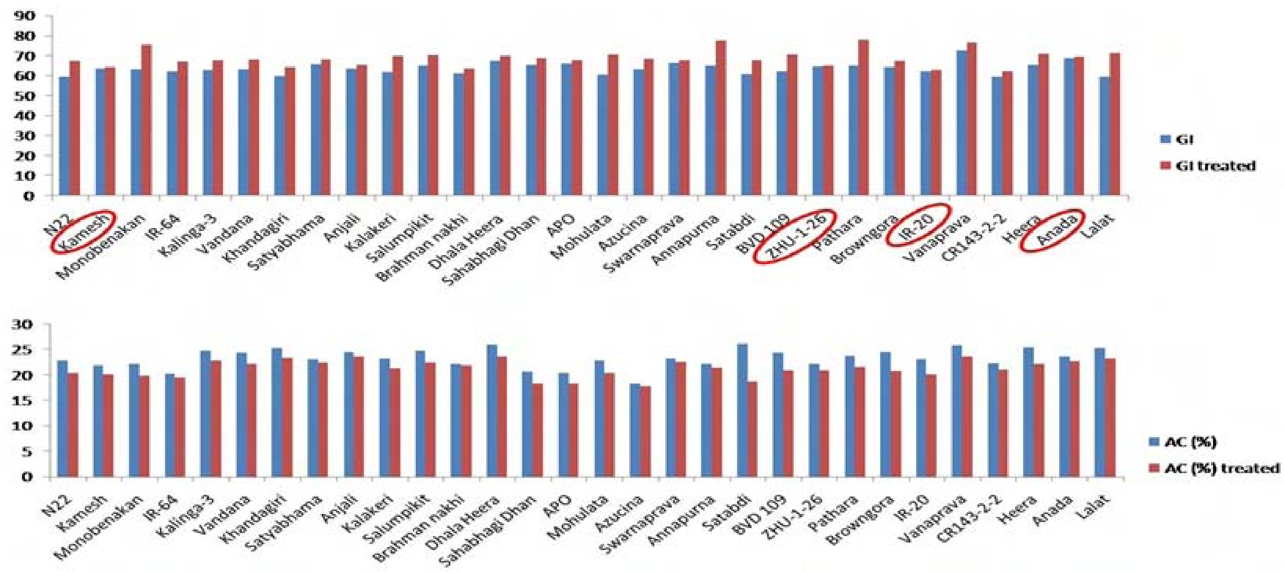


Fig. 4.2. Variation in GI and AC in selected drought tolerant genotypes

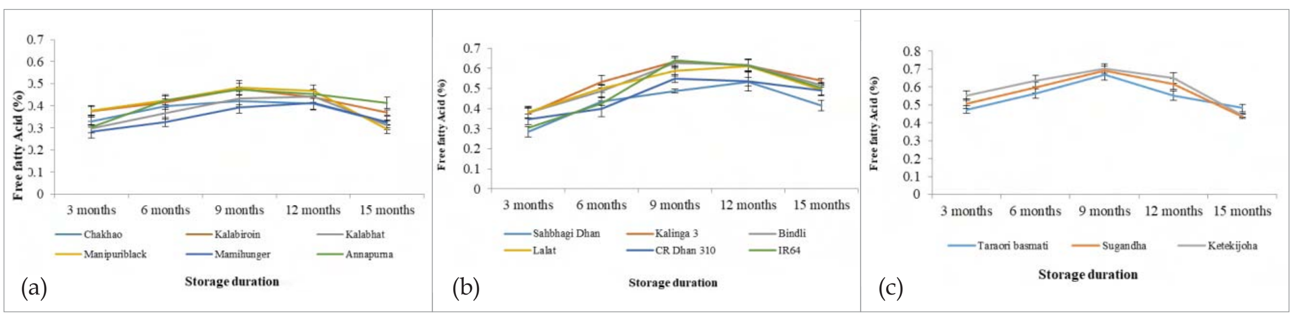


Fig. 4.3. Variation in FFA concentration in a) pigmented varieties b) non-pigmented varieties and c) non-pigmented scented varieties of rice during 15 months of aging

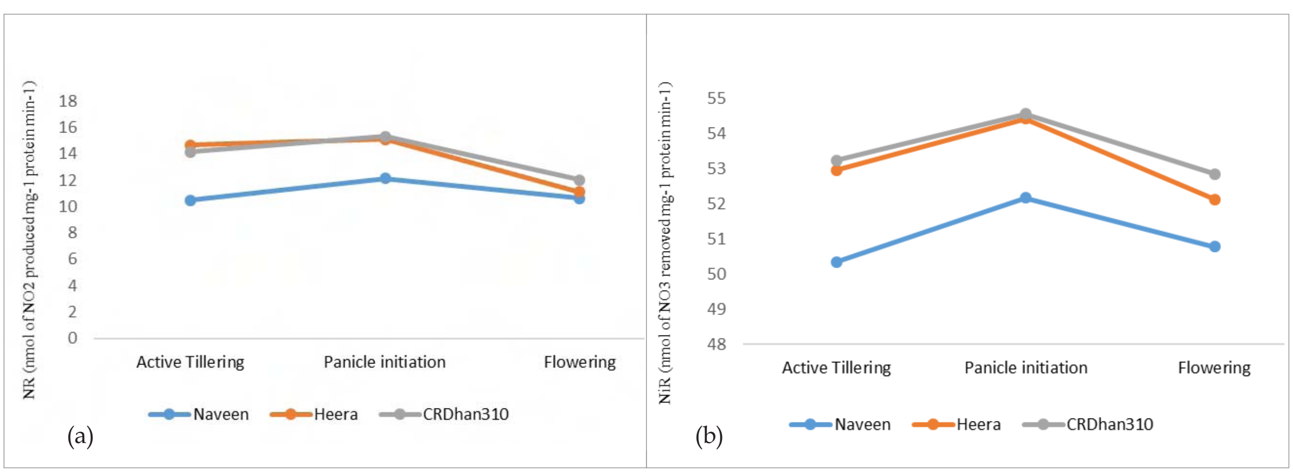


Fig. 4.4. (a & b). Activity of nitrate reductase (NR) and nitrite reductase (NiR) at different growth stages in the three varieties

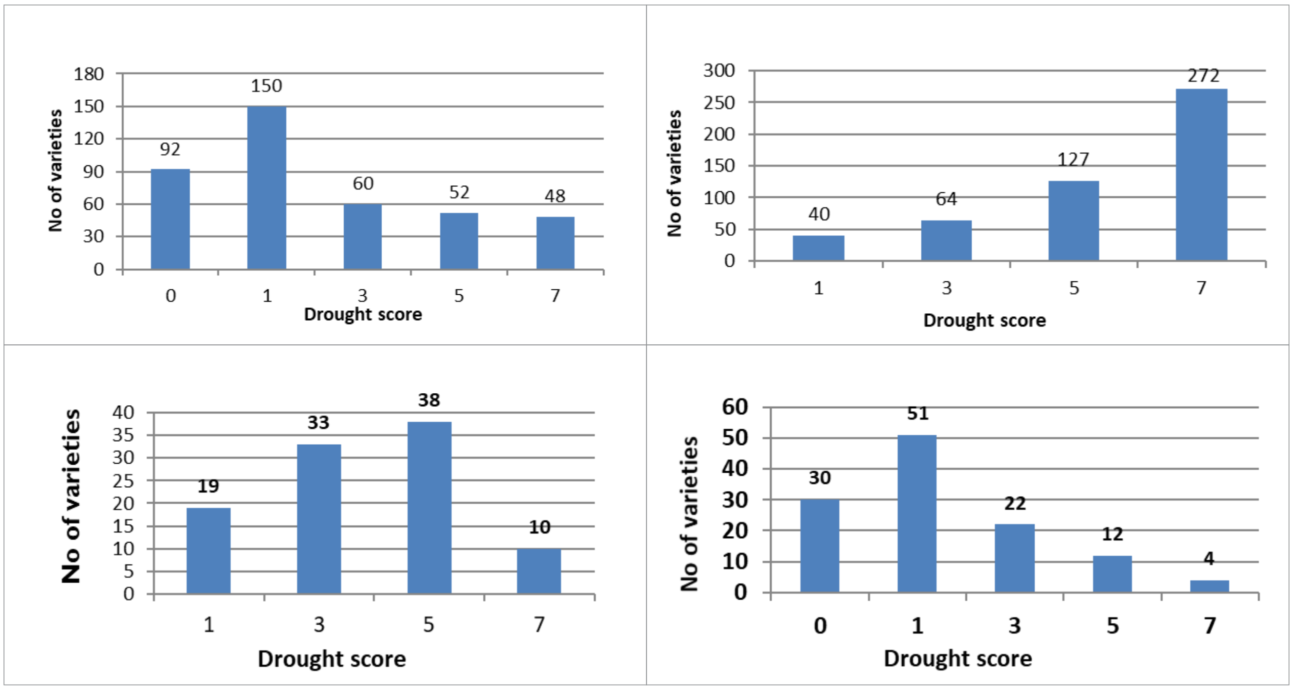


Fig. 4.5. Distribution of different group of rice genotypes for drought tolerance

Non-structural carbohydrates translocation under high temperature stress

Seven rice varieties were grown under four staggered sowing and tested for their ability of non-structural carbohydrates translocation under high temperature, it was observed that N-22, and Annapurna had better partitioning efficiency hence the yield reduction was less pronounced in these varieties. N-22, Annapurna have higher capacity to translocate NSC from source to sink tissue which could lead to more grain yield stability (Fig. 4.6).

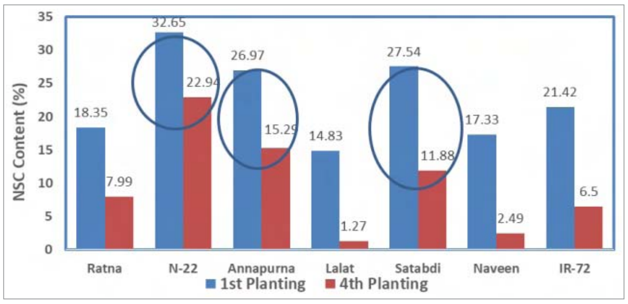


Fig. 4.6. Non-structural carbohydrates (NSC) translocation under normal and high temperature stress

Grain quality traits like milling%, HRR% and Amylose content were also affected considerably under high temperature stress for all the varieties while gel consistency was found to be less affected.

Evaluation of rice genotypes under low light stress

Eleven rice genotypes were screened for their response to light tolerance under 100%(NL), 75% and 50% of light intensities (LL). Total chlorophyll content increased and Chlorophyll a/b ratio decreased under low light stress which is considered as a marker phenotype for the screening of low light tolerant genotypes. Among the genotypes PS-3, T. Basmati and BVS-1 during dry season and Panindra and PS-3 during wet season showed a pronounced decrease in Chlorophyll a/b ratio. Relative gene expression studies of Sedoheptulose 1-7 bisphosphate by qRT-PCR were carried out for the samples collected from T. Basmati at NL, 25%-LL and 50%-LL conditions. Maximum expression of the particular gene was observed at flowering stage showing its photosynthetic adaptability to low light stress which was reflected in its non-significant yield loss (Fig. 4.7).

Evaluation of rice genotypes for multiple abiotic stress tolerance

A total of 80 genotypes, already identified for vegetative stage drought tolerance, were evaluated for submergence tolerance in *kharif* 2018. four genotypes *viz.*, Parijat, PAU 9, Mahulata and Rameswari, showed 65% survival and two genotypes AC 3577 and IC 516009, showed ~80% survival under two weeks of complete submergence imposed at early vegetative stage (25 DAS), whereas the susceptible check Swarna and tolerant check Swarna *sub-1* had

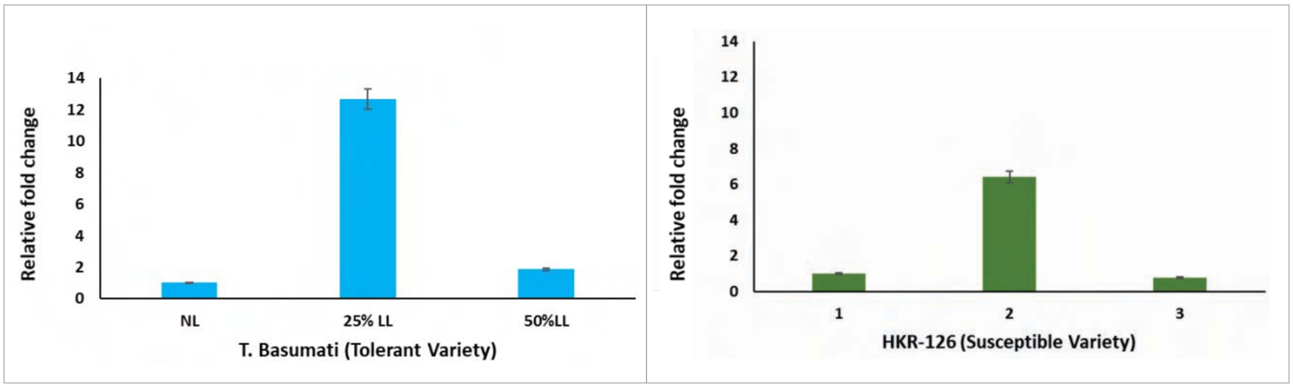


Fig. 4.7. Relative gene expression studies of Sedoheptulose 1-7 bisphosphate

survival of 22 and 94%, respectively.

In combined stresses of salinity and submergence test, genotypes AC 1303 and AC 39416A were found to be tolerant to individual stresses as well as combined stress of submergence with saline water. Rashpanjor was found to be tolerant to salinity stress at vegetative stage and tolerant to both fresh and saline water at flowering stage.

Genotypes like AC 42088, AC 42087 and AC 1303, could withstand 3-weeks of complete submergence stress compared to FR13A, the known tolerant check for submergence stress (Table 4.1)

Identification of key Na^+ and K^+ transporters for reproductive stage salt tolerance in rice

Four rice genotypes *viz.,* Pokkali (AC 41585), Chettivirippu (AC 39394), Lunidhan and Sabita were subjected to salt stress (EC_{iw}= 8.0 dS m^{-1}) at flowering stage. Ionic discrimination of flag leaf governed by differential expression of Na^+ and K^+ specific transporters/ion pumps was found to be associated with reduced spikelet sterility and reproductive stage salt-tolerance in rice (Fig. 4.8). Pokkali (AC41585), a good Na^+-excluder managed to sequester higher Na^+ load in the roots with little upward transport as evidenced by greater expression of *HKT1* and *HKT2* transporters. In contrast, moderately salt-tolerant Luni dhan found to have less selectivity in Na^+-transport, but possessed higher capacity to Na^+-sequestration in leaves. Higher K^+-uptake and tissue specific redistribution mediated by HAK and AKT transporters showed robust control in selective K^+-movement from root to flag leaf and developing panicles.

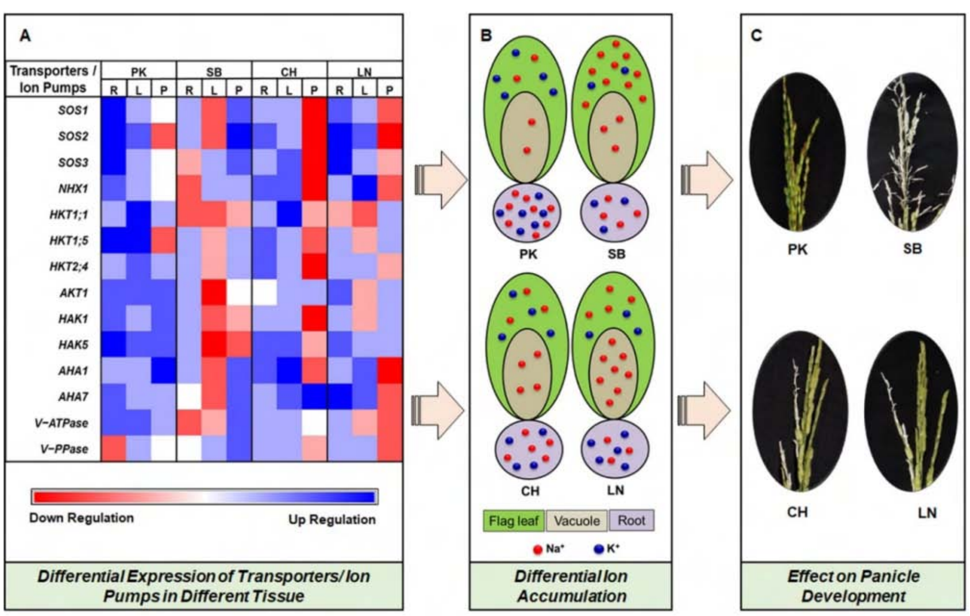


Fig. 4.8. Differential expression of Na+ and K+ ion transporters in different locations of rice plants

Effect of leaf gas film on submergence tolerance of rice

Diversity in leaf gas film (LGF) thickness was assessed in some of the known submergence tolerant genotypes and highest thickness of LGF in FR 13A and lowest in IC4 50292 was observed and removal of LGF resulted loss of submergence tolerance with higher seedling mortality. Gene controlling epicuticular wax accumulation *LGF1* found to be correlated with thickness of LGF and leaf hydrophobicity.

Influence of silicon solubilizers on induced stress tolerance in rice genotypes:

Silicon solubilizer- Silixol observed to have positive effect on increasing biomass and grain yield also mitigation option to tolerate drought in general and US-312 followed by HRI-174 indicated better performance having high grain yield (>6.5 and 4.5 t ha^{-1}, respectively) under both the conditions (Fig 4.9).

Screening of elite rice genotypes for Drought Tolerance under rainfed upland condition:

Out of thirty promising breeding lines tested under rainfed upland condition, five genotypes (RFU 213, RFU 217, RFU 219 and RFU 222 recorded high grain yield of more than 2.5 t/ha with low relative yield reduction (RYR) of 10-33% and low drought susceptibility index (DSI) of less than 0.50. However, another six lines had RYR of 39-51% and DSI of 0.61-0.78 yielding more than 2.0 t ha^{-1} under rainfed upland condition.

Table 4.1. List of rice genotypes identified for unique abilities of abiotic stress tolerance

Sl. No.	Specific abiotic stress tolerance trait	Genotypes identified/tested
1.	Drought and submergence tolerance at vegetative stage	AC 3577, IC 516009, Parijat, PAU 9, Rameswari, Mahulata
2.	Salinity, submergence and combined stresses of salinity and submergence at vegetative stage	AC 1303, AC 39416A
3.	Salinity at vegetative stage and combined stresses of waterlogging and salinity at flowering stage	Rashpanjor
4.	Submergence stress beyond two weeks	AC 42087, AC 42088, AC 1303

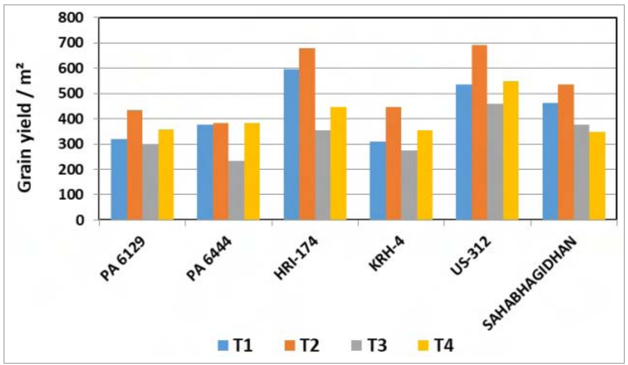


Fig 4.9. Grain yield of rice varieties influenced by silicon solubilizers (silixol) inducing moisture stress tolerance. T1- Control, T2- Control + Silixol application, T3- Water stress, T4- Water stress + Silixol application

Improvement of photo synthetic efficiency of rice

Cloning & transformation of Sorghum Carbonic anhydrase enzyme in rice

To increase the photosynthetic efficiency of rice attempt was made for cloning and transformation of C4-Sorghum carbonic anhydrase enzyme in rice.

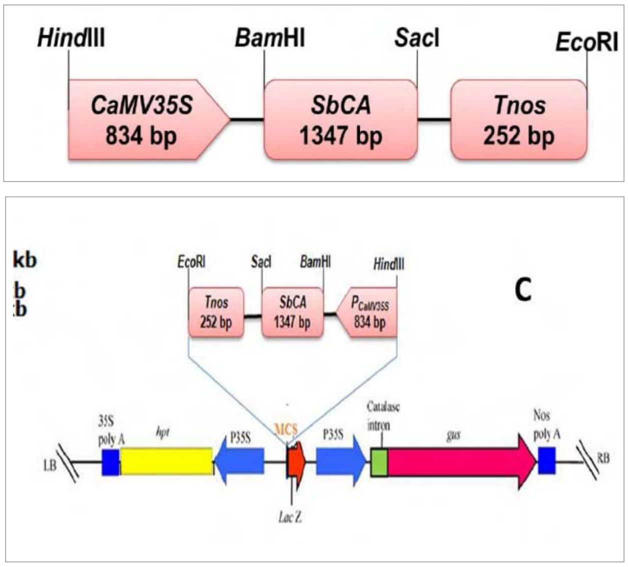


Fig 4.10. Cloning of PCaMV35S-SbCA-nos at MCS of pCAMBIA1301

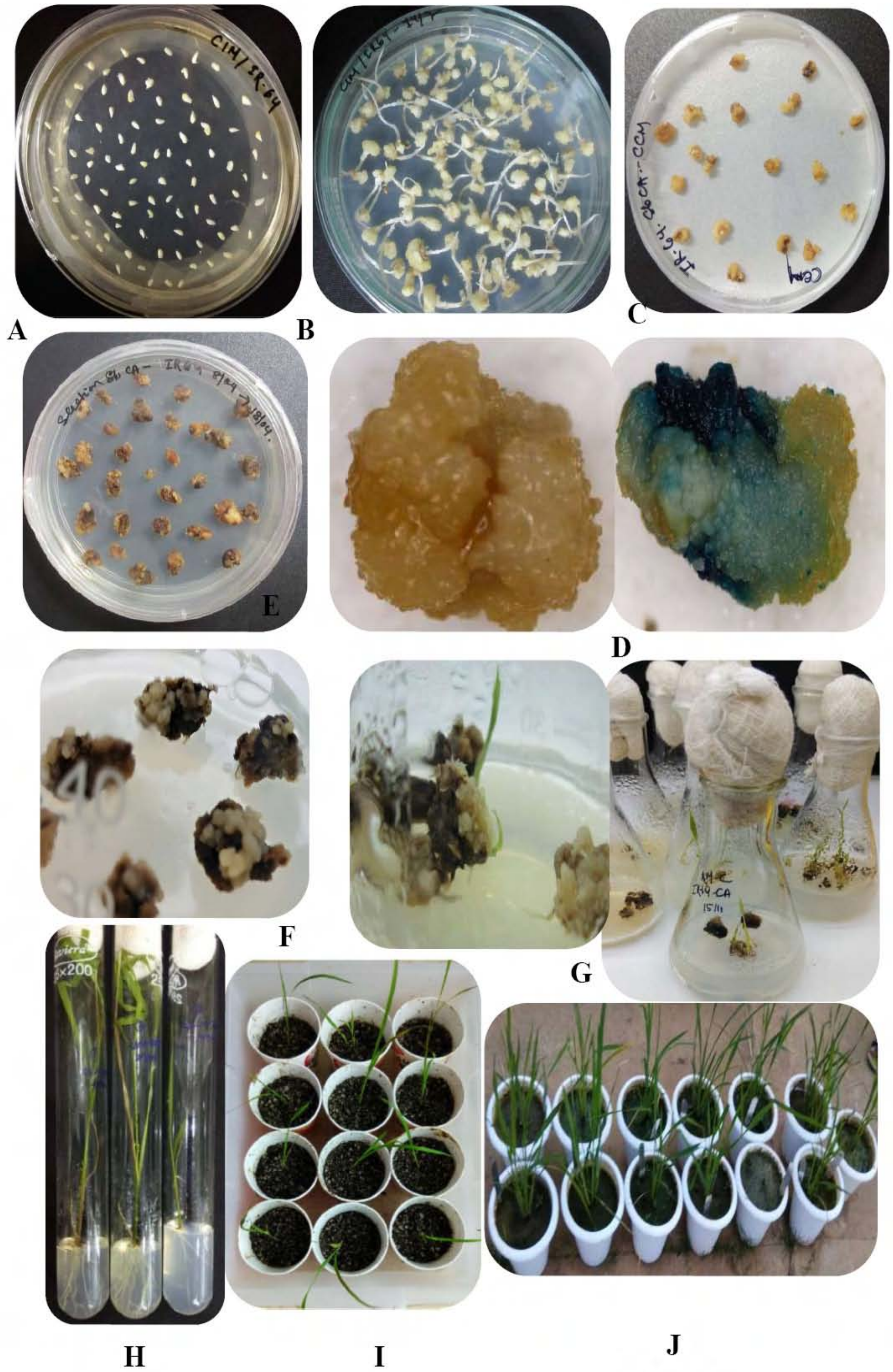


Fig. 4.11. Genetic transformation of rice with pCAMBIA vector and regeneration
A) Isolated mature embryo of rice variety IR64. (B) Calli developed in CIM. (C) Agrobacterium infected calli in the cocultivation media. (D) GUS positive transformed callus with control one after histochemical staining. (E) Selection of the putative transformed calli in hygromycin containing medium. (F) Proliferated calli selected for regeneration. (G) Regeneration of shoots from the selected calli. (H) Rooting of the plantlets. (J) Putative transgenic plants grown in pot.

Expression of gene in transgenic lines was analyzed by RT-PCR. *SbCA* transcripts were substantially increased in four different plant lines C2, C4, C12 and C17 over the control and vector plant. β- tubulin was used as internal control. The result indicates that the*SbCA* gene shows significantly higher level of expression in transgenic plants CA2, CA4, CA12 than that in non-transgenic control plants (P <0.0001). No significant difference inexpression was found between control and vector control plant.

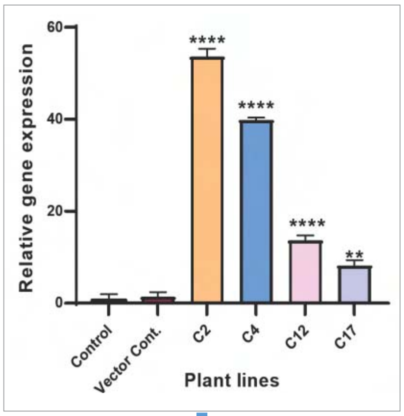


Fig. 4.12. *SbCA* gene expression in transgenic lines

Molecular & Physiological Characterization of the transgenics

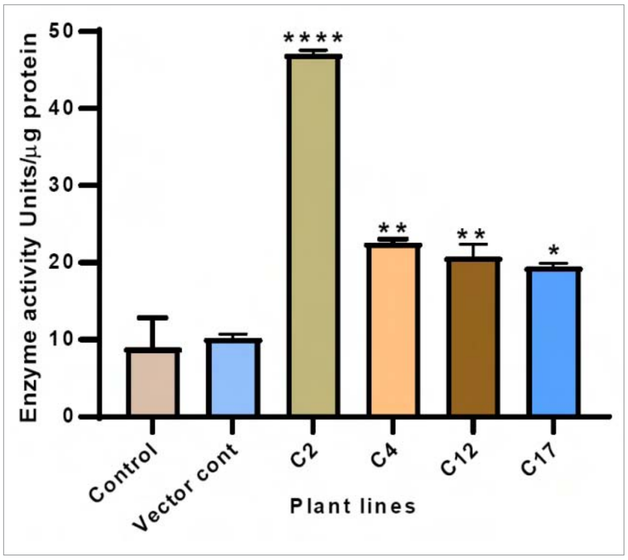


Fig. 4.13. The activity of CA enzyme ranged from ~19 to 47 units/µg protein in transgenicrice which was ~2-5 folds higher than control and vector control plants (~8.9-10.1 units/µgprotein). Each data point is the average of three replicates ±SE.

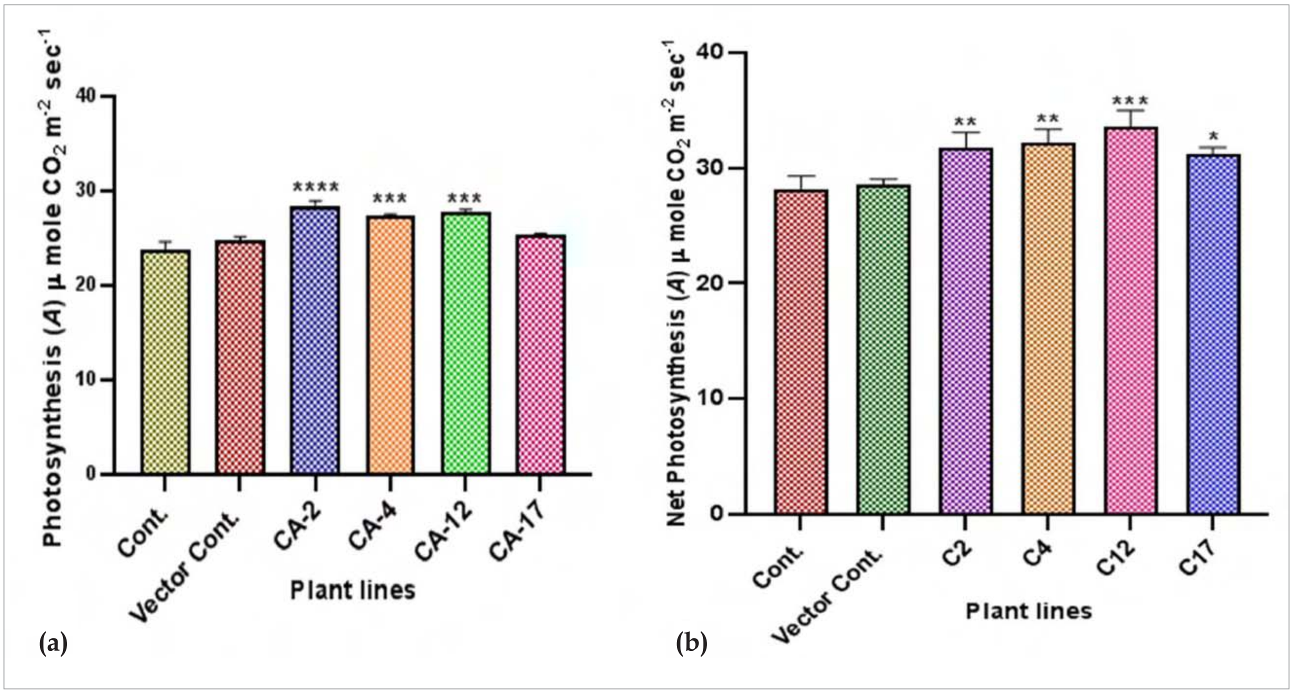


Fig. 4.14. Net photosynthetic rate (A) measured in *SbCA* transgenic and control plants (a) At vegetative stage (b) At 50% flowering stage. Values are represented as mean of three independent experiments ± SE.

Photosynthetic efficiency of SbCA transgenic plant lives (C2, C4, C12 and C17) was studied at vegetative and 50% flowering stage. All the transgenic plant lives recorded significantly high net photosynthetic rate (A) compared to control and vector control plants indicating incorporation of desired C4 gene for improvement of photosynthetic efficiency.

PROGRAMME : 5

Socio-economic Research for Enhancing Farm Income

Dissemination of the technologies has been a challenging task world over. At NRRI it is aimed to develop extension approaches, methodologies and models that would take up factors affecting dissemination among the farming communities. Accordingly, two models INSPIRE and 4S4R were developed which are being tested and validated this year. The division undertook work on Rice Value Chain and Gender in rice which were at initial stages. Besides work was done at quantification of average on-farm yield and yield gaps and factors affecting yield gaps. Impact of the technologies and training was studied to provide feedback to the technologists.

Developing extension approaches to enhance rice farmers' income

Developing extension approach for faster spread of rice varieties in different states

In order to develop an approach to narrow down the gap between varietal development and its faster spread and adoption, the institute developed an extension model known as "**IN**novative extension model for varietal **SP**read **I**n **R**ice **E**cosystems (INSPIRE). Under the INSPIRE model, on-farm demonstrations were conducted in farmers' fields with 18 newly released NRRI varieties benefiting 625 farmers and covering about 170 ha area in 12 districts of five states.

Crop cutting experiments (Fig. 5.1) followed by field days were organized with the principle of 'Seeing is believing' where, beneficiary farmers were encouraged to share their experiences (Fig. 5.1). Most of the newly released NRRI varieties outperformed the existing popular check by giving an average grain yield advantage ranging from 0 - 30 % (Table 5.1).

Testing and validating the 'Self-sufficient Sustainable Seed System for Rice' (4S4R) model of NRRI

To address the inherent problems of formal rice seed system of the country for quality, quantity, timeliness, choice of variety and cost of production, a local seed system, named as Self-sufficient Sustainable Seed System for Rice (4S4R) was conceptualized by the institute. This is being piloted with the major aim to make the district self-sufficient in quality paddy seeds and economically benefiting the participating farmers.

During *kharif* 2018-19, 922.47 quintals of foundation and certified seeds of four popular rice varieties, *viz.*, Pooja, Sarala, Gayatri and Swarna-*Sub1* were produced in 89.7 acres by 77 seed growers (Fig. 5.3). The cost of production of one kg was Rs. 30.00 which was sold at Rs. 45.00 per kg with a B:C ratio of 1.5. Also 130 farmers' interest group (FIGs) were formed with 2600 members (Fig. 5.4).

Improving gender equity in rice with emphasis on value addition and market linkage

With the objective of improving gender equity by providing equal opportunity to farm women in rice value addition, a model was developed and was tested with a group of 50 women farmers formally registered in the name of 'Ananaya Mahila Bikash Samiti' in Nischintakoili, Cuttack. Encashing their traditional skills in preparing various rice based value added products, the group members were imparted training on processing, packaging, labeling and marketing of selected products like rice cake, sweetened rice flakes enriched with dry fruits etc. with the principle of market led extension. Impact analysis will be done in subsequent years.

Development, evaluation and upscale of a Rice Value Chain (RVC) approach for enhancing farmers' income

The institute conceived and operationalized a RVC approach during 2014-15 by signing MoU in public-private-partnership (PPP) mode with the involvement of five parties including NRRI, seed growers, seed company and processor for growing and marketing of a long slender NRRI developed aromatic rice variety 'Geetanjali'. During its operation over the years, weak linkages of the existing RVC were identified, like (i) high end risk during procurement due to only one signatory processor, (ii) missing linkage in value chain financing for its sustainability and growth and (iii) unclear value chain governance mechanism. Accordingly, the model was improvised and conceptualized with an integrated rice value chain (IRVC) model for pilot testing (Fig. 5.5).

Table 5.1. Comparative crop cutting results of demonstrated varieties *vis-a-vis* local popular checks

Selected states	NRRI variety	Grain yield (t ha^{-1})	Local check	Grain yield (t ha^{-1})	Grain yield adv. (%)
Jharkhand	CR Dhan 202	5.00	Sahbhagidhan	4.80	0.04
	CR Dhan 305	4.80	Sahbhagidhan	4.80	0.00
	IR 64 *drt1*	5.60	Sahbhagidhan	4.80	16.67
Bihar	CR Dhan 201	4.24	Sahbhagidhan	4.00	6.00
WB	CR Dhan 304	6.70	IR 64	5.60	20.00
	CR Dhan 307	5.80	Swarna	4.48	29.46
Assam	CR Dhan 310	4.83	Ranjit	4.15	16.38
Odisha	CR Dhan 200	7.40	Lalat	5.80	27.60
	CR Dhan 203	7.25	Lalat	5.80	25.00
	CR Dhan 205	7.70	Lalat	6.00	28.33
	CR Dhan 206	7.80	Lalat	6.00	30.00
	CR Dhan 303	5.20	Swarna	5.20	0.00
	CR Dhan 304	6.00	Swarna	5.20	15.38
	CR Dhan 307	6.24	Swarna	5.20	20.00
	CR Dhan 409	6.30	Varshadhan	5.40	16.70
	CR Dhan 500	5.58	Sarala	5.40	3.30
	CR Dhan 507	6.50	Sarala	5.80	12.10
	CR Dhan 508	7.20	Sarala	6.10	14.70
	CR Dhan 800	8.20	Swarna	6.50	26.15
	Swarna *Sub-1*	7.10	Swarna	6.00	18.30

Fig. 5.1. Crop cutting experiments in farmers' fields in Jharkhand

Fig. 5.2. Field days and experience sharing being organized in West Bengal

Fig. 5.3. Processed and packaged seeds ready for sale

Fig. 5.4. Group meeting of FIG in progress

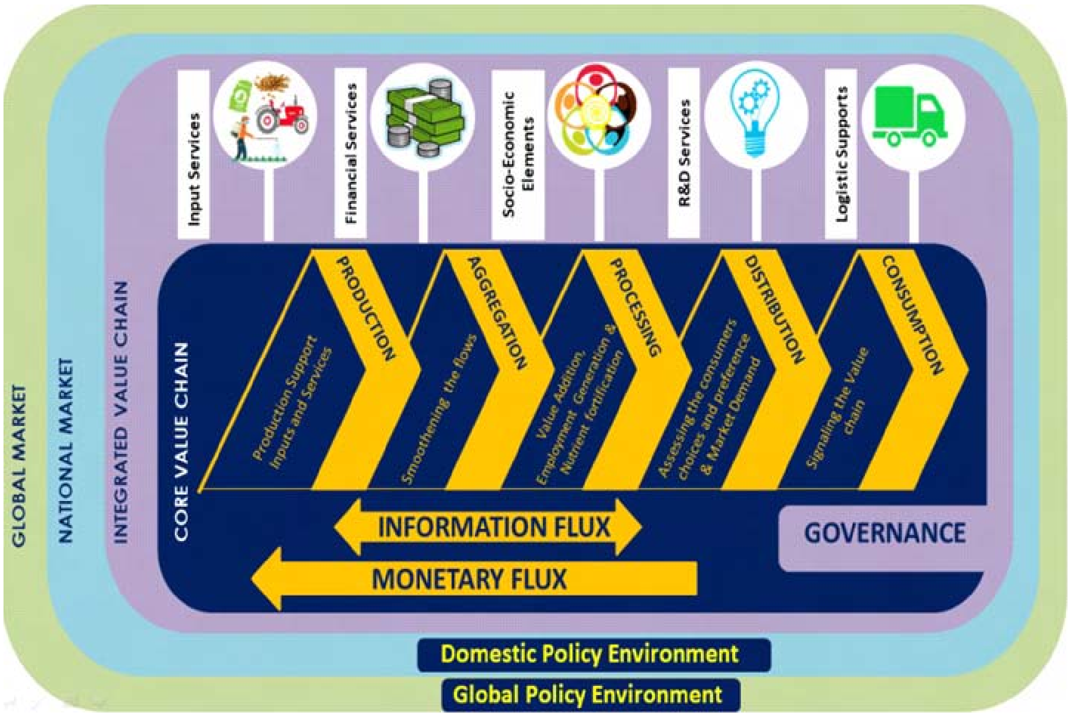


Fig. 5.5. Schematic representation of the IRVC Model of NRRI

Mera Gaon Mera Gaurav (MGMG) Activities

The MGMG programme is being implemented by ICAR-NRRI, Cuttack with 21 multi-disciplinary teams (4 scientists/team) in 21 clusters of villages (five villages/cluster) covering eight districts of Odisha (Cuttack, Dhenkanal, Jagatsinghpur, Jajpur, Kendrapada, Khurda, Nayagarh and Puri). Supports were provided through paddy seed minikits, training programme, village meeting, providing literature in local language, exposure visits, focus-group discussions and mobile advisory services (Fig. 5.6). More than 800 farmers and farmwomen from selected clusters participated in the Kisan Mela and Kisan Gosthi on 26th February, 2019 at NRRI, Cuttack.

Yield gap analysis and impact assessment to aid rice research and policies

Estimation of yield gaps, frontier yields and identification of influencing factors

Aiming at quantification of average on-farm yield and yield gaps as well as to understand the influencing factors, on-farm experiments were taken up in five

Fig. 5.6. Glimpses of MGMG Field Activities

states covering about 12 locations/districts. Varietal demonstrations-cum-experiments were conducted by providing five kg seed kits of recently released varieties to about 15 farmers at each cluster without altering farmers' own crop management practices. Apart from these, about 15 neighbouring farmers in each cluster were chosen as control. The gap in yield from the potential yields of respective varieties were ranged between 7% and 47% (Fig. 5.6).

The potential yields are often over-estimated because they are based on optimal condition and often ignore regional and farm level constraints, hence, frontier yield estimated using stochastic frontier model and deviations of individual farm from the frontier were considered as technical inefficiency of the farm which is the yield gap of a particular cultivar in a given location. Average technical inefficiency was observed as 14% and 16% for Odisha & Jharkhand states respectively. If we see variety wise, it is evident that higher yield gap was observed for CR Dhan 409, CR Dhan 202 and IR-64-*drt1* (Fig. 5.7 & 5.8). Further, it was observed that most of the input variables considered for fitting the stochastic function were significant indicating correct specification of the model (Table 5.2). Among the farm-level characteristics, extension contact possessed positive influence on technical efficiency, which advocates for strengthening of extension machineries. Land holding possesses negative influence on technical efficiency, indicating small farms more technically efficient.

Assessment of cost of cultivation of rice from field data and constraints in rice cultivation

Primary data collected on different aspects of rice cultivation were compared with the compiled data available from cost of cultivation scheme and differences were observed and among various categories of costs. However, it is noticeable that farmers used to get moderate remuneration only when family labour income is calculated (Table 5.3).

Various types of constraints in rice cultivation have also been identified and ranked using Garrett ranking technique and the results revealed that water stress and labour scarcity are the top most problems faced by the rice farmers in Odisha.

District wise trend of rice area, yield and production

Compound annual growth rate (CAGR) of area, production and yield of rice was calculated for three eastern Indian states (Assam, Odisha and West Bengal) and it was observed that the area under rice has increased in Assam and West Bengal, whereas, negative growth in area was observed for Odisha state. It was also observed that the yield growth was

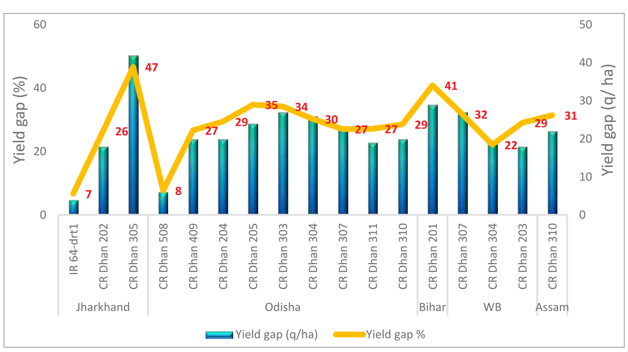


Fig. 5.7. Yield gap of test varieties from potential yield (yield gap-I)

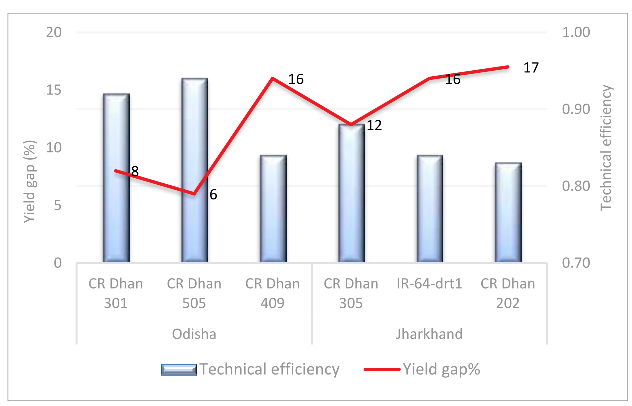


Fig. 5.8. Variety wise technical efficiency and yield gap of NRRI varieties at farmer's field

Table 5.2. Maximum likelihood estimates of parameters of the stochastic frontier model

Variables	Parameters	States	
		Odisha	Jharkhand
Constant	α	2.079*** (0.178)	7.326*** (0.648)
Seed & nursery	β1	0.054 (0.083)	0.118 (0.128)
Land preparation	β2	0.270***(0.053)	-0.047 (0.061)
Transplanting	β3	0.111 (0.071)	0.003 (0.038)
Fertilizer	β4	0.381*** (0.074)	-0.054** (0.029)
Manure	β5	0.022*** (0.006)	0.130*** (0.037)
Insect-pest control	β6	-0.027*** (0.046)	0.006 (0.005)
Weeding & inter-culturing	β7	0.057 (0.109)	0.129 (0.088)
Harvesting & threshing	β8	0.161*** (0.036)	0.238*** (0.088)
Inefficiency model			
Constant	δ0	0.100 (0.231)	0.214 (0.134)
Age (household head) (years)	δ1	-0.001 (0.004)	0.001 (0.002)
Education (household head)	δ2	-0.005 (0.043)	0.030 (0.025)
Farm size (ha)	δ3	0.018*** (0.008)	0.004 (0.005)
Labour force	δ4	0.045 (0.042)	0.029 (0.024)
Farm assets	δ5	-0.022 (0.038)	0.018 (0.024)
Non-farm income	δ6	-0.027 (0.047)	-0.017 (0.038)
Extension contacts	δ7	-0.577*** (0.106)	-0.418*** (0.820)
Variance parameter			
δ2		0.020***(0.007)	0.008*** (0.003)
γ		0.366* (0.232)	0.999*** (0.007)
Log-likelihood function		55.507	45.353
Mean Technical Efficiency		0.86	0.84

Figures in brackets indicate standard errors of coefficients. ***, ** and *: Significant at 1%, 5% and 10% level, respectively.

Table 5.3. Cost of cultivation (in Rupees) of paddy in Odisha & Jharkhand

Particulars	Odisha	Jharkhand
Cost A1	38196.73 (26918.71)	30899.17 (18511.29
Cost B1	39131.62 (27074.65)	32638.35 (20191.36)
Cost B2	49131.62 (28828.70)	40138.35 (29791.27)
Cost C1	54562.98 (46464.25)	45243.31 (27417.94)
Cost C2	64562.98 (57443.68)	52743.31 (37017.84)
Gross Returns	67497.1	58164.89
Net Returns	2934.12	5421.584
Family labour income	18365.48	12604.96

Figures in brackets indicate costs reported by cost of cultivation scheme for the year 2015-16

highest for Odisha state whereas production growth it was highest for West Bengal.

Assessing the impact of NRRI training programmes

The impact of training programmes conducted during last three years i.e., 2014-15, 2015-16 and 2016-17 at NRRI, Cuttack was assessed. The responses were collected on two aspects *viz.,* change in adoption (of ten number of technologies) and change in behavior (knowledge, skill and attitude) of the trainees towards improved rice production technologies. The change in adoption behaviour of the trainees before and after the training programme were observed and the results of impact revealed that the change in adoption rate post-training was highest for the use of CLCC (76%). Similarly, comparison of knowledge, skill and attitude between the two periods revealed average shift to the extent of 34% (knowledge), 21% (skill) and 84% (attitude); and highest shift was again for CLCC use.

Updation of data on export-import of rice

Rice export data from India for 215 countries / territories have been updated up to 2017-18 and analyzed. It was observed that 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. It was also observed that despite drought, there was consistent rise of basmati exports, which might be due to plentiful irrigation facilities in the basmati growing pockets of the country. The water footprint of rice exported to other countries has also been calculated and the result indicated that virtual water export increased by six times in a decade from 8.63×10^6 m^3 to 5.10×10^7 m^3.

PROGRAMME : 6

Development of Resilient Production Technologies for Rainfed Upland Rice Systems

Upland rice is grown in around six mha under rainfed ecology in India. Major portion of upland rice areas is in eastern and north-eastern states. Agricultural production system of upland ecology is mainly monsoon dependent where rice is the major crop. However, rice productivity of the rainfed ecology is very poor owing to several constraints like moisture stress, weeds, poor soil nutrient status and diseases. The upland rice ecosystem is extremely diverse. Soils vary from highly fertile volcanic and alluvial soils to highly weathered, infertile and acidic type. Upland rice is grown at altitudes of up to 2000 m above mean sea level (MSL) and in areas with annual rainfall ranging from 1000 to 4500 mm. But erratic rainfall frequently causes drought during growth periods and result in low and unstable yields (1–2 t ha^{-1}), compared to irrigated lowland rice (>5 t ha^{-1}). Improving productivity of rice in the upland ecosystem is essential to meet food security needs of impoverished upland communities via (i) Bringing Green Revolution to Eastern India (BGREI) and (ii) Doubling Farmers' Income (DFI). In this context, the roadmap for improving rice production system through development of resilient production technologies for this ecology has been set through: (i) breeding for drought-tolerant, high yielding rice varieties, (ii) developing climate resilient crop production technologies including crop establishment, nutrient management and (iii) establishing suitable crop protection schedule (Integrated Pest Management; IPM) including weeds, diseases and insects. The salient findings of activities under taken during 2018-19 are summarized here.

Breeding resilient high yielding rice varieties suitable for drought-prone rainfed uplands

Characterization of *Gora* rice: Drought tolerance, blast resistance and genetic diversity

Among 49 *gora* rice germplasm evaluated (including black, brown, white and other *gora* accessions), majority have shown drought tolerance at vegetative stage in terms of low leaf rolling and drying scores at 10-15% soil moisture levels. Morphological attributes revealed that black *gora* accessions were distinct from the rest of the *gora* accessions, while brown and white *gora* accessions were grouped in the same cluster (Fig. 6.1a). The genotypes were morphologically distinguished on the basis of lemma, palea colour, apiculus colour, seed coat colour, awning and awn colour.

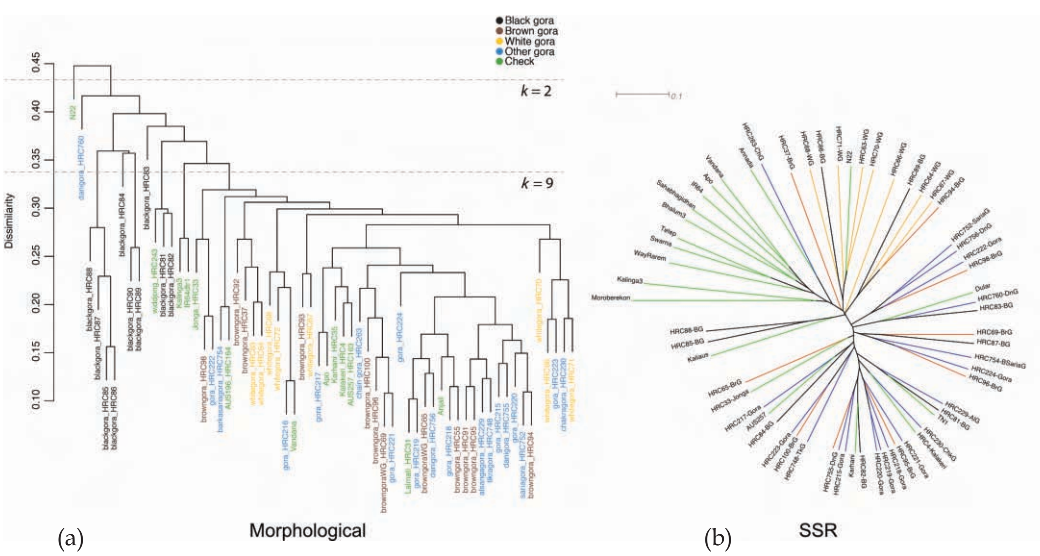


Fig. 6.1. (a) Morphological grouping based on 29 phenotypic traits

Fig. 6.1. (b) Genetic diversity assessment using 40 SSR markers

Survey of nine QTLs *(qDTYs)* for grain yield under drought using 26-linked SSRs showed that some *gora* accessions may possess *qDTYs* (Table 6.1). Molecular screening for blast resistance genes (*Pi2, Pib, Pi9, Piz* and *Pita2*) revealed that *gora* accessions were found to be negative for the surveyed *Pi* genes except *Pib* for which all accessions were positive. One black *gora* accession was found to be positive for *Pi2, Piz* and *Pita2*. Genetic diversity assessment using 40 SSR markers showed that most of the white *gora* accessions were genetically close to *indica,* while, other *gora* accessions were identified as *aus* types (Fig. 6.1b). Thirty-eight accessions were carrying *Sub1A* (marker SC3), while 32 were positive for both *Sub1B* (marker Sub1BC2) and *Sub1C* (marker ART5). In addition, presence of *PSTOL1* was detected in 35 *gora* accessions. The results showed that *gora* rice accessions possess multiple abiotic stress tolerance.

Evaluation of rice germplasm for tolerance to drought

Out of 184 rice germplasm from NBPGR, 57 entries scored for high to moderate (Score 3 & 5; SES-IRRI) level of vegetative stage drought tolerance . Variability of the germplasm for grain yield (kg ha^{-1}) under reproductive stage drought and vegetative stage drought tolerance score is presented in Fig. 6.2.

Characterization of upland rice varieties for drought and phosphorus starvation tolerance

Thirty-two rice accessions (21 varieties and 11 landraces) suitable for drought-prone ecology were surveyed for the presence of 10 *qDTYs* (QTLs for grain yield under drought) and *Phosphorus Uptake 1* (*Pup1*) locus. Positive accessions for different *qDTYs* have been presented in Table 6.2. Cluster analysis, using the SSR data, grouped 32 rice accessions in two clusters, mostly corresponds to *indica* and *aus* varietal groups (Fig. 6.3). The *aus* clad possessed nine rice accessions: Kayaker, AUS257, Katakana, Kali aus,

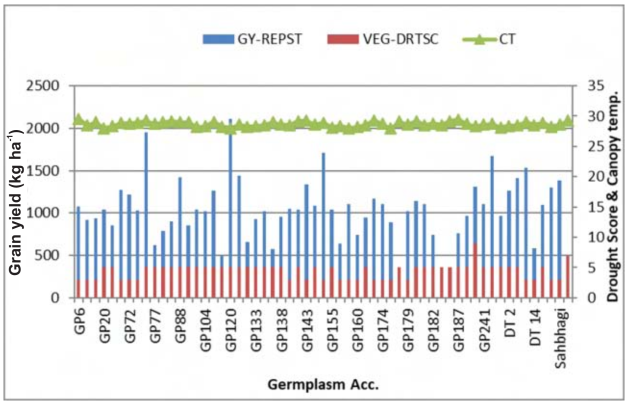


Fig. 6.2. Distribution of germplasm for grain yield under reproductive stage drought, vegetative stage drought tolerance score and canopy temperature

Table 6.1. QTLs for grain yield under reproductive stage drought stress identified in gora rice germplasm

qDTY	Marker	Donor/ Positive check (PC)	Gora genotypes carrying the similar alleles as PC
qDTY1.1	RM431, RM11943, RM12091	N22	None
qDTY1.2	RM259, RM315	Kali aus	None
qDTY2.1	RM324, RM327, RM324	Apo	White gora (HRC70), Gora (HRC224)
qDTY2.2	RM279, RM211, RM263, RM324, RM555	Kali aus	Dani gora (HRC760), Black gora (HRC88)
qDTY2.3	RM573, RM3212, RM250	Kali aus	Alsangagora (HRC229), White gora (HRC66), White gora (HRC71)
qDTY3.1	RM520, RM416	Apo	Brown gora (HRC37)
qDTY3.2	RM60, RM22, RM545	Moroberekon	White gora (HRC71)
qDTY6.1	RM204, RM589	Vandana	Gora (HRC217), Gora (HRC223)
qDTY12.1	RM28166, RM28040, RM28199	Way Rarem	Brown gora (HRC37, HRC65, HRC95, HRC98)

Black *gora*, N22, Lalnakanda 41, Dular and the *indica* cultivar Baal. The improved drought-tolerant varieties were identified as *indica*. In case of *Pup1,* the rice accessions such as Vandana, Sahbhagidhan, Black *gora*, Ananda, Apo, UPLRi7, CR Dhan 103, Dular, Kali *aus*, Kataktara, NDR1045-2, AUS 257 and Kalakeri were identified as positive based on the amplification profiles of three marker combinations. Hydroponic screening for P-starvation tolerance, however, did not exhibit significant correlation among *PSTOL1,* biomass and root length.

Marker assisted selection combined with phenotyping for drought and blast resistance

Population (F_5) derived from *Sahbhagidhan X IR87707-446-B-B* was genotyped with the linked SSR markers of 3 DTY QTLs (DTY2.2, DTY4.1 & DTY12.1) and blast resistance gene *Pita2*. Lines with different combinations of DTY QTLs and *Pita2* alleles were identified. Many superior lines having higher or comparable grain yield, and other traits than the parental genotypes with one or more DTY QTLs/ *Pita3* alleles were selected for potential stable drought and blast resistant rice genotypes (Table 6.3).

Preliminary yield trial (PYT) of advanced breeding lines under direct seeding (DS) and transplanting (TP)

Out of 40 entries evaluated, only three entries resulted in significantly higher yield than the best check variety Vandana under direct seeded rice (DSR). The top yielding entry CRR564-5-1-1-1-B produced a grain yield of 1774 kg ha^{-1} under DS and 1127 kg ha^{-1} under TP against that of 1206 and 391 kg ha^{-1}, respectively of Vandana.

Strategizing management options for sustainable rice production under DSR

Effect of seed and fertilizer management on productivity of upland rice

Results of P application (30 kg P_2O_5 ha^{-1}) in the form of single super phosphate (SSP) with phosphorus solubilizing bacteria (PSB) alone or PSB & Arboscurlar mycorrhiza (AM) for to consecutive years revealed that agronomic fertilizer use efficiency of 20 and 22.2 kg grain yield per kg of P_2O_5 then 14.2 kg grain yield per kg of P_2O_5 with out any supplementation.

Application of 30 kg P_2O_5 ha^{-1} increased mean grain yield of rice by 26% over no P application, whereas supplementing 30 kg P_2O_5 ha^{-1} with PSB alone or both PSB and AM increased grain yield further in the magnitude of 8.8 to 12.2% (Table 6.4).

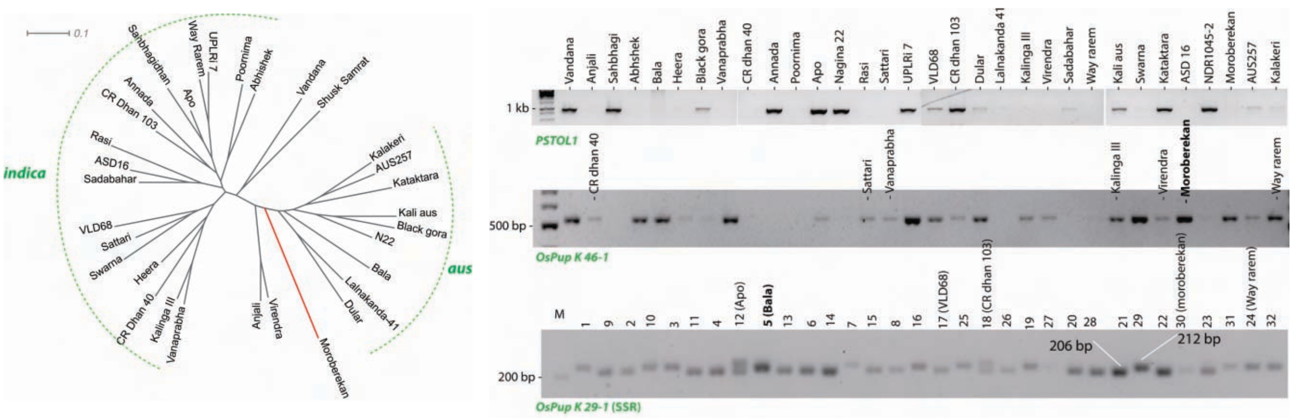
Soaking seeds in water mixed with S*yzygium cumini* aqueous extract (1.7%) and GA_3 (100 ppm) produced maximum mean grain yields followed by different strains of *Trichoderma*. Least increase in grain yield over water primed seeds was observed with GA_3 alone as evident by 7.5% mean gain in yield (Table 6.4).

Table 6.2. Survey of qDTYs in upland rice germplasm

qDTY	Markers used	Donor (Positive check)	Positive accessions
1.1	RM11943, RM431, RM12091	N22	None
1.2	RM259, RM315	Kali *aus*	AUS257, Lalnakanda 41, Kalakeri
1.3	RM488, RM315	Kali *aus*	AUS257, Dular, Kalakeri, Kataktara, Lalnakanda 41, Vandana
2.1	RM327, RM262	Apo	CR Dhan 103, Sahbhagidhan
2.2	RM211, RM263, RM279, RM555	Kali *aus*	AUS257, Kalakeri
2.3	RM263, RM573, RM3212, RM250	Kali *aus*	None
3.1	RM520, RM416	Apo	Dular
3.2	RM60, RM22	N22	Kalakeri, Poornima, Vandana
6.1	RM589, RM204	Vandana	Abhishek, Poornima
12.1	RM2804, RM28166, RM28199	Way rarem	Sahbhagidhan, UPLRi17

Table 6.3. Performance of the selected Sahbhagi dhan x IR87707 lines under preliminary testing

Entries	Days to flowering (Non-stress)	Grain yield (kg ha^{-1})			*DTY2.2*	*DTY4.1*	*DTY12.1*	*Pita2*
		Non-stress	DSR rainfed stress	RoS managed stress				
CRR759-11-B-1	83	2273	2051	172	A	B	A	A
CRR759-12-B-1	87	5253	1842	319	A	B	B	B
CRR759-B-12-B-1	83	3912	1778	454	B	B	A	B
CRR759-B-36-B-1	88	6279	1082	66	A	B	A	A
CRR759-B-7-B-1	86	6337	794	115	A	B	A	A
CRR759-44-B-1	90	5743	698	50	B	B	A	A
Sahbhagidhan	93	5079	297	51	A	A	A	A
IR64 Drt1	93	3139	121	22	B	B	B	B
LSD (0.05)	2.7	1619	341	83				



Cluster analysis using *qDTY*-linked SSRs

Survey of *Pup1* gene models in upland rice germplasm

Fig. 6.3. Cluster analysis, using the SSR data

Residual effects of AM (Arbuscular mycorrhiza) inoculums application in soils

The fixed plot study was initiated in the wet seasion of 2010 with two AM supportive cropping rotations (two years) viz., (i) maize relay cropped by horse gram in first year (2010) and DSR (Vandana) in next year (2011) (M-HG/R) and (ii) pigeon pea sole in first year (2010) and DSR in next year (2011) (PP/R) which were subjected to various P sources and combinations. In treatment plot, mass inoculums (MI) of AM were applied every year prior to sowing while no inoculation was applied for control. The most AM-supportive combination (P sources) was identified as 50% in the form of DAP and 50% in the form of Purulia Rock Phosphate (PRP; 18-20 @ P_2O_5 content). The two year rotations were repeated during (i) 2012-13, (ii) 2014-15, (iii) 2016-17, (iv) 2018 (to be repeated with DSR in 2019). To observe residual effects of AM inoculation, MI application was withdrawn w.e.f. 2016 (after five years of continuous application) after obtaining confirmation on stabilization of increased initial (June) AM population (25-33 cfu g^{-1} soil) in soil. While one year (2010) of application (MI) resulted in attaining the higher soil population of (AM) at which it was stabilized (25 – 33 cfu g^{-1} soil) under M-HG/R rotation, it took three years (2010, 2011 and 2012) under PP/R rotation. After withdrawal of inoculums application, initial (June) population, though significantly reduced, remained statistically higher and above threshold level than initial population (2010) until 2018 (three years; 2016, 2017 & 2018). In the second year of withdrawal (2017), root

Table 6.4. Effects of seed and fertilizer management on growth, yield and yield parameters of DSR (Vandana) in rainfed uplands

Treatments	Grain yield ($t\ ha^{-1}$)		Tiller (no. m^{-2})		Plant dry wt. ($g\ m^{-2}$)		Panicle wt.	
	2017	2018	2017	2018	2017	2018	2017	2018
P levels*								
P1- 0 kg P	1.70	1.52	324	272	259.5	238.8	2.79	2.59
P2- PSB+AM	1.82	1.62	332	290	280.5	256.5	2.95	2.82
P3- 30 kg $P_2O_5 ha^{-1}$	2.26	1.81	345	316	297.5	264.6	3.15	3.07
P4= 30 kg $P_2O_5 ha^{-1}$ +PSB	2.41	2.01	360	320	309.5	275.2	3.25	3.19
P5= 30 kg $P_2O_5 ha^{-1}$ +PSB+AM	2.45	2.10	369	322	321.5	295.4	3.29	3.26
LSD 5%	0.36	0.29	36	28	29.4	32	0.3	0.4
CV%	16.4	14.5	16.5	17	9.8	8.6	6.4	8.2
Priming**								
S1= seed primimg (*S. cumini*)	2.24	1.84	355	308	301.0	268.4	3.21	3.04
S2= seed proming (GA_3)	2.04	1.69	347	304	291.0	256.5	3.15	2.96
S3= S1 + S2	2.31	1.92	347	313	306.0	272.5	3.26	3.08
S4= seed priming (*Trichoderma* Str. 1)	2.12	1.78	339	320	302.0	261.6	3.15	2.98
S5= seed priming (*Trichoderma* Str. 2)	2.13	1.96	344	323	301.0	283.6	3.18	3.08
S6= seed priming (*Trichoderma* Str. 3)	1.94	1.90	351	296	284.0	276.5	3.02	3.12
S7= water primed seeds	1.89	1.58	335	266	271.0	241.8	2.98	2.66
LSD 5%	0.18	0.21	ns	36	24.2	28.4	0.14	0.25
CV%	18.4	16.2	18.8	20.4	7.6	6.6	8.85	9.4

* P sources- SSP; PSB (@4 kg ha^{-1}); AM (@0.5 t ha^{-1}); ** *Syzygium cumini* aq. extract @1.7%; GA_3 @100 ppm; *Trichoderma* @10 g kg^{-1} seed

colonization in rice (% root length colonization; % RLC) remained significantly higher than that of initial second year (2011) of MI application and was at par with forth year (2013) of application. This indicated that one year and three years of continuous AM inoculums application, respectively under crop rotations (i) M-HG/R and (ii) PP/R (with 50% DAP + 50% PRP of P dose), the residual effects in terms of enhanced population of (AM) and % RLC continued until next three years.

Nutrient management strategy for rice-based cropping systems in favorable uplands

The first year's result indicated best performance of 100% RDF (60: 30: 30) over organic and combinations of inorganic + organic fertilizer application in terms of yield in rice (DSR). The comparable performances on the cropping systems could be examined after at least three years' of fixed plot experimentation.

Biotic stress management strategies for rainfed upland rice

Identification of resistant donors for leaf blast (LB) and brown spot (BS)

Out of 2054 rice lines/germplasms screened under UBN against leaf blast during the wet season of 2018, 17.58% (70/398) of NSN-1, 15.39% (105/682) of NSN-2, 10.85% (14/129) of DSN, 20.0% (5/20) of blast differentials,1.05% (1/95) of OYT, 25.0% (12/48) of

AYT, 10.25 % (4/39) of DDPS, 54.2% (13/24) were found resistant (0-1 SES score; IRRI).

Similarly, 5.52 % (22/398) of NSN-1, 10.55% (72/682) of NSN-2 and 89.14 % (115/129) of DSN entries have been recorded as resistant to brown spot of rice with 1-2 SES score during wet season 2018 at CRURRS, Hazaribagh.

Fine tuning of IPM for upland (unfavorable) rice for major biotic stresses (diseases & weeds)

All the evaluated five IPM modules (Table 6.5) significantly reduced diseases and weeds infestation and increased grain yield of rice (cv. Vandana) over control with highest efficacy of module four (comprising; mechanical seed separation (MSS) with brine solution + seed treatment with *Trichoderma* @ 5g kg^{-1} seed + pre-emergence application of pendimethaline + need based, post emergence application of bispyribac-Na (35-40 DAE) + I/C with pigeon pea (cv. Birsa arhar 1) (4:1) + N: 15 + 30 + 15 (kg ha^{-1}) + need based application of tebuconazole 50% + trifloxystrobin 25% WG) (Table 6.5).

Haplotypic diversity of blast resistance genes (*Pi2* and *Pi9*)

Survey of *Pi2* and *Pi9* was carried out in a set of 70 rice landraces from North-eastern India. *Pi2* was detected in four accessions (Chakhao, Haflongbuh, Kbapnah and Anadi) using marker *Pb8*, while, *Pi9* was present in only two (Chakhao and Anadi). Further amplification and sequencing of these genes have been undertaken to understand the haplotype diversity. In further survey, with additional targeted genes, *Pib* was found omnipresent, *Piz* was detected in Chakhaoangouba, *Pizt* in seven accessions and *Pikh* in 15 accessions. Chakhao (SR/RJ-3) cultivar from Manipur was positive for four blast resistant genes viz., *Pi2*, *Pib*, *Pizt* and *Pi9*.

Field evaluation of botanical oils against major upland (favorable) rice diseases

Among nine botanical oils evaluated at different doses (Table 6.6), clove oil resulted highest significant reduction of leaf blast, brown spot and false smut in rice variety Sahbhagidhan which was statistically at par with spray of carbendazim. This was followed by Citronella oil> Eucalyptus Oil>Nirgundi oil> Neem oil>Cedar Wood Oil>Lemon Grass oil in terms of reduction in diseases incidence.

Integrated disease management (IDM) for false smut of transplanted rice under shallow rainfed ecology

Among nine potential fungicide formulations evaluated under field condition, Nativo was found most effective (Table 6.7) under identified best false smut cultural management options combination of early transplanting (20 July) and moderate fertilizer dose (N: P: K; 80: 40: 40) in susceptible hybrid PHB 71.

Table 6.5. Evaluation of IPM modules for upland (unfavourable) rice (cv.Vandana) under DSR (WS, 2018)

IPM Modules	% Incidence (blast)	% RDI (blast)	Weed Biomass (g m^{-2})	Yield (q ha^{-1})	% Increase in Yield
Control	8.25 e	-	65.8 b	18.75d	-
IPM module 1	5.5 d	33.3	14.5 a	21.2c	13.1
IPM module 2	4.3 c	47.9	13.7 a	25.1b	33.9
IPM module 3	4.7 c	43.0	12.6 a	22.3 bc	18.93
IPM module 4	2.4 a	70.9	11.0 a	32.3 a	72.26
IPM module 5	3.0 b	63.6	11.6 a	26.7 b	42.4
LSD 5%	0.55		20.5	3.9	

Module 1= Mechanical seed separation (MSS) with brine solution + seed treatment with *Trichoderma* @ 5 g kg^{-1} + pre-emergence application of pendimethaline + need based post emergence application of bispyribac-Na (40 DAS) + N: 15+30+15 kg ha^{-1}); **Module 2**= M 1+I/C with pigeon pea (4: 1); **Module 3**= M 1+I/C with pigeon pea (8: 1); **Module 4**= M 2 + need based application of tebuconazole 50% + trifloxystrobin 25% WG; **Module 5**= M3 + need based application of tebuconazole 50% + trifloxystrobin 25% WG

Table 6.6. Comperative efficacy of botanical oils against major upland rice (cv Sahabhagidhan) diseases under DSR (WS, 2018)

Treatments	% Blast incidence	% RDI	% Brown spot incidence	% RDI	% False smut incidence	% RDI	Yield (q ha^{-1})	% increase in yield
Citronella oil	3.51 ab*	37.32	4.46 b	36.28	4.25 b	34.61	23.12 a	53.62
Eucalyptus oil	3.85 b	31.25	5.21 c	25.57	4.84 c	25.54	22.68 b	50.69
Cedar wood oil	4.2 c	25.00	6.42 e	8.28	6.00 d	7.69	20.94 b	39.14
Nirgundi oil	4.3 cd	23.21	5.75 d	17.85	5.09 c	21.69	21.62 b	43.65
Lemon grass oil	4.81e	14.11	6.73 e	3.85	6.15 d	5.38	19.62 c	30.65
Clove oil	3.35 a	40.17	3.77 a	46.14	3.94 a	39.38	23.62 a	56.94
Neem essential oil	4.57 d	18.39	5.98 d	14.57	5.67 cd	12.76	21.37 b	41.99
Emulsifier	5.25 f	6.25	6.7 e	4.28	6.11 d	6.00	17.37 d	15.41
Carbendazim	3.12 a	44.28	3.33 a	52.43	3.51 a	46.00	24.75 a	64.45
Control	5.6 f	-	7.0 f		6.5 e		15.05d	-
LSD 5%	0.39		0.71		0.55		2.01	

Table 6.7. Comparative efficacy of fungicide formulations under most effective cultural management options combination against false smut in transplanted rice (Hybrid: PHB 71) under rainfed ecology (WS 20118)

Treatments	Early transplanting	
	Disease incidence	Yield (q ha^{-1})
SAAF (Carbendazim + Mancozeb)	17.00	61.42
Copper hydroxide	18.10	61.33
Tebuconazole	19.41	54.00
Tricyclazole	20.60	57.00
Tricyclazole + Tebuconazole	15.31	66.83
Tricyclazole + Mancozeb	18.35	59.75
Bavistin	21.80	50.20
Picoxystrobin + Propiconazole	15.80	63.00
Nativo (Trifloxystrobin + Tebuconazole)	14.56	68.58
Control	44.70	35.23
LSD 5%	1.05	1.76

PROGRAMME : 7

Genetic Improvement and Management of Rice for Rainfed Lowlands

Assam is characterized by rainfed agro-ecosystem where around 2.5 m ha is cultivable rice area. The irregularities in South–West monsoons do result in moderate to severe droughts. Flood/submergence is one of the critical constraints in lowland and deep water areas. Most traditional varieties are low yielder and can neither elongate fast nor survive inundation and suffer from lodging when water table recedes. Weather related constraints, poor drainage and mostly acidic soils with iron (Fe) and aluminium (Al) toxicity are other limiting factors in realizing higher productivity. Continuous rain during harvest cause germination on the plant and incomplete drying and high humidity affect the grain quality.

Depending on the rainfall pattern, there are three distinct rice growing seasons *viz., ahu* or autumn rice (March/April to June/July), *sali* or winter rice (June/July to November/December) and *boro* or summer rice (November/December to May/June). The ideal rice production practices and the requirements vary depending on the seasons. Utilizing local genetic resources to develop suitable rice varieties for *boro* and *ahu* season will be the major thrust area. For *sali/winter* season, rice varieties of 130-140 days duration having medium slender grain and submergence tolerance will perform better in rainfed lowlands of Assam. Exploration of geographical distribution of biotic factors and development of pest management strategies are important to management schedule of pests in rainfed lowlands of Assam.

Genetic improvement and management of rice for rainfed lowlands

Maintenance of rice germplasm

A total of 803 accessions of rice germplasm were maintained during *kharif* 2018. Observations on plant height, number of effective tillers, panicle length and grain yield were recorded for all the genotypes. A sub-set of the germplasm comprising 30 lines of the aromatic *Joha* types and 97 lines of the deep water *Bao* rice were further evaluated in augmented design-II for important agronomic traits (Table 7.1).

Generation advance of segregating/fixed materials

a) Pedigree nursery of 61 F_3 progenies of Swarna *sub-1*/CR 1014 was raised during *Sali* season for development of lowland (semi-glutinous and soft) rice and F_4 seeds were advanced. Thirteen lines out of 61 were selected and advanced for F_4 generation.

b) Total 124 advanced entries (semi-glutinous rice) were evaluated keeping CR Dhan 909 and Naveen as check with two replications. Out of 124 entries, 19 performed better than that of check. The range of yield was 1230.8 kg ha^{-1} (CRL-148-23-2) to 5967.9 kg ha^{-1} (CRL-145-18-3).

c) For the development of *boro* rice, F_9 nursery of 59 advanced breeding lines from 28 crosses were evaluated keeping CR Dhan 601, Jaymati and IR 64 as check with two replications. Out of 59 entries, 15 performed better than that of check. The range of yield was 2414.2 kg ha^{-1} (CRL-122-1-3-B) to 8396.4 kg ha^{-1} (CRL-122-9-1-1-B). For the development of pre-flood *ahu* rice, F_8 nursery of 20 advanced breeding lines from five crosses were evaluated keeping Sahabhagidhan, Anjali and BAU 404 as check with two replications. Out of 20 entries, four entries performed better than check. The range of yield was 1902.06 kg ha^{-1} (CRL-151) to 6189.30 kg ha^{-1} (CRL-192).

Maintenance of elite breeding materials

During *Sali/kharif* 2018, total 27 advanced breeding lines (semi-deep and deep water rice) were evaluated keeping CR Dhan 505, Swarna *sub-1* and Panikekuwa as check with two replications. Out of 27, six entries performed better than that of check. The range of yield was 1324.3 kg ha^{-1} (Panikeko) & 2000.0 kg ha^{-1} (CRL-77-80-4-2-B) to 4867.9 kg ha^{-1} (CRL-67-27-1-1-B).

Evaluation of breeding materials in All India Co-ordinated Rice Improvement Programme (AICRIP) trials

A total of 164 breeding materials were evaluated under AICRIP trial during *boro* and *sali* seasons in 2018-19.

Table 7.1. Summary of the phenotypic evaluation of *Joha* and *Bao* landraces for important agronomic traits

Trait	Range		Genotype with the lowest value		Genotype with the highest value	
	Joha (N=30)	Bao (N=97)	Joha	Bao	Joha	Bao
Plant height (cm)	126.0-161.0	122.0-175.0	Pipli Joha	Jalpriya	Kanak Jeer	Pani Maguri
Panicle/plant	6.0-19.0	5.0-13.0	Keteki Joha	Nayanpuria	Kan Joha	Kekoa
Panicle length (cm)	23.9-30.3	20.90-31.80	Bhaboli Joha	Amona Boga	Bakul Joha	Nolini Bao
Flag leaf length (cm)	20.0-47.3	21.1-45.4	SR-67	Jul Bao-3	Kanak Jeer	Jeng Bao
Flag leaf width (cm)	0.98-1.38	1.2-2.1	Sonachur	NegriBao	Jeera 32 (27)	Jalmagna
Panicle weight (g)	1.43-3.79	1.74-6.56	Kunkuni Joha	Buruli Bao	Kan Joha	Jul Dubi Bao
Primary branches/ panicle	7.0-13.0	8.00-14.00	Tulsi Joha	Tarkekoa Bao	Kan Joha	Behuri Bao
Spikelets/ panicle	112.0-412.0	84.0-258.0	Bhaboli Joha	Jul Bao	Kan Joha	Kamini Bao
Grains/ panicle	92.0-310.0	46.0-219.0	Tulsi Joha	Buruli Bao	Kan Joha	Behuri Bao
Grains/ panicle (%)	61.20-87.84	34.74-90.32	Kanak Jeer	Buruli Bao	Tulsi Prasad	Padumoni
Test weight (g)	8.95-22.92	16.22-33.16	Maniki Madhuri	Jalpriya	Bhaboli Joha	Late Deep Water

Breeder seed multiplication of high yielding varieties

A total of 146.78 q of breeder seed (*boro* and *sali* season) was produced for the varieties Chandrama, Naveen, Sahbhagidhan, CR Dhan 310 and CR Dhan 909 and 113.69 q was sold to the government and private organizations. Nucleus seeds are also being maintained (Table 7.2).

Survey on the incidence of major insect-pest and diseases of rice in rainfed lowlands of Assam

Survey was conducted in rainfed lowland of Golaghat, Jorhat, Sivsagar, Charaideo and Baksa districts of Assam for recording the incidence of insect-pest and diseases on rice during *kharif* 2018. Yellow stem borer (*Scirpophaga incertulas*), leaf folder (*Cnaphalocrosis medinalis*) and gundhi bug (*Leptocorisa accuta*) were found to be the major insect pest. Infestation of army worm (*Mythimna* sp.) was observed in Tupalia village of Baksa district (Fig. 7.1). Major diseases observed in farmer's field were blast, brown spot, bacterial leaf blight and sheath blight. Sporadic appearance of false smut and *bakanae* disease were also observed in different areas.

Table 7.2. Indent received and production shortfall

S. No.	Variety name	Indent (in q)	Actual seed production-shortfalls if any (in q)
		State	State
1	Chandrama	38	45.8
2	Naveen	---	62.2
3	SahabhagiDhan	---	11.6
4	CR Dhan 310	---	20.0
5	CR Dhan 909	---	7.58
	Total	**38**	**147.18**

Fig 7.1. Army worm larva

Population dynamics of yellow stem borer on rice in Assam

Moths of yellow stem borer (*Scirpophaga incertulas*) were captured through installing two light traps in the experimental farm of RRLRRS, Gerua during *kharif* 2018. Moth activity of yellow stem borer started at the first fortnight of October. Daily catches of rice stem borer reached its first peak (12.3 nos. of moth/trap) on 23-10-2018 (Fig 7.2). Thereafter stem borer moth population declined and maintained a low population level upto the second fortnight of November.

Date of transplanting and stem borer infestation in rainfed lowland

Rice variety Naveen was transplanted on three different dates at fifteen days intervals during *boro* 2017-18 and *kharif* 2018. Rice stem borer infestation was the lowest in the *boro* season crop transplanted in second fortnight of February (2.16% dead hearts (DH)) as compared to first fortnight of March (2.20%) and second fortnight of March (2.27%) transplanted crop (Table 7.3). Rice stem borer infestation on *kharif* rice was the lowest in the crop transplanted in second fortnight of July (1.69% DH) as compared to first fortnight of August (1.91%) and second fortnight of August (2.17%) transplanted crop (Table 7.4). Crop transplanted in second fortnight of July recorded the highest yield of 5.07 t ha^{-1} as compared to crop transplanted in first (4.50 t ha^{-1}) and second fortnight of August (4.20 t ha^{-1}).

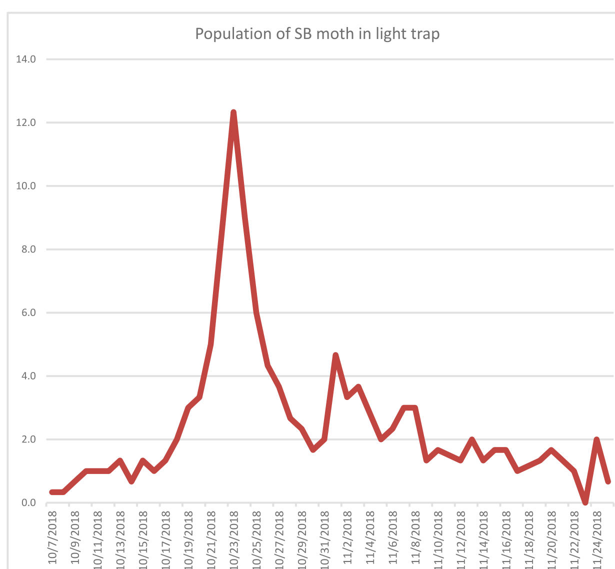


Fig 7.2. Population of yellow stem borer moth in light trap

Table 7.3. Date of transplanting and stem borer infestation during *boro* 2017-18

Date of transplanting	Percent dead heart as on				Yield (t ha^{-1})
	11-06-2018	18-06-2018	24-06-2018	Mean	
17-02-2018	2.70	1.62	2.17	2.16	3.70
04-03-2018	3.03	1.59	1.98	2.20	3.83
19-03-2018	3.29	1.35	2.16	2.27	3.82

Table 7.4. Date of transplanting and stem borer infestation during *kharif* 2018

Date of transplanting	Percent dead heart as on				Yield (t ha^{-1})
	10-11-2018	15-11-2018	25-11-2018	Mean	
30-07-2018	1.79	1.62	1.67	1.69	5.07
14-08-2018	2.04	1.92	1.78	1.91	4.50
29-08-2018	2.31	2.23	1.98	2.17	4.20

Management of rice stem borer, leaf folder and gundhi bug

Spraying of chlorantraniliprole 18.5% @ 150 ml ha^{-1} recorded the 1.85 per cent dead heart lowest as compared to 2.75 in control at 45 days after treatment (DAT) (Table 7.5). Application of cartap hydrochloride 4% granule @ 20 kg ha^{-1} recorded the lowest 0.33 and 0.58 percent leaf folder folded leaves at 45 and 60 DAT, respectively in comparison to 0.97 and 1.46 percent in the control plot. Use of crab trap @ 20/ha was found to be superior over all other treatments. Spraying of cypermethrin @ 2ml ha^{-1} recorded the lowest 0.20 number of gundhi bug per hill and was followed by dusting with malathion @ 20 kg ha^{-1} (0.25 nos/hill) and crab trap @ 20 nos. ha^{-1} (0.25 nos/hill). Spraying of chlorantraniliprole 18.5% @ 150 ml ha^{-1} recorded the highest yield 5.13 t ha^{-1} as compared to control (4.41 t ha^{-1}).

Efficacy of fungicide against rice bakanae disease

It has been observed that root dip treatment with bavistin & tilt solution is effective to prevent the spread of disease for a certain period although the spray was not effective (Table 7.6).

Screening of rice entries against leaf blast under UBN pattern

The screening experiment of 30 entries of rice differentials were raised under UBN pattern for screening against leaf blast. The first symptom of disease appeared on 25-07-18 and blast appeared from last week of July up to end of September, 2018. Mahsuri (local check) scored 9, and resistant reaction found in varieties- IR64, Chandrama, Pankaj, IR 20, CR Dhan-310, CR Dhan-311, CR Dhan-909, BJ1 and Tetep and the LSI in the year 2018 was 3.03. The disease pressure was considerably low under natural conditions.

Table 7.5. Management of rice stem borer, leaf folder and gundhi bug

Treatment	Dead Heart (%)		Leaf folder folded leaves (%)		Gundhi bug (nos)	Yield (t ha^{-1})
	45 DAT	60 DAT	45 DAT	60 DAT		
Cartap hydrochloride 4% granule @ 20 kg ha^{-1}	1.87	2.58	0.33	0.58	1.10	4.89
Chlorantraniliprole 18.5% @ 150 ml ha^{-1}	1.85	2.21	0.45	0.68	1.05	5.13
Scorpolure @ 20 nos. ha^{-1}	1.98	2.41	0.51	0.89	1.20	4.87
Azadirechtin 0.03% @ 2 lit ha^{-1}	2.03	2.25	0.45	0.69	1.15	4.85
Cypermethrin @2 ml/lit	2.09	2.51	0.50	0.79	0.15	4.81
Malathion dust @ 20 kg ha^{-1}	2.25	2.18	0.50	0.78	0.20	4.76
Crab trap @ 20 ha^{-1}	2.23	2.25	0.91	0.90	0.25	4.53
Control	2.75	2.97	0.97	1.46	1.75	4.41

Table 7.6. Rroot dip treatment with bavistin & tilt solution

Treatment	Disease appeared
Root dip treatment by soaking in bavistin @ 2gm l^{-1} of water solution for 2 hrs before transplanting	1.750
Apply tilt @2 ml l^{-1} of water	1.250
Spray bavistin @ 2gm l^{-1} of water	19.500
Spray tilt @ 2 ml l^{-1} of water	24.000
Control	22.250
CV	19.51
CD (p=0.05)	1.002

Publications (2018-19)

RESEARCH PUBLICATIONS	NUMBER
Publications with NAAS score of >10	08
Publications with NAAS score of 8-10	22
Publications with NAAS score between 6 - 8	26
Publications with NAAS score below 6	34
Total Research Publications	**90**
Total NAAS Score	**586.91**
Citation for These Publications	**40**
OTHER PUBLICATIONS	
Book	01
Book Chapters	35
Technology Bulletin	04
Research Bulletin	03
Research Notes	22
Popular Articles	07
Training Compendium	02
Conference Proceedings Abstracts	20
Leaflets/Flyer	04
Total (Other Publications)	**98**
Total (Reseach + Other Publications)	**188**


ह्यूमिडिफायर

Events and Activities

RAC, IMC, IRC, SAC and IJSC Meetings

Research Advisory Committee (RAC)

Twenty fourth RAC meeting

The 24th meeting of the Research Advisory Committee (RAC) of ICAR-NRRI was held at Cuttack from 10 to 11 October 2018. Prof. SK Datta, Chairman, RAC and members Dr. DK Mishra, Dr. AR Sharma, Dr. JS Bentur, Dr. PK Mohapatra, Dr. RP Singh Ratan, Shri SK Panigrahi and Shri A Mishra were present during the meeting. Dr. SR Voleti, Director (A), IIRR, Hyderabad attended as Special Invitee. Dr. H Pathak, Director, NRRI presented the highlights of the research achievements and infrastructural developments since last RAC meeting.

Chairman and members, RAC in open session with the scientists

Institute Management Committee (IMC)

Thirty first IMC meeting

The XXXIth Institute Management Committee (IMC) meeting of NRRI was held on 28 July 2018 at Cuttack under the Chairmanship of Dr. H Pathak, Director. The members present were Dr. KK Rout, Dean of Agriculture, OUAT, Bhubaneswar, Shri SK Pathak, Deputy Director (Finance), ICAR, New Delhi, Dr. Shiv Sewak, PS, IIPR, Kanpur, Shri A Mishra, Bhubaneswar (Non-Official), Shri SK Panigrahi, Nayagarh (Non-Official). Matters related to infrastructure development and budgetary provisions for construction works were discussed.

Institute Research Council (IRC)

Thirty seventh IRC meeting

The 37th meeting of Institute Research Council (IRC) was held at NRRI, Cuttack from 16 to 19 May 2018 under the Chairmanship of Dr. H Pathak, Director and Chairman of IRC. In the opening session, Dr. (Mrs.) Mayabini Jena, Secretary, IRC welcomed the members including newly joined scientists. The house greatly acknowledged the contribution of Dr. TK Dangar, Dr. SG Sharma and Dr. P Samal to rice research.

Scientific Advisory Committee (SAC)

KVK, Santhapur

The 19th Scientific Advisory Committee meeting of Krishi Vigyan Kendra Cuttack, Santhapur was held on 20 April 2018.

KVK, Koderma

Scientific Advisory Committee meeting of Krishi Vigyan Kendra, Koderma, Jharkhand was held on 13 February 2019.

Institute Joint Staff Council (IJSC)

IJSC meeting

The 4th & 5th Institute Joint Staff Council meetings were held on 20 June & 14th November 2018 at NRRI, Cuttack.

Participation in Symposia/ Seminars/ Conferences/ Trainings/ Visits/ Workshops

Participation in Symposia / Seminars/ Conferences/ Trainings/ Visits/ Workshops/ Meetings	No. of Scientists
Trainings	16
Symposia	5
Seminars	9
Conferences	20
Workshops	17
Visits	20
Meetings	61

Organization of Events, Workshops, Seminars and Farmers' Day

SAARC Agriculture Centre's Regional Consultative meeting

One day "Regional consultative meeting for exchange of rice-based production and value chain development technologies in the SAARC Member

States" was organized at ICAR-NRRI on 14 August 2018. Delegates from Afghanistan, Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka participated in the Regional Consultative Meeting (RCM).

Union Agriculture & Farmers' Welfare Minister inaugurated Kisan Mela

A Kisan Mela was organized at Cuttack on 26 February 2019. Shri Radha Mohan Singh, Hon'ble Union Minister of Agriculture and Farmers Welfare graced the occasion as Chief Guest and Shri Dharmendra Pradhan, Hon'ble Union Minister of Petroleum & Natural Gas and Skill Development & Entrepreneurship graced as Guest of Honour. Dr. T Mohapatra, Secretary, DARE and DG, ICAR also graced the occasion. Over 4000 farmers, farmwomen, scientists and senior officials from ICAR, OUAT, KVKs, state line departments participated in the event.

Secretary, DARE reviews doubling farmer's income (DFI) in Odisha

Dr. T Mohapatra, Secretary, DARE and DG, ICAR reviewed the progress of activities being undertaken by ICAR Institutes, OUAT and KVKs of Odisha towards doubling farmer's income.

Dr. T Mohapatra, Secretary, DARE and DG, ICAR addressing the gathering

Seventy two Foundation day and kisan mela

The ICAR-National Rice Research Institute, Cuttack, observed its 72nd Foundation day and Kisan Mela on 23 April 2018.Dr. T Mohapatra, Secretary, DARE and Director General, ICAR, Govt. of India, New Delhi graced the occasion as Chief Guest. Dr. AK Singh, Deputy Director General (Horticulture & Crop Science), ICAR, New Delhi graced as Guest of Honour. Prof. PB Kirti, Professor, Department of Plant Science, School of Life Sciences, University of Hyderabad, Telengana delivered the Foundation day lecture on the topic "Towards enhancement of water use efficiency in rice".

Release of publications during the occasion

Meeting with Hon'ble Minister In-charge, Agriculture; Govt. of West Bengal

A meeting was held on 27 August 2018 at Nabanna, Howrah with Hon'ble Minister In-charge, Agriculture, Govt. of West Bengal to discuss about collaboration with State Department of Agriculture (SDA) and State Agricultural Universities (SAUs), West Bengal for promotion of research, training, teaching, entrepreneurship development and technologies related to rice and rice-based production system. Shri Pradip Mazumder, Advisor to Chief Minister, Govt. of West Bengal and Smt. Nandini Chakravorty, Secretary, Agriculture were also present.

Meeting with Hon'ble Minister In-charge, Agriculture; Govt. of West Bengal

Seventh Agriculture Education day

The ICAR-National Rice Research Institute, Cuttack celebrated the 7th Agriculture Education Day on 3 December 2018 with the participation of 150 students of class VIII to XII from 13 Schools and Junior Colleges around the city along with their teachers.

Release of Educational bulletin during the occasion

Industry-Farmer-Institute meet

ICAR-National Rice Research Institute, Cuttack organized an Industry-Farmer-Institute Meet on 1 December 2018. About 90 representatives from industry, rice millers, seed growers etc. from West Bengal, Assam and Odisha participated.

Eastern India Rainfed Lowland Shuttle Breeding Network (EIRLSBN) selection activity

Under ICAR-IRRI collaborative STRASA project, breeders involved in EIRLSBN participated in the selection activity at NRRI, Cuttack from 19 to 20 November 2018.

Interaction of EIRLSBN members with Dr. H Pathak, Director, NRRI, Cuttack

PM-KISAN programme

ICAR-NRRI, Cuttack arranged live webcast/telecast of inauguration of Pradhan Mantri Kisan Samman Nidhi (PM-KISAN) by Hon'ble Prime Minister of India at three places on 24 February 2019. The programme was directed by ICAR, New Delhi and organized at ICAR-NRRI, Cuttack; NRRI-Krishi Vigyan Kendra, Santhapur, Cuttack and Modi Ground in Bargarh District of Odisha. About 4000 farmers and officials took part in the programme. Hon'ble Union Minister of Tribal Affairs Sh. Jual Oram also participated in the event at Bargarh, Odisha.

Administrative building of KVK, Cuttack

The administrative building of Krishi Vigyan Kendra Cuttack, was inaugurated by Dr. T. Mohapatra, Secretary (DARE) and DG (ICAR) on 2 December 2018 in presence of Dr. AK Singh, DDG (Agricultural Extension) and Dr. SS Singh, Director, ATARI, Zone-V, Dr. H Pathak, Director.

Ninth Dr. GS Sekhon Memorial Lecture

The Cuttack Chapter of Indian Society of Soil Science, organized 9th Dr. GS Sekhon Memorial lecture-2018 on 3 November 2018. Dr. SK Ambast, Director, IIWM, Bhubaneswar delivered the lecture on "Water, energy and foods security nexus: a national perspective".

Dr. SK Ambast, Director, IIWM delivering the lecture

Hindi fortnight

Hindi fortnight-2018 was celebrated from 14 and 29 September 2018 at NRRI, Cuttack.

Vigilance awareness week

The Vigilance awareness week was observed from 29 October to 3 November 2018. Shri Sanjib Panda, IPS, Transport Commissioner-cum-Chairman, State Transport Authority, Odisha and Chief Guest distributed the certificates and prizes to the winners of the competitions.

Rashtriya mahila kisan divas

Farmer FIRST Programme of the ICAR-NRRI and Krishi Vigyan Kendra, Cuttack jointly organized the *"Rashtriya Mahila Kisan Divas"* programme on 15 October 2018. About 120 farmwomen along with women staff of NRRI, other ICAR institutes participated in this programme.

Participants of Rashtriya Mahila Kishan Diwas

Rice germplasm field day

The ICAR-NRRI, Cuttack organized Rice Germplasm Field Day on 30 October 2018. More than 65 participants from various parts of the country.

Swachhata pakhwada and kisan diwas

The Institute Swachh Bharat Committee organized Swachhata Pakhwada from 16 to 31 December 2018 and Kisan Diwas on 23 December 2018 at NRRI, Cuttack.

CRURRS, Hazaribagh observed the "Swachhata Pakhwada" from 16 to 31 December 2018.

RRLRRS, Gerua observed the "Swachhata Pakhwada" from 16 to 31 December 2018.

Fifty one TOLIC meeting

The 51[st] Half Yearly meeting of Town Official Language Implementation Committee (TOLIC), Cuttack was held for the member offices of TOLIC on 30 October 2018.

International women's day

International Women's Day was celebrated at ICAR-NRRI, Cuttack on 8 March 2019.

Live Webcast of Hon'ble Prime Minister's direct dialogue with farmers

Hon'ble Prime Minister had a direct dialogue with the farmers across the country and the programme was webcasted at the Institute auditorium on 20 June 2018.

Live Webcast of interaction of Hon'ble PM with members of SHGs and women groups

Hon'ble Prime Minister had a video interaction with the members of SHGs and women groups across the country. KVK, Cuttack organized the live webcasting of the interaction on 12 July 2018.

World soil day for creating awareness on soil pollution

KVK Cuttack celebrated World Soil Day on 5 December 2018 on the theme '*Be the solution to soil pollution*' at Baliapada village of Nischintakoili block.

KVK Koderma celebrated World Soil Day on 5 December 2018 in its Jainagar campus.

Distinguished Visitors

Dr. T Mohapatra, Secretary, DARE and Director General, ICAR, Govt. of India, New Delhi visited NRRI, Cuttack on 23 April 2018.

Dr. AK Singh, DDG (Horticulture & Crop Science), ICAR, New Delhi visited NRRI, Cuttack on 23 April 2018.

Prof. PB Kirti, Professor, Department of Plant Science, School of Life Sciences, University of Hyderabad, Telengana visited NRRI, Cuttack on 23 April 2018.

Dr. SM Bokhtiar, Director, SAARC Agriculture Centre, Dhaka, Bangladesh, Dr. PR Pandey (Nepal), Senior Programme Specialist (Crops), Dr. RSK Keerthisana, Dept. of Agriculture, Sri Lanka, Dr. Pema Crofil, Program Director, Bhutan, Dr. RB Yadav, Rice Coordinator, Nepal and Dr. M Yousuf, PARC, Islamabad, Pakistan visited NRRI, Cuttack on 16 August 2018.

Shri Radha Mohan Singh, Hon'ble Union Minister of Agriculture and Farmers Welfare graced the occasion as the Chief Guest and Shri Dharmendra Pradhan, Hon'ble Union Minister of Petroleum & Natural Gas and Skill Development & Entrepreneurship graced as the Guest of Honour and Dr. T Mohapatra, Secretary, DARE and DG, ICAR visited NRRI, Cuttack on 26 February 2019.

Foreign Deputation

Dr. H Pathak, Director, NRRI attended "Third Lead Author Meeting (LAM3) for the elaboration of the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2019 Refinement) at Cairns, Australia from 10 to 13 April 2018.

Dr. A Anandan attended the Junior Fellowship for 2017-18 (NEWS India-UK Research Fellowship) at University of Aberdeen, United Kingdom from 16 April to 21 May 2018.

Dr. (Mrs.) Sangita Mohanty and Dr. Dibyendu Chatterjee attended the Senior Fellowship for 2017-18 (NEWS India-UK Research Fellowship) from 1 May to 30 May 2018.

Dr. GAK Kumar attended the 'Exposure visit of Farmers on Community Engagement of Seed Sovereignty for Resilient Agriculture in South Asia' at Bogra, Bangladesh from 19 to 21 May 2018.

Dr. AK Nayak attended Endeavour Executive Fellowship at Global Centre of Environmental Remediation, University of New Castle, Australia from 15 July to 14 October 2018.

Dr. GAK Kumar attended the first SAARC Agriculture Cooperative Business Forum-Organizing and Strengthening Family Farmers Cooperatives to attain SDG-1 and SDG-2 in South Asia at Kathmandu, Nepal from 28 to 30 August 2018.

Dr. P Bhattacharyya attended a conference on ECSA57 Changing Estuaries Coast and Shelf Systems-Diverse threats and opportunities-2018 at Perth, Australia from 3 to 6 September 2018.

Dr. B Mondal attended the workshop as expert to develop approaches for N threat-benefit valuation under the project towards International Nitrogen Management System (INMS) at Fort Collins CO, USA from 10 to 13 September 2018.

Dr. RP Sah and Dr. RL Verma attended a programme on Indian NARES-BRRI Interactive Meeting under Transformative Rice Breeding at BRRI, Bangladesh from 15 to 18 September 2018.

Drs. H Pathak and SD Mohapatra participated in the 22nd Annual Meeting of the Council for partnership on Rice Research in Asia (CORRA) at Singapore from 14 to 17 October 2018.

Drs. JN Reddy, P Swain, MJ Baig and M Shahid participated in the 5th International Rice Congress-2018 organized by International Rice Research Institute, Philippines at Singapore from 15 to 17 October 2018.

Dr. H Pathak attended 4th Lead Author Meeting (LAM4) 'for elaboration of the 2019 refine to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2019 refinement)' at Rome, Italy from 22 to 26 October 2018.

Drs. AK Nayak and Rahul Tripathi attended the Annual Meeting of project entitled 'Delivering Food Security of Limited Land (DEVIL)' at Ubatuba Sao Paulo State, Brazil from 4 to 7 November 2018.

Dr. H Pathak participated in the International Conference on 'Role of Soil and Plant Health in Achieving Sustainable Development Goals' at Bangkok, Thailand from 22 to 24 November 2018.

Commercialization of ICAR-NRRI Technologies

During the year, 15 MoUs were signed by the institute with 10 companies. They were licensed on non-exclusive basis for three years for commercialising the NRRI technologies in large scale for the benefit of farming communities.

No. of Variety Registration

i) PPV&FRA Registration

During the period, CR Dhan 303 (CR 2649-7) (IET 21589) was registered at PPV&FRA as New variety on 11 December 2018.

ii) NBPGR Registration

During the period, four unique rice germplasm were registered with the Plant Germplasm Registration Committee (PGRC) of ICAR-NBPGR, New Delhi having the unique traits of tolerance/resistance to both abiotic and biotic stresses. They are Khora-1 (AC 41620; IC0574806), Cherayi Pokkali (AC 39416A; IC 0413644) for salinity cum submergence stress tolerance and Salkathi (AC 35181; PB 289), Dhobanumberi (IC 0256804) for BPH resistance.

Award and Recognition

1. ICAR-NRRI, Cuttack received the Best Exhibition Award 2017 from the Chief Guest Dr. T. Mohapatra, Secretary, DARE & DG, ICAR during the World Food Day Theme Discussion Meet on 25 October 2018 organized by the Orissa Krushak Samaj in Bhubaneswar.

2. Dr. SK Pradhan received 1st Dr. AB Joshi Memorial Award (triennial)-2017 for the year 2014, 2015 and 2016 on 14 December 2018 from Dr. T. Mohapatra during the 1st National Genetics Congress at New Delhi. The Award was for contribution in the field of Breeding and Genetics.

Dr. SK Pradhan received 1st Dr. AB Joshi Memorial Award

3. Dr. AK Nayak was nominated as Member of the Institute Management Committee at NRRI, Cuttack for the period of 5 March 2019 to 4 March 2022.

4. Dr. AK Nayak acted as member of 43rd Institute Management Committee at CIFA, Bhubaneswar on 15 March 2019.

5. Dr. AK Nayak was nominated as expert committee member for selection of Odisha states' awards on 24 February 2019.

6. Dr. PC Rath received Bharat Jyoti Award 2018 – for outstanding service, achievement and contributions in the field of research by India International Friendship Society (IIFS), New Delhi on 4 December 2018.

7. Dr. PC Rath was awarded Fellow of Indian Climate Congress 2018 – for outstanding contribution in agricultural research and climate change by India Climate Congress (ICC), Satyasai Charitable & Educational Trust, Mahanadi Vihar, Cuttack on 29 December 2018.

8. Dr. SK Mishra was conferred with the 'KrushiRatnaSamman 2018' by the Chief Guest Dr. TMohapatra, Secretary, DARE & DG, ICAR during the 60th Foundation Day of Orissa KrushakSamaj (OKS) and World Food Day Theme Discussion Meet at Bhubaneswar on 25 October 2018.

9. Dr. AK Mukherjee received "Sir CV Raman Life Time Achievement National Award" for outstanding excellence and remarkable achievement in the field of Teaching, Research & Publications at Chennai by IRDP group of journals, Chennai on 28 October 2018.

10. Dr. M Shahid received the ISSS-Golden Jubilee Commemoration Young Scientist Award during 83rd Annual Convention of the Indian Society of Soil Science and National Seminar on Developments in Soil Science at Anand, Gujarat.

11. Dr. A Kumar received Best Doctoral Research Presentation Award 2018 by ISSS, New Delhi.

12. Drs. AK Nayak, Anjani Kumar, P Panneerselvam and Upendra Kumar received Rula Award for International innovation and betterment in technical research.

13. Dr. S Shekhar received Fellow Award 2018 from the Society for upliftmentof Rural economy (SURE) during International Conference on Rural Livelihood Improvement by enhancing famers income through sustainable innovative Agri & Allied Enterprises (RLISAAe) from 30 October to 1 November 2018.

14. Dr. ChanchilaKumari, Dr. S Shekhar and Mr. Rupesh Ranjan received Best KVK Professional Award in 9th National Extension Education Congress-2018 at CAPHET, Ranipool, Sikkim from 15 to 17 November 2018.

15. Dr. S Shekhar received Best KVK Scientist award (SamgraBiksh Bharti)-2018 at BBAU, Lucknow.

16. Shri BB Polai received appreciation certificate for his contribution on implementing PFMS and

Awardees at Institute Foundation Day

Name	Category
Dr. BB Panda	Principal Scientist
Dr. S Lenka	Senior Scientist
Dr. NN Jambhulkar	Scientist
Dr. RK Mohanta	Technical (T6 and above)
Shri Rupesh Ranjan Shri Haladhar Dhakuria	Technical (T4 and T5)
Shri SK Tripathy	Technical (T1 and T3)
Shri Birenchi Bhoi Shri Madhab Pradhan	Skill Supporting Staff
Shri Sudhakar Dash	Administration (Category 3)
Shri NN Mohanty	Administration (Category 2)
Dr. GP Pandi G	Best Sports Person
EAP-245: Strategic research component of National Innovation in Climate Resilient Agriculture (NICRA)	Best EAP

HRD - Training and Capacity Building

Capacity Building of the Students at NRRI for the year 2018-19

Human Resource Development (HRD) cell was created at NRRI for strengthening and facilitating training and capacity building of the students/ scientists/other staff members to work in the emerging areas of rice research and management.

The research areas identified for MSc and PhD students are nutrient management, crop physiology and biochemistry, climate change adaptation and mitigation, agronomy, crop protection seed systems, plant breeding and varietal evaluation, geospatial analysis and yield modelling, land use-land cover mapping,extrapolation domains, crop insurance, impact assessment, knowledge management, innovations in extension, gender and youth research, entrepreneurship in agri-food systems.

Physical targets and achievements

Sl. No.	Category	Total No. of employees	No.of training planned for 2017-18 asper Annual Training Plan	No.of employees undergone training during 2017-18	% realization of trainings planned during 2017-18
1.	Scientist	99	16	34	212.50
2.	Technical	100	31	37	119.35
3.	Administrative & Finance	62	24	28	116.67
4.	SSS	44	-	-	-

Achievements of the HRD programmes for the students during 2018-19

No. of students completed M.Sc. dissertation	No. of students awarded Ph.D.	No. of students enrolled for Ph.D.	No. of Ph.D. students availed IRRI-NRRI fellowship	No. of students undertook Summer Training	Specialized Training on Doubled Haploid Technology
41	5	10	5	16	1 (scientist, ICAR-SBI, Coimbatore for 1 month)

Financial targets and achievements for 2018-19 of all NRRI employees

Sl. No.	RE 2018-19 for HRD			Actual Expenditure 2018-19 for HRD	% Utilization
	Plan	Non-Plan	Total		
	(Lakh Rs.)			(Lakh Rs.)	2018-19
1.	6.00		6.00	6.00	100%

Extension Activities

With the aim of transferring the research findings to farmers field for improvement of agriculture and efficient utilization of resources, the Institute propelled the following extension activities:

Field demonstrations with newer rice varieties

Field demonstrations were conducted using newly released rice varieties and crop production /protection technologies in the farmers' field under different research programmes to convince the extension functionaries and farmers about potentialities of the Institute-released varieties and technologies. About 15 varieties were demonstrated in Assam, Bihar, Jharkhand, Odisha and West Bengal during the year 2018-19.

Participation in exhibition

The institute and its sub-stations participated 18 events like farmers fair, workshop, symposia, etc. and during 2018-19 and displayed its exhibits for showcasing the technologies and achievements made by the Institute.

Fortnightly agro-advisory services

A total of 24 agro-advisories on rice were issued on fortnightly basis in English as well as Odia language during the year 2018-19. The advisories were sent by mail to the officials of agriculture and related departments of the state as well as uploaded in Institute website for public awareness and reference.

Visitor's advisory services

A total of 8439 visitors including 4909 farmers, 2399 farm-women, 769 students and 362 agriculture officers from Odisha, West Bengal, Jharkhand, Assam, Bihar, Tamil Nadu, Jammu and Kashmir, Chhattisgarh, Andhra Pradesh, Madhya Pradesh, Karnataka, Maharashtra, Uttarakhand and New Delhi visited demonstrations and experimental plots, agricultural implement workshop, net houses and *Oryza* museum of the institute during 2018-19.

Training programmes for farmers and extension professionals

A total of 41 training programmes of different durations (2-8 days) were conducted for farmers, extension officials, administrative personnel and others in the area of improved rice production and protection technologies, integrated farming system (IFS), rice seed production technologies, enterprise management, financial management system (FMS), etc.

Mera Gaon Mera Gaurav (MGMG) Programme

To promote the direct interface of scientists with the farmers through providing information, knowledge and advisories, working at 21 clusters of villages (comprising five villages each) covering eight districts of Odisha benefitting about 25,000 farmers; among which 26% belong to SC/ST and 66% landless and small farmers.

Tribal Sub-Plan (TSP) Programme

The Institute adopted two villages, namely Bandhasahi and Pitabari in Kandhamal district of Odisha under TSP programme with the aim of all-round development of tribal populations (in selected villages) through demonstration of improved rice varieties and production technologies as well as other developmental activities. Seeds of seasonal vegetables, saplings of tuber roots, yams, etc. were distributed to ensure their nutritional security. Animal health camps organized and feed supplements distributed for development of livestock. For enhancing the capacity building of the beneficiaries, a training programme on “small-scale farming for livelihood & nutritional security” was organized before onset of cropping season, in which about 100 tribal farmers participated.

Field demonstrations with newer rice varieties

Field demonstrations were conducted using newly released rice varieties and crop production/ protection technologies in the farmers’ field under different research programmes to convince the extension functionaries and farmers about potentialities of the technologies. Fifteen varieties were demonstrated during last year in Assam, Bihar, Jharkhand, Odisha and West Bengal.

In-charge and Members of Different Cells

Research Advisory Committee (RAC)

Prof. SK Datta, VC, Visva Bharati University, Shantiniketan, West Bengal – Chairman

Dr. DK Mishra, Director Farms, JN Krishi VishwaVidyalaya, Jabalpur, Madhya Pradesh – Member

Dr. AR Sharma, Ex-Director, Weed Science, Directorate of Weed Research, Jabalpur – Member

Dr. JS Bentur, Ex-Principal Scientist, ICAR-IIRR, Hyderabad – Member

Dr. PK Mohapatra, Ex-Professor, Life Sciences, Sambalpur University, Odisha – Member

Dr. RP Singh 'Ratan', Dean, Extension, BAU, Ranchi – Member

Shri Sukanta Kumar Panigrahi, Farmer's Representative – Member

Shri Amareswar Mishra, Farmer's Representative – Member

Dr. H Pathak, Director, NRRI, Cuttack – Member

ADG (FFC), ICAR, New Delhi – Member

Dr. SR Voleti, Director(A), IIRR – Special Invitee

Dr. JN Reddy, PS & Head, NRRI, Cuttack – Member Secretary

Institute Management Committee (IMC)

Dr. H Pathak, Director, NRRI, Cuttack – Chairman

Director of Agriculture & Food Production, Govt. of Odisha – Member

Director of Agriculture, Govt. of West Bengal, Kolkata – Member

Dean, College of Agriculture, OUAT, Bhubaneswar – Member

Dr. AK Nayak, PS &Head, NRRI, Cuttack – Member

Dr. (Mrs.) Padmini Swain, PS & Head, NRRI, Cuttack – Member

Dr. LV Subba Rao, PS & Head, IIRR, Hyderabad – Member

Dr. D Sarkar, Principal Scientist, CRIJAF, Barrackpore, Kolkata – Member

ADG (FFC), ICAR, New Delhi, Member

DD (F)-III, ICAR, New Delhi – Member

Shri Sukanta Kumar Panigrahi, Patanda, Nayagarh, Odisha (Non-Official) – Member

Shri Amareswar Mishra, Bhubaneswar, Odisha, Member (Non-Official) – Member

Shri BK Sahoo, Head of Office, NRRI, Cuttack – Member Secretary

Personnel

(From April, 2018to March, 2019)

Dr. Himanshu Pathak, Director

Crop Improvement Division

Name of the Scientist ....Designation

Dr. ON Singh ....I/c Head (On Deputation)

Dr. JN Reddy ....Pr.Scientist

Dr. BC Patra..Pr.Scientist

Dr. (Mrs.) S Samantaray ....Pr.Scientist

Dr. (Mrs.) Meera Kumari Kar ....Pr.Scientist

Dr. SK Pradhan ....Pr.Scientist

Dr. Lamobodar Behera...............................Pr.Scientist

Dr. Hatanath Subudhi................................Pr.Scientist

Dr. Lotan Bose ....Pr.Scientist

Dr. K Chattopadhyay ....Pr.Scientist

Dr. SK Dash ....Pr.Scientist

Dr. A Anandan..Pr.Scientist

Shri RK Sahu ....Scientist

Shri SSC Patnaik ....Scientist

Shri BC Marndi ....Scientist

Shri J Meher ....Scientist

Shri Mridul Chakraborti ....Sr.Scientist (w.e.f. 21.04.2018)

Dr. JL Katara ....Scientist

Dr. RL Verma ....Scientist

Dr. RP Sah ....Scientist

Dr. (Mrs.) P Sanghamitra...............................Scientist

Dr. N Umakant......Scientist (Relieved on 23.06.2018)

Dr. Kutubuddin Ali Molla.............................Scientist

Dr. (Mrs.) Sutapa Sarkar ....Scientist

Shri Parameswaran C.....................................Scientist

Dr. Devanna ....Scientist

Crop Production Division

Name of the Scientist ....Designation

Dr. AK Nayak...Head

Dr. PK Nayak ....Pr. Scientist

Dr. Sanjoy Saha ....Pr. Scientist

Dr. Pratap Bhattacharyya ....Pr. Scientist

Dr. BB Panda ....Pr. Scientist

Dr. (Mrs.) Annie Poonam ....Pr. Scientist

Dr. P Panneerselvam ....Sr. Scientist

Dr. Rahul Tripathi....................................Sr. Scientist (w.e.f. 10.02.2018)

Dr. (Mrs.) SangitaMohanty...................... Sr. Scientist (w.e.f. 21.04.2018)

Dr. Mohammad Shahid ....Sr. Scientist (w.e.f. 23.06.2018)

Dr. (Mrs.) Debarati Bhaduri ....Scientist

Dr. Upendra Kumar ....Scientist

Shri BS Satapathy...Scientist

Shri Anjani Kumar..Scientist

Dr. (Mrs.) Sushmita Munda ....Scientist

Dr. Dibyendu Chatterjee................................Scientist

Shri Prabhat Kumar Guru ....Scientist

Shri BN Totaram ....Scientist

Shri Sumanta Chaterjee ....Scientist

Shri Manish Debanath ....Scientist

Mrs. Rubina Khanam ....Scientist

Dr. (Ms.) M Sivashankari...............................Scientist

Dr. Vijayakumar S ....Scientist

Ms. Kavita Kumari ....Scientist (Joined on 09.10.2018)

Ms. Himani Priya..Scientist (Joined on 26.07.2018)

Ms. Supriya Priyadarsani ....Scientist (Joined on 26.07.2018)

Crop Protection Division

Name of the Scientist ....Designation

Dr.(Mrs.) Mayabini Jena ....Head (Retired on 30.06.2018)

Dr. PC Rath ....Pr. Scientist

Dr. KR Rao ....Pr. Scientist

Dr. SD Mohapatra.....................................Pr. Scientist

Dr. AK Mukherjee ....Pr. Scientist

Dr. Manas Kumar Bag ....Pr. Scientist

Dr. Srikanta Lenka.....................................Pr. Scientist (w.e.f. 08.06.2017)

Dr. Sudhamoy Mondal ....Pr. Scientist (Joined on 20.08.2018)

Dr. Totan Adak ....Scientist

Shri Somnath Suresh Pokhare........................Scientist
Shri Manoj Kumar Yadav ....Scientist
Shri Aravindan S ....Scientist
Dr. Naveen Kumar B Patil.............................Scientist
Dr. Raghu S...Scientist
Dr. Guruprasanna Pandi G ....Scientist
Dr. Basana Gowda G......................................Scientist
Dr. Prabhukarthikeyan SR ....Scientist
Dr. Mathew Saikholen Baite ....Scientist
Shri M. Annamalai ....Scientist
Ms. Golive Prasanthi ....Scientist
Dr. (Mrs.) Sankari Meena K ....Scientist
Mrs. Keerthana U..Scientist
(Joined on 02.07.2018)

Crop Physiology and Biochemistry Division

Name of the Scientist ....Designation

Dr. (Mrs.) Padmini Swain.........................Pr. Scientist
Dr. MJ Baig ....Pr. Scientist
Dr. Koushik Chakraborty ....Scientist
Shri Torit Baran Bagchi..................................Scientist
Dr. Awadhesh Kumar....................................Scientist
Dr. PS Hanjagi...Scientist
Mrs. Nabaneeta Basak...................................Scientist
Sri Gaurav Kumar ....Scientist
Dr. (Mrs.) Sushma M. Awaji ....Scientist
(Joined on 09.10.2018)

Social Science Division

Name of the Scientist ....Designation

Dr. P Samal ....Pr.Scientist (Retired on 30.04.2018)
Dr. NC Rath ....Pr. Scientist
Dr. GAK Kumar ....Pr. Scientist
Dr. SK Mishra ....Pr. Scientist
Dr. (Mrs.) Lipi Das.....................................Pr. Scientist
(Relieved on 28.06.2018)
Dr. Biswajit Mondal ....Pr. Scientist
Dr. NN Jambhulkar ....Scientist
Shri Jaiprakash Bisen.......................................Scientist
(Joined on 26.07.2018)

Central Rainfed Upland Rice Research Station, Hazaribagh, Jharkhand

Name of the Scientist ....Designation

Dr. D Maiti ....Head
Dr. NP Mandal ....Pr. Scientist
Dr. Shiv Mangal Prasad ....Pr. Scientist
Dr. Someshwar Bhagat ....Pr. Scientist
Dr. CV Singh ....Pr.Scientist
(Retired on 31.12.2018)
Dr. BC Verma ....Scientist
Dr. Somnath Roy ....Scientist
Dr. (Mrs.) Amrita Banerjee ....Scientist

Regional Rainfed Low Land Rice Research Station, Gerua, Assam

Name of the Scientist ....Designation

Dr. Rupankar Bhagwati ....Pr. Scientist
Dr. Kanchan Saikia ....Pr. Scientist
Shri SK Ghritlahre ....Scientist
Md. Azharudeen TP ....Scientist
Shri B. Raghavendra Goud............................Scientist

Technical Staff, NRRI, Cuttack

Category-III

Name ....Designation

Shri KK Swain ....Chief Technical Officer
(Mechanical) (Retired on 28.02.2019)

Category-II

Name ....Designation

Dr. Ramesh Chandra.............Chief Technical Officer
(Sr. Farm Assistant)
Shri Prakash Kar ....Chief Technical Officer
(Photography)
Shri P Jana...............................Chief Technical Officer
(Rice Production Training)
Dr. Pradeep Kumar Sahoo ....Assistant Chief
Technical Officer (Fishery)
Shri AK Dalai................Asst. Chief Technical Officer
(Electrical) Retired on 31.10.2018
Shri BK Mohanty ....Sr. Technical Officer
(Hindi Translator)
Shri Sunil Ku. Sinha .....Technical Officer (Computer)
Shri Manoj Ku. Nayak .....Technical Officer (Library)
Shri J Sai Anand...................Technical Officer (Farm)
Shri Santosh Ku. Sethi ..Technical Officer (Computer)
Shri PL Dehury ....Technical Officer (Farm)
Shri Brundaban Das ....Technical Officer (Farm)
Shri Prempal Kumar ....Technical Officer (Farm)
Smt. Sandhya Rani Dalal ...Technical Officer (Editor)

Smt. Rosalin Swain...............Technical Officer (Farm)

Smt. Gayatri Sinha ....Technical Officer (Farm)

Shri Smruti Kanta Rout ....Technical Officer (Computer)

Smt. Chandamuni Tudu......Technical Officer (Farm)

Shri Lalan Kumar Singh ....Technical Officer (Training)

Smt. Baijayanti Nayak ....Technical Officer (Farm)

Shri Dharmendra Baral ....Technical Assistant (Farm Assistant)

Shri Debakanta Nayak.................Technical Assistant (Farm Assistant)

Shri Jeetendra Senapaty ....Technical Assistant (Farm Assistant)

Shri Ekamra Kanan Padhan.........Technical Assistant (Farm Assistant)

Shri Susanta Kr. Mahapatra.........Technical Assistant (Farm Assistant)

Shri Surya Prasad Lenka ....Technical Assistant (Mechanical Engineer)

Shri Sarat Chandra Sahoo ....Technical Assistant (Farm Assistant)

Dr. Sagar Banerjee ....Technical Assistant (Farm Assistant)

Ms. Baneeta Mishra......................Technical Assistant (Farm Assistant)

Ms. Mamata Meena......................Technical Assistant (Farm Assistant)

Shri Debabrata Samal ....Technical Assistant (Farm Assistant)

Shri Biswaranjan Behera ....Technical Assistant (Farm Assistant)

Shri Punyaloka Samantaray ....Technical Assistant (Civil Engineer)

Shri Arnab Malik..........................Technical Assistant (Farm Assistant)

Shri Harmohan Pradhan ....Technical Assistant (Farm Assistant)

Shri Abinash Parida ....Technical Assistant (Engineering-Instrument)

Shri E.Venkat Ramaiah................Technical Assistant (Farm Assistant)

Shri Abhishek Meena ....Technical Assistant (Farm Assistant)

Ms. Saloni Baskey.........................Technical Assistant (Farm Assistant)

Shri Satyabrata Mohanty.............Technical Assistant (Electrical Engnr.)

Shri Arabinda Mahanty................Technical Assistant (Farm Assistant)

Shri Gaban Mandi ....Technical Assistant (Farm Assistant)

Shri Rodda Prabhakar Rao ....Technical Assistant (Farm Assistant)

Mrs. Anindita Pal ....Technical Assistant (Farm Assistant)

Shri Ankit Anand ....Technical Assistant (Farm Assistant)

Category-I

Name ....Designation

Shri AK Mishra ....Sr.Technical Officer (Field Assistance)

Shri KK Suman.............................Sr.Technical Officer (Field Assistance)

Shri Bhagaban Behera.......................Technical Officer (Photography)

Shri KC Bhoi ....Technical Officer (Blacksmith) Retired on 31.01.2019

Shri Srikrishna Pradhan.......Technical Officer (Field)

Shri JC Hansda ....Technical Officer (Field)

Shri Aparti Sahoo.................Technical Officer (Field)

Shri Arun Panda ....Technical Officer (Library)

Shri KC Palaur ....Technical Officer (Driver)

Shri JP Behura ...Technical Officer (Supervisor-Civil)

Shri Santosh Ku. Ojha.Technical Officer (Electrician)

Shri Prahallad Moharana.....Technical Officer (Field)

Mrs. Nibedita Biswal ....Technical Officer (Lab. Technician)

Shri Ramrai Jamunda..Sr.Technical Assistant (Fitter)

Shri Arun Kumar Parida ....Sr.Technical Assistant (Painter)

Shri DR Sahoo..Sr.Technical Assistant (Projectionist)

Shri AK Moharana...................Sr.Technical Assistant (Field Asst.)

Shri Prasanta Kumar Jena ....Sr.Technical Assistant (Driver)

Shri Bansidhar Ojha..................Sr.Technical Assistant (Welder)

Mrs. Chintamani Majhi...........Sr.Technical Assistant (Field Asst.)

Shri Kailash Ch. Mallick ....Sr.Technical Assistant (Field Asst.)

Shri Srinibas Panda ....Sr. Technical Assistant (Electrician)

Shri Parimal Behera.................Sr. Technical Assistant (Field Asst.)

Shri Bhakta Charan Behera ....Sr. Technical Assistant (Field Asst.)

Shri Nakula Barik ....Sr. Technical Assistant (Field Asst.)

Shri Mansingh Soren ....Sr. Technical Assistant (Field Asst.)

Shri AC Moharana..................Sr. Technical Assistant (Field Asst.) Retired on 31.10.18

Shri Jogeswar Bhoi ....Sr. Technical Assistant (Field Asst.)

Shri Pradeep Kumar Parida.........Technical Assistant (Driver)

Shri Debasis Parida ....Technical Assistant (Tractor Driver)

Sri Pramod Kumar Ojha...............Technical Assistant (Tractor Driver)

Shri Debaprakash Behera.............Technical Assistant (Driver)

Shri Gyanaranjan Bihari ....Technical Assistant (Driver)

Shri Ajaya Kumar Nayak ....Sr. Technician (Pharmacist)

Shri Surendra Biswal ....Sr.Technician (Field Asst.)

Shri Susanta Ku. Tripathy ....Sr. Technician (Field Asst.)

Shri Baidyanath Hembram ....Sr. Technician (Field Asst.)

Shri Dularam Majhi ....Sr.Technician (Field Asst.)

Shri Sesadev Pradhan ......Sr.Technician (Field Asst.)

Shri Chandan Kumar Ojha...................Sr. Technician (Field Asst.)

Shri RamudevBeshra ....Sr. Technician (Farm Mechanic)

Shri Pramod Kumar Sahoo ....Sr. Technician (Machine Operator)

Shri Bhagyadhar Pradhan ....Sr. Technician (Farm Mechanic)

Shri Keshab Chandra Das ....Sr. Technician (Machine Operator)

Shri Alok Kumar Panda ....Technician (Extension Asst.)

Shri Ajaya Kumar Naik.........Technician (Field Asst.)

CRURRS, Hazaribagh (Jharkhand)

Category-II

Name ....Designation

Shri Dharm Raj Meena ....Technical Assistant (Farm Assistant)

Shri Jitendra Kumar ....Technical Assistant (Computer)

Category-I

Name ....Designation

Shri Ranjit Tirky...................Technical Officer (Field)

Shri AN Singh ....Technical Officer (Field)

Shri Sawan Oran ....Technical Officer (Field)

Shri Ugan Saw ....Technical Assistant (Driver)

Shri Jitendra Prasad ......Technician (Extension Asst.)

RRLRRS, Gerua (Assam)

Category-II

Name ....Designation

Shri Bibhash Medhi....Technical Officer (Farm Asst.)

Smt. Sikimoni Baruah ....Technical Officer (F.Mt.)

Shri Dibakar Khan ....Sr. Technical Assistant (Computer)

Category-I

Name ....Designation

Shri Haladhar Thakuria ....Technical Officer (Field Asst.)

Shri Bhupen Kalita ....Technician (Field Asst.)

KVK, Santhpur, Cuttack

Category-III

Name ....Designation

Mrs. Sujata Sethy..........Asst. Chief Technical Officer, SMS (Home Sci.)

Shri Dillip Ranjan Sarangi ....Asst. Chief Technical Officer, SMS (Soil Science)

Dr. Manish Chourasia ....Asst. Chief Technical Officer, SMS (Plant Protection) Relieved on 21.02.2019

Shri Tusar Ranjan Sahoo............Sr. Technical Officer, SMS (Horticulture)

Dr. Ranjan Kumar Mohanta......Sr. Technical Officer, SMS (Animal Science)

Category-I

Name ....Designation

Shri Makardhar Behera...........Sr. Technical Assistant (Tractor Driver) Retired on 31.05.2018

Shri Arabinda Bisoi ....Sr. Technician (Driver)

KVK, Jainagar, Koderma

Category-III

Name ....Designation

Mrs. Chanchila Kumari ....Chief Technical Officer, STA (Home Science)

Dr. Shudhanshu Sekhar ....Asstt. Chief Technical Officer, STA (Veterinary Science)

Shri Bhoopendra Singh ....Sr. Technical Officer, SMS (Horticulture)

Category-II

Name ....Designation

Shri Rupesh Ranjan ....Technical Officer (Training)

Shri Manish Kumar ....Technical Officer (Training)

Category-I

Name ....Designation

Shri Sanjay Kumar ....Technical Assistant (Driver)

ADMINISTRATIVE STAFF, NRRI, Cuttack

Name ....Designation

Shri KC Joshi..Joint Director (Admn.-cum-Registrar) (Relieved on 15.05.2018)

Shri BK Sahoo ....Administrative Officer (In-charge of Head of Office w.e.f. 16.05.2018)

Shri Sunil Kumar Das.....Finance & Accounts Officer

Shri AK Tiwari ....Assistant Director (Official Language)

Shri Nabakishore Das ....Security Officer

Shri SK Mathur ....Administrative Officer

Shri SK Das ....Assistant Administrative Officer

Shri NC Parija ....Assistant Administrative Officer

Shri NK Swain ....Assistant Administrative Officer

Shri CP Murmu ......Assistant Administrative Officer

Shri SK Jena...........Assistant Administrative Officer

Shri GK Sahoo ....Private Secretary

Shri NN Mohanty ....Private Secretary

Shri Janardan Nayak........................Private Secretary

Shri Narayan Mahavoi ....Private Secretary

Shri Trilochan Ram ....Personal Assistant (Retired on 31.01.2019)

Shri A Kullu ....Personal Assistant

Smt. Belarani Mahana ....Personal Assistant

Shri Daniel Khuntia ....Personal Assistant

Smt. Nirmala Jena ....Personal Assistant

Shri Manas Ballav Swain ....Personal Assistant

Smt. Snehaprava Sahoo.................Personal Assistant

Miss Sabita Sahoo ....Personal Assistant

Shri Manoranjan Swain.................Personal Assistant

Shri KK Sarangi ....Assistant

Shri SK Behera ....Assistant

Shri Satyabrata Nayak...................................Assistant

Shri Subodh Kumar Sahu ....Assistant

Shri RK Behera...Assistant

Shri Ramesh Ch. Das ....Assistant

Smt. Rosalia Kido ....Assistant

Shri NP Behura ....Assistant

Shri Sanjaya Kr. Sahoo ....Assistant

Shri Munael Mohanty...................................Assistant

Shri Saroj Kumar Nayak ....Assistant

Shri Dillip Kumar Parida ....Assistant

Shri SK Satapathy..Assistant

Shri Manoj Kumar Sethi...............................Assistant

Shri KC Behera ....Assistant

Shri PC Das ....Assistant

Shri AK Pradhan ....Assistant

Sri RC Pradhan ....Assistant

Shri Vishal Kumar...Assistant

Smt. Gourimani Dei ....Assistant

Shri Rajdip Dutta...Assistant

Shri Samir Kumar Lenka..............................Assistant

Shri Sanjeeb Kr. Sahoo..................................Assistant

Smt. Manasi Das..Assistant

Shri Ramesh Ch. Nayak ....Upper Division Clerk

Shri Sunil Pradhan ....Upper Division Clerk

Smt. Ambika Sethi....................Upper Division Clerk

Shri Ranjan Sahoo ....Upper Division Clerk

Shri Amit Kumar Sinha ....Lower Division Clerk

Shri BK Gochhayat...................Lower Division Clerk

Shri Harihar Marandi ....Lower Division Clerk

Shri Santosh Kr. Bhoi ....Lower Division Clerk

Shri Dhaneswar Muduli..........Lower Division Clerk

Shri Rahul Kumar Singh ....Lower Division Clerk

Shri Rabinder Pal Sing Sabarwal ....Lower Division Clerk

Shri Santosh Kumar Patra........Lower Division Clerk

Shri Susanta Kumar Das ....Lower Division Clerk

CRURRS, Hazaribagh (Jharkhand)

Name	Designation
Shri R Paswan	Personal Assistant
Shri Sanjeev Kumar	Assistant
Shri CR Dangi	Upper Division Clerk
Shri Arbinda Kumar Das	Lower Division Clerk
Shri Satish Kr. Pandey	Lower Division Clerk

RRLRRS, Gerua (Assam)

Name	Designation
Shri DK Mohanty	Assistant Administrative Officer
Smt. Jali Das	Upper Division Clerk

KVK, Santhpur, Cuttack

Name	Designation
Shri Bibhuti Bhusan Polai	Stenographer

Others (Canteen Staff), NRRI, Cuttack

Name	Designation
Shri Arabinda Jena	Canteen Manager
Shri Meru Sahu	Bearer
Shri Markanda Nayak	Bearer
Shri Madhaba Pradhan	Bearer
Shri Nityananda Naik	Wash Boy

SKILLED SUPPORT STAFF

NRRI, Cuttack

Name	Designation
Shri Sahadev Naik	Skilled Support Staff (Retired on 31.10.2018)
Smt. Gurubari Dei	Skilled Support Staff
Shri Dambarudhar Das	Skilled Support Staff (Retired on 31.05.2018)
Shri Fakira Charan Sahu	Skilled Support Staff
Shri Jogendra Biswal	Skilled Support Staff
Smt. Snehalata Biswal	Skilled Support Staff
Smt. Namasi Singh	Skilled Support Staff (Retired on 28.02.2019)
Shri Lawa Murmu	Skilled Support Staff
Smt. Surubali Hembram	Skilled Support Staff
Smt. Mukta Hembram	Skilled Support Staff (Retired on 31.05.2018)
Smt. Basanti Marandi	Skilled Support Staff
Shri Dasia Naik	Skilled Support Staff (Retired on 31.03.2019)
Shri Krushna Naik	Skilled Support Staff
Shri Ganesh Chandra Sahoo	Skilled Support Staff
Shri Bichitrananda Khatua	Skilled Support Staff
Smt. Santi Dei	Skilled Support Staff
Smt. Deba Dei	Skilled Support Staff (Retired on 30.09.2018)
Shri Dharmananda Bhoi	Skilled Support Staff (Retired on 31.01.2019)
Shri Kirtan Bhoi	Skilled Support Staff
Shri Sarat Chandra Bhoi	Skilled Support Staff
Shri Narayan Das (B)	Skilled Support Staff
Shri Sudhir Kuamar Bhoi	Skilled Support Staff
Shri Gokuli Majhi	Skilled Support Staff
Smt. Mini	Skilled Support Staff
Smt. Kuni Dei	Skilled Support Staff
Shri Duruja Naik	Skilled Support Staff
Smt. Pramila Dei	Skilled Support Staff
Smt. Ramani Dei	Skilled Support Staff
Shri Biranchi Bhoi	Skilled Support Staff
Shri Pradeep Kumar Das	Skilled Support Staff
Shri Sadananda Naik	Skilled Support Staff (Expired on 01.08.2018)
Shri Jagu Marandi	Skilled Support Staff
Smt. Jayanti Dei	Skilled Support Staff
Shri Rabi Naik	Skilled Support Staff
Shri Bijay Naik	Skilled Support Staff
Shri Pandab Naik	Skilled Support Staff
Shri Debaraj Naik	Skilled Support Staff
Shri Bansidhar Naik	Skilled Support Staff

CRURRS, Hazaribagh, Jharkhand

Name	Designation
Shri Rameswar Ram	Skilled Support Staff
Shri Liladhar Mahato	Skilled Support Staff
Smt. Sita Devi	Skilled Support Staff
Smt. Nagiya Devi	Skilled Support Staff
Sri Bhuneswar Oran	Skilled Support Staff
Smt. Panwa Devi	Skilled Support Staff
Smt. Karmi Devi	Skilled Support Staff
Smt. Dhanwa Devi	Skilled Support Staff
Shri Tirath Ram	Skilled Support Staff
Shri Shambhu Gope	Skilled Support Staff
Shri Gopal Gope	Skilled Support Staff
Shri Megh Narayan Prasad	Skilled Support Staff
Shri Harish Chandra Bando	Skilled Support Staff

RRLRRS, Gerua, Assam

Name	Designation
Shri Manoranjan Das	Skilled Support Staff

KVK, Jainagar, Koderma

Name	Designation
Shri Mukesh Ram	Skilled Support Staff

Financial Statement for 2018-19

(As on 31 March 2019)

Plan **(Rs. in Lakh)**

Head of Account	R.E.	Expenditure
Establishment charges	3694.02	3694.02
Over Time Allowance (OTA)	0.08	0.08
Travel Allowance (TA)	80.00	80.00
Human Resource Development (HRD)	5.97	5.97
Pension	4500.00	4500.00
REPAIR & MAINTENANCE		
Equipment	44.19	44.19
Office Building	45.98	45.98
Residential Building	35.13	35.13
Minor Works	39.26	39.26
Contingencies	1279.95	1279.95
CAPITAL		
Equipment	210.43	210.44
Works	787.82	787.82
Furniture	16.97	16.96
TOTAL	**10739.80**	**10739.80**

Externally Aided Projects (EAPs)

Sl. No.	Project No.	Title of the Project	Principal Investigator	Source of Funding
1.	EAP-27	Revolving fund scheme for seed production of upland rice varieties at CRURRS, Hazaribagh	NP Mandal	AP Cess
2.	EAP-36	National Seed Project (Crops)	RK Sahu, RP Sah, P Sanghamitra	NSP
3.	EAP-49	Revolving fund scheme for breeder seed production	RK Sahu, RP Sah, P Sanghamitra	NSP/Mega seed
4.	EAP-60	Front line Demonstration under Macro-Management scheme of Ministry of Agriculture – New High Yielding Varieties	Y Kumar	DAC
5.	EAP-100	Seed Production in Agricultural Crops	RK Sahu, RP Sah, P Sanghamitra	ICAR
6.	EAP-125	Stress tolerant rice for poor farmers of Africa and South Asia – Drought prone rain-fed rice areas of South Asia – Hazaribagh Centre	NP Mandal	ICAR - IRRI (BMGF)
7.	EAP-126	Stress tolerant rice for poor farmers of Africa and South Asia- Drought prone areas- CRRI Centre	A Anandan, P Swain	ICAR - IRRI- (B&MGF)
8.	EAP-127	Stress tolerant rice for poor farmers of Africa and South Asia - Submergence and Flood prone areas (STRASA)	JN Reddy, SSC Patnaik K Chakraborty, K Chattopadhyay	ICAR-IRRI (B&MGF)
9.	EAP-128	Stress tolerant rice for poor farmers of Africa and South Asia – Salt affected areas (STRASA)	B Marandi, A Nayak, A Poonam K Chattopadhayay K Chakraborty	ICAR-IRRI (B&MGF)
10.	EAP-130	All India Network Project on Soil Biodiversity - Biofertilizers	D Maiti	ICAR
11.	EAP-139	AICRP on energy in agriculture and agro-based industries	PK Guru, NT Borkar	AICRP (DRET-SET/ DRET-BCT)
12.	EAP-140	Intellectual Property Management and Transfer/ commercialization of agricultural technology under National Agricultural Innovation Fund (NAIF)	BC Patra	ICAR
13.	EAP-141	DUS Testing of Rice and documentation	BC Patra	PPV&FRA
14.	EAP-161	Monitoring of the new initiative of "Bringing Green Revolution to Eastern India (BGREI) under the RashtriyaKrishiVikasYojana"	H Pathak, BB Panda	DAC, GOI
15.	EAP-163	Stress tolerant rice for poor farmers of Africa and South Asia – Sub grant, Seed (CRRI, Cuttack)	RK Sahu, P Sanghamitra RP Sah	IRRI-ICAR (STRASA)
16.	EAP-176	Using wild ancestor plants to make rice more resilient to increasingly unpredictable water availability	SK Das , P Swain, L Behera, BN Sadangi (up to 30.11.16), P Samal (w.e.f. 01.12.16)	DBT-BBSRC (DFI, UK)
17.	EAP-178	National Initiative on Climate Resilient Agriculture	Sudhanshu Shekhar	NICRA (ICAR)

18.	EAP-183	Characterization of toxins of Bacillus thuringiensisisolated from rice genotypes and their virulence assessment against leaf folder (*Cnaphalocrocis medinalis* Guenee)	Sonali Acharya & TK Dangar	DST Inspire
19.	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
20.	EAP-185	Development of crop and nutrient management practices in rice for Odisha state	S Saha, BC Patra, S Munda	ICAR-IRRI STRASSA
21.	EAP-186	Use of microbes for management of abiotic stresses in rice	AK Mukherjee	ICAR-IRRI
22.	EAP-187	Low carbon resource conservation technologies for sustainable rice production in low land ecology	P Bhattacharyya	ICAR
23.	EAP-189	Front Line Demonstrations under NFSM	NC Rath	DAC – DRR (NFSM)
24.	EAP-190	Multi location evaluation of rice germplasm (CRP on Ag. Bio)	NP Mandal	CRP-ICAR
25.	EAP-191	CRRI-NCIPM collaborative project on development and validation of IPM module for rice	SD Mohapatra, S Lenka, J Berliner, K Saikia, KB Pun , T Singh, T Adak, U Kumar	CRRI/NCI PM
26.	EAP-192	DNA marker based pyramiding and study of interactions among QTLs for higher grain number in rice (Oryza sativa L.)	Gayatri Gouda & T Mohapatra	DST Inspire
27.	EAP-193	Future rainfed lowland rice systems in Eastern India 15 (T3) (Development of crop and nutrient management practices in rice)	AK Nayak, P Gautam, B Lal, Md. Shahid, R Tripathi, D Bhaduri, K Chakraborty	STRASSA South Asia
28.	EAP-195	Artificial induction of chlamydospore in Trichodermasp. and identification of genes expressed during the process	HK Swain & AK Mukherjee	DST Inspire
29.	EAP-197	Consortia research platform (CRP) on bifortification	K Chattopadhyay, S Samantaray, M Chakraborty, A Kumar, N Basak, LK Bose, A Poonam, N Umakant	ICAR Plan-CRP
30.	EAP-198	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
31.	EAP-199	Incentivizing Research in Agriculture: Towards understanding the C3-C4 intermediate pathway in Poaceae and functionality of C4 genes in rice	MJ Baig, P Swain, L Behera, Gaurav Kumar, A Kumar, K Alimolla	ICAR Plan
32.	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
33.	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, S Aravindan, NP Mandal, S Samantaray, M Azharudheen	ICAR Plan

34.	EAP-202	Associated mapping of genes/QTLs for yield under reproductive stage drought stress in rice (Oryza sativa l.)	L Behera, P Swain, SK Dash, SK Pradhan, BC Patra, ON Singh	BIRAC
35.	EAP-203	Strategic development of water utilization in rice production system for higher crop and water productivity and profitability	BB Panda, P Swain, SK Pradhan, L Behera, R Tripathi	CRP – water (ICAR)
36.	EAP-204	CRP on Agro biodiversity: PGR Management and Use of Rice (Component & II)	BC Patra, G P Pandi, AK Mukherjee, K Chakraborty	CRP –Agrobiodiversity (ICAR)
37.	EAP-205	Nutrient cycle in agricultural system at field and regional scales	AK Nayak, S Mohanty, R Tripathi, M Shahid, A Kumar, P Gautam	ISRO – EOAM
38.	EAP-206	Eliciting soil microbiome responses of rice for enhanced water and nutrient use efficiency under anticipated climate changes	AK Nayak, P Bhattacharyya, MJ Baig, Md. Shahid, S Raj, A Kumar, T Adak, S Roy, U Kumar	NASF – ICAR
39.	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, P Guru SD Mohapatra, R Khanam	CAP - ICAR
40.	EAP-208	Evaluation of efficiency of zinc metalosate and boron metalosate foliar supplements for maximizing yield through balanced nutrition of important crops grown in India	M Shahid, AK Nayak, A Kumar, B Lal	AICRP (Contract)
41.	EAP-209	CRP on hybrid technology	RL Verma, JL Katara	CRP - ICAR
42.	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
43.	EAP-211	CRP on molecular breeding	M K Kar, L Behera, G P Pandi, A Mukherjee, M Chakraborti, N Umakanta, S Aravindan, P C Rath	CRP - ICAR
44.	EAP-212	Multilocational monitoring of Rynaxypyr 20SC against Scirpophagaincertulas in rice and rice hopper susceptibility survey in India for DPH-RAB55 106SC against Nilaparvatalugensand Sogatellafurcifera	SD Mohapatra, M Jena, B Gowda	Du Pont
45.	EAP-213	Maintenance, characterization and use of EMS of upland variety Nagina 22 for functional genomics in rice – Phase II	M K Kar, P Swain, AK Mukherjee, M Chakraborti, S Saha	DBT
46.	EAP-214	Energy and mass exchange in tropical rice-rice system (Completed on 31/03/2017)	D Chatterjee, R Tripathy, AK Nayak	ISRO
47.	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	NAIF, IP & TM – ICAR
48.	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 Sarka, SK Dash	DBT

49.	EAP-218	Evaluation of XR-848 benzyl ester alone; XR-848 Benzy ester + cyhalofop-butyl and penoxulam + cyhalofop-butyl for broad-spectrum weed control in wet direct-sown rice under shallow lowland and irrigated ecology	S Saha, S Munda	Dow agro sciences India Pvt. Ltd.
50.	EAP-219	Genetic enhancement of rice for low moisture stress tolerance	NP Mandal, Y Kumar	ICAR
51.	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
52.	EAP-222	Earth observation application mission	AK Nayak, S Mohanty, R Tripathi, M Shahid, A Kumar, P Gautam	ISRO
53.	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
54.	EAP-224	Understanding mechanism of tolerance to low light intensity in rice	MJ Baig, P Swain, SK Pradhan	NASF - ICAR
55.	EAP-225	Forewarning of major crop pests on special scale for their integrated management	SD Mohapatra, MK Yadav, G Pandi, S Bhagat	SAC-ISRO
56.	EAP-226	Study of host induced gene silencing (HIGS) and its utility in rice-R. solanipathosystem to controlsheath blight disease	KA Molla, A Mukherjee	DST
57.	EAP-227	Creation of seed hub for increasing indigenous production of pulses in India	DR Sarangi, TR Sahoo, M Chourasia, RK Mohanta	DAC &FW
58.	EAP-228	Increasing productivity and sustaining the rice-based production system through farmer FIRST approach	SK Mishra, B Mondal, SK Pradhan, S Saha, PK Nayak, S Lenka, R Tripathi, NT Borkar, G Prasanthi, M Sivashankari, Lipi Das, GC Acharya, SC Giri, JP Bisen, S Priyadarsani	ICAR-Farmer FIRST
59.	EAP-229	Phenomics of moisture deficit stress tolerance and nitrogen use efficiency in rice and wheat – Phase II	P Swain, SK Das, J Meher	NASF – ICAR
60.	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 Panneerselvam, U Kumar	DBT (NER-BPMC)
61.	EAP-231	Evaluation of bio efficacy and phytotoxicity of NN1-1501 on rice BPH + WBPH	M Jena, T Adak, GP Pandi	Hyderabad Chem Pvt. Ltd.
62.	EAP-233	Accelerated decomposition of rice straw using novel Trichoderma strain and its mutant s	A Mukherjee, T Adak	BRNS – DAE
63.	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

64.	EAP-235	Study and investigation of major QTLs associated with panicle compactness, ethylene receptor expression and grain filling in rice	S Sekhar & L Behera	DST, SERB
65.	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, B Lal, D Chatterjee	CSISA
66.	EAP-237	Effect of time of application and maintaining water level on bio-efficacy of flucetosulfuron (10% WG) against weed complex of direct-sown and transplanted rice	S Saha, S Munda	Indofil Industries Limited
67.	EAP-238	Efficacy of phosphine fumigant against storage pests of pulses, wheat, rice and coffee beans and residue analysis for quarantine and long term storage purpose	NKB Patil, T Adak	DAC
68.	EAP-239	Pyramiding and understanding the interaction of QTLs for deeper rooting and phosphorous uptake in rice (Oryza sativaL.)	E Pandit & SK Pradhan	DST (WOS-A)
69.	EAP-240	Potential gene mining from salt tolerant grasses for improvement of stress tolerance in crops	C Parameswaran	NASF-ICAR
70.	EAP-241	Genetic improvement of hybrid rice parental lines for enhancing yield heterosis	RL Verma, RP Sah, JL Katara, LK Bose, S Samantaray	ASEAN
71.	EAP-242	Targeting rice- fallows: a cropping system based extrapolation domain approach	BB Panda, R Tripathi, AK Nayak, H Pathak	STRASSA Phase III
72.	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
73.	EAP-244	Validation and promotion of IPM in Rice in Tribal Region of Jharkhand	S Bhagat, A Banerjee, D Maiti	ICAR-NCIPM
74.	EAP-245	Strategic research component of National Innovation in climate resilient agriculture (NICRA)	P Swain, AK Nayak, P Bhattacharyya, K Chattopadhya, A Anandan, S Mohanty, H Pathak, D Chatterjee, K Chakraborty	ICAR Net work
75.	EAP-246	Raising productivity and profitability of rice-based cropping system in Odisha through rice crop manager	S Saha, S Munda, BS Satapaty	IRRI
76.	EAP-247	Bio-efficacy evaluation of 'Agri-BoosterTMKSi' against major insect pests and diseases of rice	M Annamalai, T Adak, GP Pandi, B Gowda, MK Yadav	Noble Alchem Pvt. Ltd., Indore
77.	EAP-248	Accounting greenhouse gases (GHGs) emission and carbon flow in temporal shift of tropical mangrove to agriculture	P Bhattacharyya	ICAR-National Fellow
78.	EAP-249	Strengthening seed system of STRVs through innovative demonstrations and extension approaches in Odisha	RK Sahu, RP Sah, P Sanghamitra	IRRI-Odisha

79.	EAP-250	Validation and promotion of IPM in rice based cropping system	SD Mohapatra, S Lenka, U Kumar, BS Satapathy Raghu S, Prasanthi G, S Bhagat, D Maiti, A Banerjee, SM Prasad	NRRI-NCIPM
80.	EAP-251	IT-enabled Self- sufficient Sustainable Seed System for Rice	GAK Kumar, RK Sahu, BC Patra, B Mondal, AK Mukherjee, P Sanghamitra, RP Sah, NKB Patil	RKVY, Odisha
81.	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
82.	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
83.	EAP-254	Cereal Systems Initiative for South Asia (CSISA)-KVK, Cuttack	DR Sarangi, TR Sahoo, M Chourasia, RK Mohanta	IRRI-CSISA Project
84.	EAP-255	To evaluate the bio-efficacy of PII 1721 60% WG against sucking pests of rice	GP Pandi G, NKB Patil, T Adak, Prasanthi G	PI Industries Pvt. Ltd.
85.	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, Awadhesh Kumar	NASF
86.	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)	N Umakanta, S. Samantray, Awadhesh Kumar, Parameswaran C	NASF
87.	EAP-258	Evaluation of different formulations of Penoxsulam alone and Penoxsulam+ Cyhalofop butyl for broad spectrum weed control in rice	S Saha, BS Satapathy, S Munda, D Bhaduri	Dow Agro Sciences India Pvt. Ltd.
88.	EAP-259	Bio-efficacy, phytotoxicity and effects of Spinetoram 0.8% GR insecticide on natural enemies and rice pests	B Gowda, M Annamalai, Prasanthi G	Dow Agro Sciences India Pvt. Ltd.
89.	EAP-260	Development of climate smart practices for climate resilient varieties	Anjani Kumar, H Pathak, AK Nayak, S Saha	IRRI
90.	EAP-261	Establishment of State of Art of Pesticide Residue Analysis in Odisha for its Optimum and Safe Use	T Adak, GPPandi G, NKB Patil, Basana Gowda, Raghu S, S Munda, PC Rath, Prabhukarthikeyan SR	RKVY
91.	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	DST

92.	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	JN Reddy, ON Singh, BC Marandi, P Swain, JL Katara	DBT
93.	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
94.	EAP-265	Prospects of interactions of multistrain stress resilient beneficial phytotonic microbes and rice to improve productivity under environmental adversities (Emeritus Scientist Project)	TK Dangar	ICAR Emeritus scheme
95.	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)
96.	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
97.	EAP-268	Development and implementation of Rice Doctor for Odisha	PC Rath, AK Mukherjee, S Lenka	IRRI
98.	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)
99.	EAP-270	Evaluation and utilization of BPH resistant rice gene pool for multiple insect resistant traits	M Jena	ICAR Emeritus scheme
100.	EAP-271	Harvest Plus Programme : Biofortification of rice	K Chattopadhyay, Awadhesh Kumar, P Sanghamitra, G Kumar, LK Bose	IFPRI & CIAT
101.	EAP-272	Strengthening entrepreneurs in marketing and export of value added agricultural products by establishing a state of art quality assessment laboratory in Odisha	Sutapa Sarkar, N Basak, P Sanghamitra, T Adak, B Mondal, M Chakraborty, M J Baig, G Kumar, S Priyadarsani	RKVY-Odisha
102.	EAP-273	Introgression of saltol and Sub-1 genesinto restorer line of popular rice hybrid Ajay and Rajalaxmi through marker assisted selection	JL Katara	SERB, DST, Govt. of India
103.	EAP-274	Bio-Bank: Production and promotion of biocontrol agents and entrepreneurship development in aspirational districts of Odisha	Basana Gowda G, NKB Patil, GP Pandi, Totan Adak, Prasanthi G, Annamalai M, Raghu S, Prabhukartikheyan SR, PC Rath, AK Mukherjee	RKVY-Odisha
104.	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, Himani Priya, AK Nayak, SK Mishra, PK Nayak, Anjani Kumar, PK Guru	RKVY-Odisha
105.	EAP-276	Inclusive development through knowledge, innovative extension methods, networks and capacity building in Odisha	Rahul Tripathi, S Samantray, GP Pandi	IRRI

106.	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
107.	EAP-278	Efficacy of Chlorantraniliprole 625g/l FS (Lumivia) for the management of stem borer and leaf folder in paddy crop	NKB Patil, B Gowda, Annamalai M, PC Rath	E I Dupont India Pvt. Ltd.
108.	EAP-279	Performance Evaluation of rice pure lines and hybrids	RP Sah, RL Verma, BC Patra, Raghu S, NKB Patil	Pan Seed Pvt. Ltd.
109.	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
110.	EAP-281	Upgradation and validation of existing alternate energy (solar) light trap developed by ICAR-NRRI	SD Mohapatra	M/s Fine trap India
111.	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
112.	EAP-283	Building climate resilience of Indian small holders through sustainable intensification and agro-ecological farming systems to strengthen food and nutritional security	AK Nayak, BB Panda, SD Mohapatra, R Tripathy, Md. Shahid, S Mohanty, S Priyadarsani, S Saha, H Pathak, DR Sarangi	Norwegian Institute of Bioeconomy Research (NIBIO), Norway
113.	EAP-284	RKVY-RAFTAAR-Agribusinees incubation	GAK Kumar, BC Patra, RK Sahu, AK Mukherjee, Sanjoy Saha, BB Panda, Narayan Borkar, M Sivashankari, B Mondal, Rameswar Sah	RKVY
114.	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 Tripathy, U Keerthana	SAC-ISRO
115.	EAP-286	Bio-efficacy of triflumezopyrim 5% w/v + spinetoram 9% w/v (14% SC) and andtriflumezopyrim 5% w/w + spinetoram 12% w/w(22%) WDG against yellow stem borer, leaf folder and sucking pests (BPH & WBPH)	SD Mohapatra	Du Pont India Pvt. Ltd.

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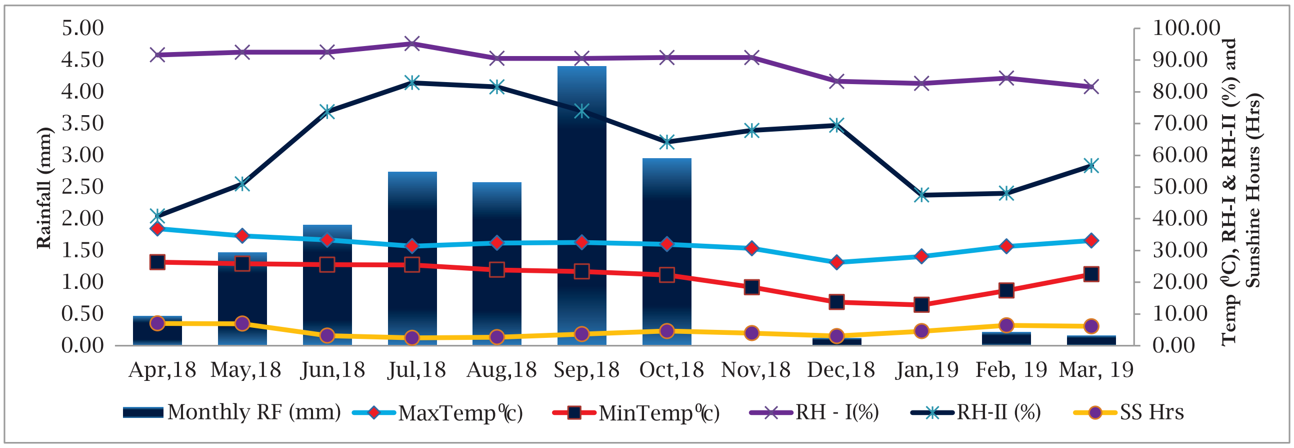

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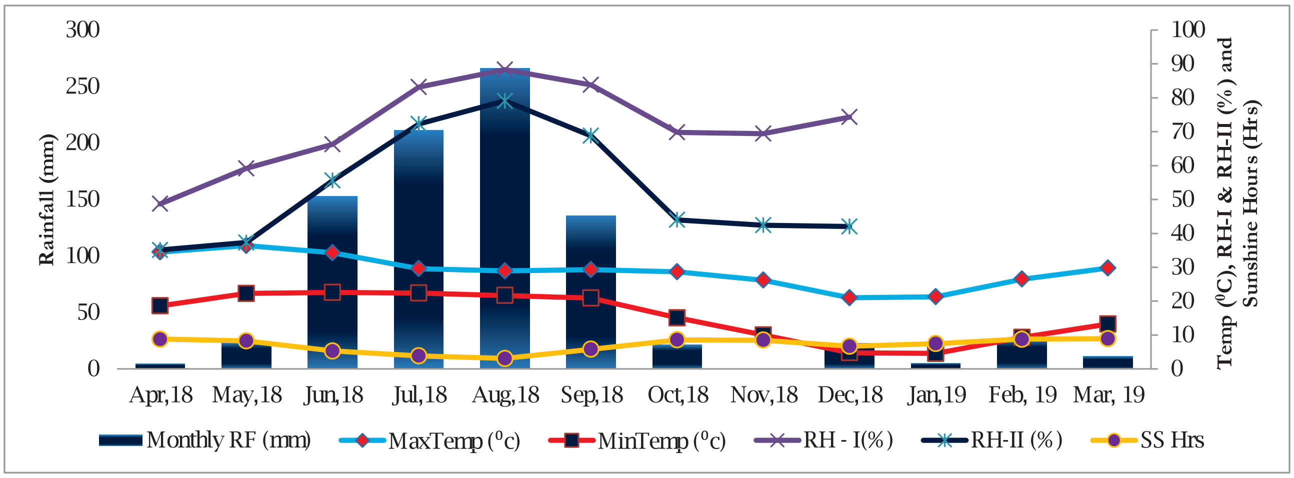

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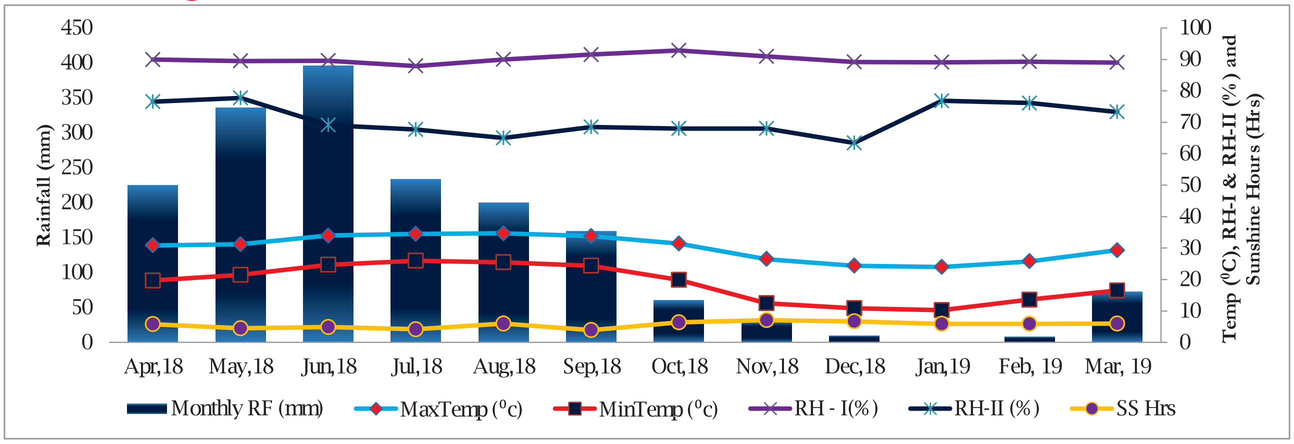

ISBN 818840910-3

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