ICAR-National Rice Research Institute

भाकृअनुप-राष्ट्रीय चावल अनुसंधान संस्थान

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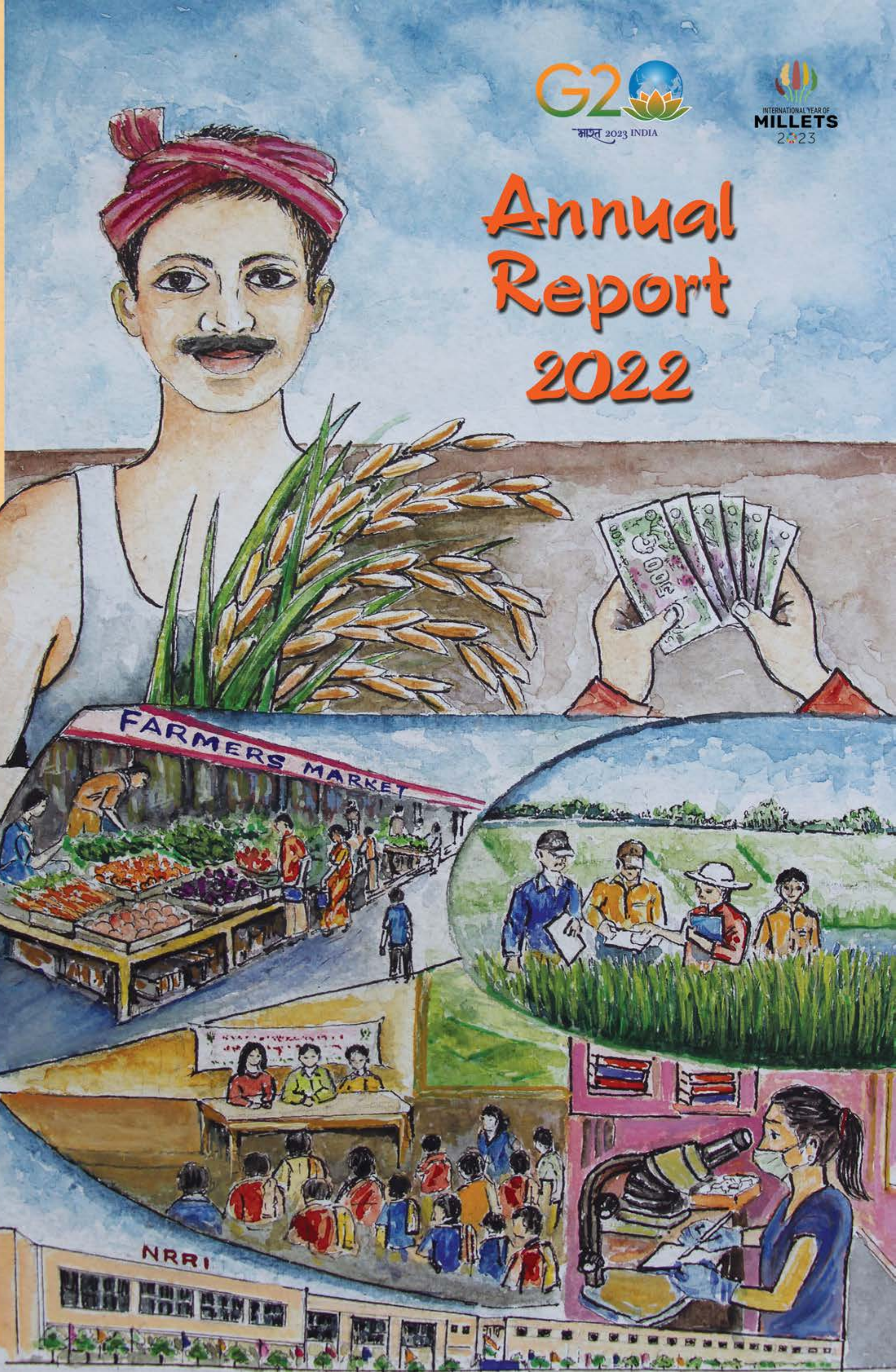

ANNUAL REPORT 2022

NRRI

वार्षिक प्रतिवेदन
Annual Report
2022

भाकृअनुप - राष्ट्रीय चावल अनुसंधान संस्थान
कटक (ओडिशा) 753 006, भारत
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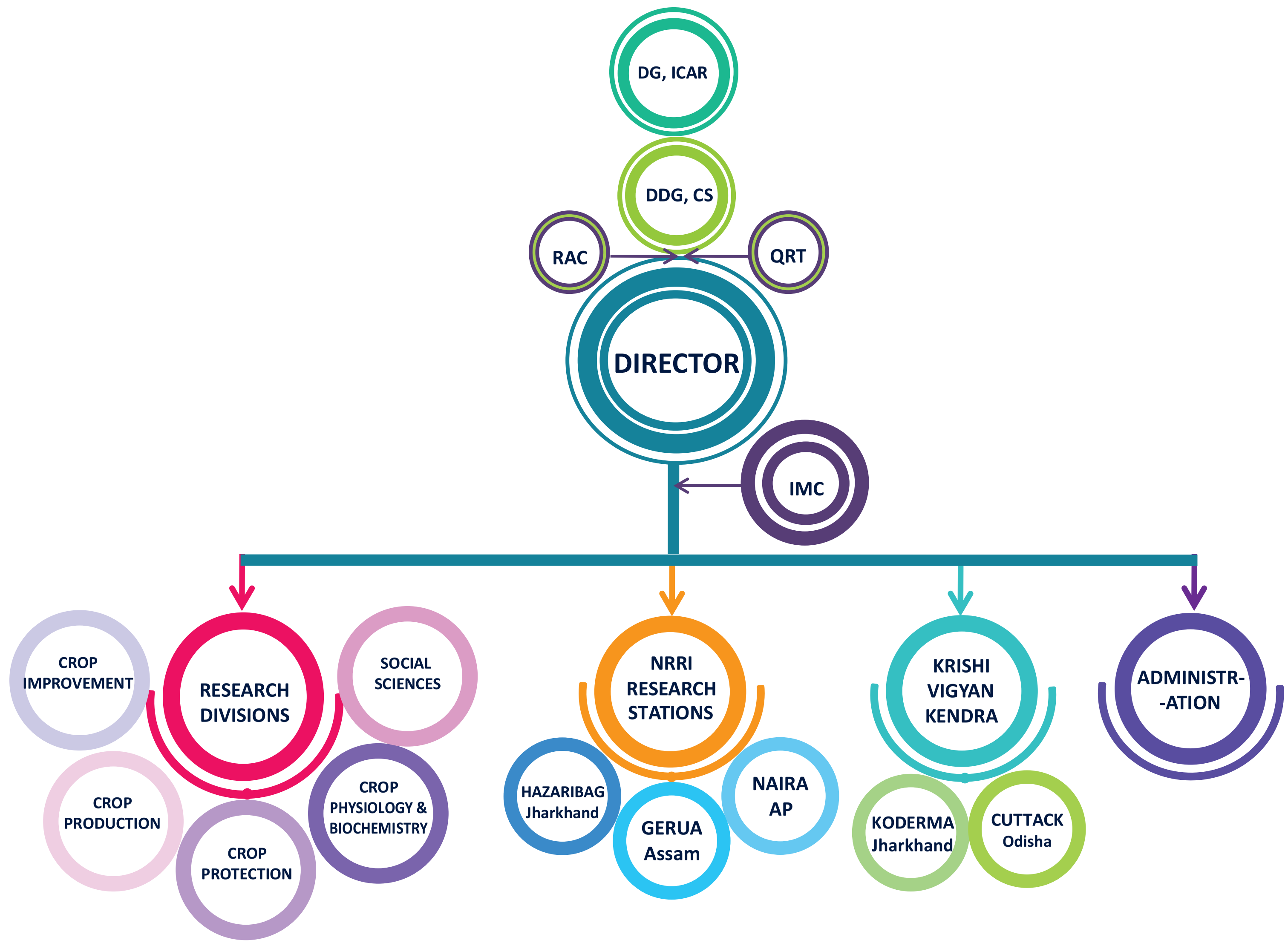
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ADMINISTR- -ATION

PREFACE

ICAR-National Rice Research Institute was established in the year 1946 with the primary motto of addressing human hunger so that the country should not face any eventuality anytime again like the infamous Bengal famine of 1943. However, with its growth the institute has broadened and aligned its activities with the national and global agendas and priorities. During its 76-year journey, the Institute has not only emphasized on addressing yield growth of one of the most staple grain "rice", but also given equal emphasis on nutrition, environment, natural resources and biodiversity among others.

Currently with its five divisions, three regional stations and two Krishi Vigyan Kendras (KVKs), the institute is working on genetic improvement of crop, conservation of genetic resources, improving and restoring soil health, resource conservation through its technologies and products, holistic management of pests, diseases and weeds using advanced technologies like remote sensing and drones, biofortified rice, agricultural waste management with the aim of achieving green growth in farming and reducing environmental footprints, enhancing profitability of rice based farming system and providing nutritious and safe food to the consumers. Additionally, the institute is also working on value addition of rice and providing services to different stakeholders through state of the art laboratories and infrastructures, generating new scientific knowledge and concepts through various in-house and externally funded research projects and upgrading the capacities of farmers and different stakeholders on rice crop.

In the year 2022, the institute has released 12 rice varieties for different ecologies of the country out of which one is biofortified (CR Dhan 411) while others are high yielding with moderately tolerant to resistant to different pests and diseases. The institute has organized 24 training programmes during the year 2022 and built up capacity of 1376 participants on different aspects of rice crop management. Additionally, demonstration of high yielding rice varieties is being conducted in the field of 1576 farmers in 10 states of the country which include Andhra Pradesh, Assam, Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Maharashtra, Odisha, Telangana and West Bengal. Further, the institute has mobilized different farmers and established 10 rice-based farmer producer companies (FPCs) in Odisha which is bringing prosperity to the life of the farmers. Further, the institute got one patent granted during the year and 4 patents have been filed by the institute. Additionally, the institute has published 144 research articles including 86 articles with NAAS rating >6.0; 25 popular articles; 44 book chapters; 6 books; 3 research bulletins; 34 technology bulletins; 5 extension bulletins; 7 training manuals and delivered 17 radio and TV talks.

Currently the institute has more than 160 rice varieties and hybrids, including 17 climate smart varieties, 5 hybrids, 4 biofortified varieties, 10 aromatic rice varieties; 100 released varieties are conserved in gene bank; 60 varieties (including 3 hybrids) are in seed chain; many state-of the-art laboratories like grain quality laboratory, pesticide residue laboratory, environmental soil science laboratory, genome editing laboratory, C-4 rice laboratory, etc.; 3 patents; 97 commercialized technologies and products etc. with 88 scientific staff, 111 technical staff, 55 administrative staff and 23 skilled supporting staff.

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

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

(Amaresh Kumar Nayak)
Director

EXECUTIVE SUMMARY

The Institute under crop improvement programme has steered ground breaking research in development of high yielding rice varieties that have contributed immensely to achieve self-sufficiency in rice production. During 2022, twelve rice varieties were released and eleven were notified. Twenty-nine new wild rice germplasm accessions were collected from Maharashtra. Besides, a total of 2949 accessions of rice germplasm / elite lines / donors / varieties were supplied to the researchers. About 34.92 q nucleus seed of 90 varieties and 537.64 q breeder seed of 60 varieties was produced. Further, 22 new QTL were identified for desirable traits like seed vigour, grain protein content, amylose content, seed germination percentage, seed vigour index II, root-shoot ratio, seed vigour index I, rate of root growth, root-shoot ratio, superoxide dismutase, flavonoids, anthocyanins, γ-oryzanol, ABTS, tiller number, panicle length, flag leaf width, root length, number of fertile grains, grain yield and straw quality. Donors for various traits like for BPH resistance (01), anaerobic germination (01), multiple abiotic stresses (01), high grain Zn and Fe (02), high photosynthetic rate (03), panicle length (05), heavy panicle (10), high grain number (07), large leaf area (04) and high tiller number (06) were identified. Furthermore, 08 genes responsible for multiple abiotic stresses (heat, drought salinity, submergence and cold) were identified. The efficiency of in *vitro* mutation was proved by developing mutants with 28.5% height reduction in Kalajeera and glyphosate tolerance in Shaktiman. Potentiality of genome editing through *CRISPR/Cas9* was evaluated by targeting *IPA1, EPFL9* and *Gn1a* for yield improvement and drought tolerance. Isogenic lines for submergence and multiple stresses (submergence, BLB, drought) were developed. Two-hundred and seven new nominations were sent for evaluation under AICRIP-2022.

The Crop Production programme aims at development of improved agro-technologies to enhance productivity, profitability, input use efficiency and resilience of rice-based production system. The nano-clay polymer composites (NCPC) were synthesized and loaded with three low molecular weight organic acids (citric, malic and tartaric acids) and three sources of Phosphorus (diammonium phosphate, DAP; single super phosphate, SSP and rock phosphate, RP). It was observed that DAP, SSP and RP can be loaded maximum up to 10%, 20% and 10%, respectively. Taxonomic profile of 52 years old LTFE paddy soils revealed that soil viruses and eukaryotes were abundant in control (without fertilizer application), whereas fertilizer application either inorganic or organic or combinational promotes the abundance of bacteria and archae. Tracing the translocation of Arsenic from soil-root-shoot-grain-polished to cooked rice, rice straw compost and its combination with silica solubilizing bacteria was found as most effective in curbing Arsenic loading in rice grain (53.2%). Application of *Pseudomonas and Trichoderma* (NRRI formulation) @ 10 g kg^{-1} of seeds as seed treatment produced comparable grain yield, which was significantly higher than control. Significantly higher system yield was recorded in rice when additional 25% P was applied through FYM (@ 5 t ha^{-1}) with RDF followed by RDF + PSB inoculation + DAP foliar spraying. Application of AM fungi significantly increased total root length (cm), surface root area (cm^2), projected root area (cm^2), root volume (cm^3) and number of root tips (nos), per cent root colonization, uptake of P in most of the varieties under low soil P as compared to high P soil.

Under Crop Protection programme, one patent on “Efficient portable insect collector with automated counter (Application number: 202211047342)” was filed which is a hand-held and battery-operated insect collector and consumes less energy and time. The complete mitochondrial genome of rice earhead bug, *Leptocorisa oratoria* (Fabricius, 1794) from India was sequenced for the first time. The mitogenomes of *L. oratoria* are 17 584 bp long with 73.57% AT content. Genetic diversity among the *Nilaparvata lugens* populations was understood and north and west Indian population showed high genetic similarity and assembled into one cluster. Genetic diversity of *Rhizoctonia solani* (AG1-IA) isolates were done and they were clustered into four groups. Elucidation of mating type of *Fusarium fujikuroi* species complex and genetic diversity analysis using ISSR/URP markers were done. Salkathi, PTB-33, TKM-6 varieties have shown consistent level of resistance at vegetative stage against Yellow Stem Borer. Seven, six and eleven genotypes were found resistant against *leaf folder, Cnaphalocrocis medinalis,* false smut (*Ustilaginoidea virens*) and sheath rot (*Sarocladium oryzae*), respectively. Identification of hyperspectral bands (519, 670 and 718 nm) gave maximum accuracy of about 83.66% which indicates that the green, red and red edge region were mostly responsible for the detection of BPH in rice. Transcriptomics analyses unravel that a total of 111 genes were showing upstream expression in *Trichoderma erinaceum* treated plants and 167 genes were down stream expression. Denovo sequencing of *Trichoderma erinaceum* (NRRI-T2) was done and the number of unique genes predicted by Glimmer HMM were 18815. Proteomic analysis of *R. solani*, the sheath blight pathogen, identified 48 differentially abundant proteins in the virulent isolate; out of which 27 proteins were with higher abundance and 21 proteins with lower in abundance in the virulent isolate. Silver nanoparticles were synthesized using extracts of fungus *Aspergillus niger* and bacterium *Pseudomonas fluorescens* was effective at 50 ppm. Except Jagatsinghpur (RRC, Erasama), other 11 populations *of Sitophilus oryzae* were resistant to phosphine. A study demonstrated phosphine-induced hormesis at LC_5 in the host *C. cephalonica*, which might help improve the quality of mass rearing of the parasitoid *H. hebetor*. Spatio-temporal variability of pesticides in small streams was studied and sixteen pesticides were detected with a detection frequency of 20% and above. Insecticide usage selection pressure has its effect on gut microbes, which in turn can have its role in xenobiotics metabolism by the host insect.

Under the Crop Physiology & Biochemistry programme, one unique line IC-516149 was found to possess tolerance against multiple abiotic stresses *viz.,* drought, submergence and anaerobic germination on screening. Besides, 32 rice genotypes were identified as highly tolerant to drought stress and eight genotypes were tolerant to lowlight and drought stresses. Among *O. nivara* introgressed lines, four stable lines were identified for submergence tolerance. It is shown that relative contribution and complementation of ion exclusion and tissue tolerance traits were crucial for reproductive stage salt tolerance in rice. It was found that spraying rice seedlings with KNO_3 and Thiourea were effective in imparting tolerance to drought and salinity stress. The potential of viviparous germination or pre-harvest sprouting were analysed in 450 rice lines and those were classified into different groups based on their tolerance level. About 1400 genotypes were screened for their biomass and grain yield efficiency, from which 25 genotypes were found promising. In order to improve yield and photosynthetic efficiency transgenic lines with *NADP-ME* (NADP-dependent malic enzyme) gene from *S. italica ME* were developed. Three important traits harvest index, total biomass and plant height were identified for CO_2-responsiveness in rice. A number of genotypes were screened for different nutritional traits and superior lines were identified for starch digestibility traits, phytic acid, antioxidant and amino acid content in brown rice. Scanning electron micrographs of non-parboiled and parboiled rice grains showed that endosperm of CR Dhan 310 had higher protein content than other varieties. Mineral contents of rice grain under different processing techniques were estimated and it was found that the contents were highest in raw rice (for Fe) and cooked rice (for Zn). Besides, a chemical method was developed and validated using mixed pH indicators to determine the age of the stored rice grains by which the age can be determined based on colour variations.

Under Social Science programme, two variants (1.0 and 2.0) of the NRRI extension model, INSPIRE were tested for their prospective validation and country-wide recommendation. During 2022, farmers' field demonstrations of 28 rice varieties were conducted in 927 farmers' fields covering about 116 hectares of land area in 26 districts from nine states namely Assam, Andhra Pradesh, Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Maharashtra, Odisha, and West Bengal of the country. A majority of the demonstrated varieties outperformed the existing popular varieties in the same ecology with a grain yield advantage up to 51.22%. An analysis of disaggregated, cross sectional, household survey based primary data extracted from the NEMA database revealed that 28.42% of the sampled farmers adopted at least one NRRI variety. *Pooja* was found to be the most popular variety adopted by 12.16% of the farmers in the sample, followed by Lalat (6.08%), Sahbhagidhan (3.55%), *Sarala* (3.14%), and Savitri (2.94%). Estimating social value of two rice varieties in terms of aggregated economic benefits generated, were attempted using economic surplus approach, which indicate that the two varieties under study generated about 11.33 crores and 5.48 crores, respectively as net-present value (NPV) of the benefit. In terms of returns on investment (RoI), these were about 18 times and 13 times, respectively. An analysis of willingness to pay for specialty rice suggests that people are willing to pay (WTP) extra for specialty rice as well as premium seed; the maximum increment in WTP reached upto Rs.18.75, 15 and 40 for high protein rice, scented non-basmati rice and premium seed, respectively over and above the rate of similar category of products. In quantifying the impact of MSP using the propensity score matching (PSM) technique, it was found that the farmers who have access to MSP realized Rs. 545 extra for a quintal of paddy than the farmers who doesn't have access.

Programme-6 deals with upland, coastal and lowland rice ecology focused on developing stress tolerant varieties, and improved integrated crop production and protection packages for the small and marginal farmers. During 2022, four varieties for rainfed drought-prone ecologies of Jharkhand. Simultaneously, production technologies have been assessed to improve and stabilize rice yield under rainfed conditions. Newer diagnostics for rice pathogens, false smut and tungro virus, using RPA techniques have been developed. Demonstrated the effectiveness of integrated nutrient management options in rice based cropping system. Improved management options [RDF (N in three splits) + application of Zn as $ZnSO_4$ (25 kg ha^{-1})] provided significant improvement in grain yield under drought-prone shallow lowland. The focus is also on developing resilient technologies for coastal rice ecology, survey was conducted in three coastal districts of Andhra Pradesh and the insect pest incidence in rice crop (*var.* MTU 1061) was recorded.

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

कार्यकारी सारांश

संस्थान की फसल उन्नयन प्रभाग ने उच्च उपज वाली चावल की किस्मों के विकास में अभूतपूर्व अनुसंधान किया है, जिसने चावल उत्पादन में आत्मनिर्भरता प्राप्त करने में अत्यधिक योगदान दिया है। वर्ष 2022 के दौरान चावल की 12 किस्में विमोचित की गईं और ग्यारह अधिसूचित की गईं। महाराष्ट्र से उनतीस नई जंगली चावल जननद्रव्य प्रविष्टियों को एकत्र किया गया। इसके अलावा, शोधकर्ताओं को चावल जननद्रव्य/श्रेष्ठ वंश/दाताओं/किस्मों की कुल 2949 प्रविष्टियों की आपूर्ति की गई। चावल की 90 किस्मों के लगभग 34.92 क्विंटल न्यूक्लियस बीज और 60 किस्मों के 537.64 क्विंटल प्रजनक बीज का उत्पादन किया गया। इसके अलावा, वांछनीय गुणों जैसे बीज ओज, अनाज प्रोटीन मात्रा, एमाइलोज मात्रा, बीज अंकुरण प्रतिशतता, बीज ओज सूचकांक II, जड़-तना अनुपात, बीज ओज सूचकांक I, जड़ वृद्धि का दर, जड़-अंकुर अनुपात, सुपरऑक्साइड डिसम्यूटेज, फ्लेवोनोइड्स, एंथोसायनिन, γ-ओराइजानोल, एबीटीएस, दौजी संख्या, बाली की लंबाई, ध्वज पत्ता चौड़ाई, जड़ लंबाई, पूर्ण दानों की संख्या, अनाज उपज और पुआल गुणवत्ता सहित 22 नए क्यूटीएल की पहचान की गई। भूरा पौध माहू प्रतिरोधिता (01), अवायवीय अंकुरण (01), बहु अजैविक तनाव (01), उच्च जस्ता एवं लौह वाली अनाज (02), उच्च प्रकाश संश्लेषक दर (03), बाली लंबाई (05), वजनदार बाली (01) जैसे विभिन्न लक्षणों के लिए दाता 10), उच्च अनाज संख्या (07), बड़ी पत्ती क्षेत्र (04) और अधिक दौजी संख्या (06) की पहचान की गई। इसके अलावा, कई अजैविक तनावों (गर्मी, सूखा लवणता, जलमग्नता और ठंड) के लिए जिम्मेदार 08 जीनों की पहचान की गई। कालाजीरा किस्म की पौधों की ऊंचाई में 28.5% कमी और शक्तिमान में ग्लाइफोसेट सहिष्णुता सहित म्यूटेंट विकसित करके इन विट्रो म्यूटेशन की दक्षता की पुष्टि की गई। उपज सुधार और सूखा सहिष्णुता के लिए IPA1, EPFL9 और Gn1a को लक्षित करके CRISPR/Cas9 के माध्यम से जीनोम संपादन की क्षमता का मूल्यांकन किया गया। जलमग्नता और बहु-तनावों (जलमग्नता, जीवाणुज पत्ता अंगमारी, सूखा) के लिए आइसोजेनिक वंशावली विकसित की गईं। AICRIP-2022 के तहत मूल्यांकन के लिए दो सौ सात नई प्रविष्टियां नामांकित किए गए।

फसल उत्पादन कार्यक्रम का उद्देश्य चावल आधारित उत्पादन प्रणाली की उत्पादकता, लाभप्रदता, निवेश उपयोग दक्षता और अनुकूलनीयता को बढ़ाने के लिए उन्नत कृषि-प्रौद्योगिकियों का विकास करना है। नैनो-क्ले पॉलिमर कंपोजिट को तीन कम आणविक भार कार्बनिक अम्ल (साइट्रिक, मैलिक और टार्टरिक एसिड) और फास्फोरस के तीन स्रोतों (डायमोनियम फॉस्फेट, डीएपी; सिंगल सुपर फॉस्फेट, एसएसपी और रॉक फॉस्फेट, आरपी) के साथ संश्लेषित और सम्मिलित किया गया। यह देखा गया कि डीएपी, एसएसपी और आरपी को क्रमशः अधिकतम 10% डब्लू/डब्ल्यू, 20% डब्ल्यू/डब्ल्यू और 10% डब्ल्यू/डब्ल्यू तक शामिल किया जा सकता है। लगभग 52 साल पुरानी एलटीएफई धान मिट्टी के टैक्सोनॉमिक प्रोफाइल से पता चला है कि मिट्टी के वायरस और यूकेरियोट्स नियंत्रण उर्वरक प्रयोग के बिना) में प्रचुर मात्रा में थे जबकि उर्वरक प्रयोग या तो अजैविक या जैविक या संयोजन में बैक्टीरिया और आर्की की प्रचुरता को बढ़ावा देता है। मिट्टी-जड़-तना-अनाज-पॉलिश से पके हुए चावल, चावल पुआल खाद में आर्सेनिक के स्थानान्तरण का पता लगाना और सिलिका घुलनशील बैक्टीरिया के साथ इसका संयोजन चावल के दाने (53.2%) में आर्सेनिक लोडिंग को रोकने में सबसे प्रभावी पाया गया। बीज उपचार के रूप में स्यूडोमोनास और ट्राइकोडर्मा (एनआरआरआई सूत्रण) 10 ग्रा/किग्रा बीज दर के प्रयोग से तुलनीय अनाज की पैदावार हुई, जो नियंत्रण से काफी अधिक थी। संस्तुत की गई उर्वरक की मात्रा के साथ सड़ी हुई गोबर (5 ट/हे) के साथ अतिरिक्त 25% फास्फोरस प्रयोग किया गया और उसके बाद आरडीएफ + पीएसबी प्रयोग + डीएपी का पर्णीय छिड़काव करने पर चावल में उल्लेखनीय रूप से उच्च प्रणाली उपज दर्ज की गई। उच्च फास्फोरस वाली मिट्टी की तुलना में कम फास्फोरस वाली मिट्टी के तहत एएम कवक के प्रयोग से अधिकांश किस्मों में कुल जड़ लंबाई (वर्ग सेमी), सतही जड़ क्षेत्र (घन सेंटीमीटर), अनुमानित जड़ क्षेत्र (वर्ग सेमी), जड़ मात्रा (घन सेंटीमीटर) और रूट टिप्स की संख्या, जड़ मात्रा की प्रतिशतता, फास्फोरस अधिग्रहण में काफी वृद्धि देखी गई।

फसल सुरक्षा कार्यक्रम के तहत, «स्वचालित काउंटर वाली कुशल पोर्टेबल कीट संग्राहक» पर एक पेटेंट (आवेदन संख्या: 202211047342) दायर किया गया है। यह हाथों से चलने वाला और बैटरीचालित कीट संग्राहक है एवं कम ऊर्जा और समय की खपत करता है। भारत में चावल फसल में लगने वाली गंधी बग, लेप्टोकोरिसा ओरटोरिया (फैब्रिकियस, 1794) का पूर्ण माइटोकॉन्ड्रियल जीनोम पहली बार अनुक्रमित किया गया। एल. ओरोटोरिया के माइटोजीनोम 73.57% एटी मात्रा सहित 17 584 बीपी लंबे हैं। नीलपर्वत ल्यूगेंस कीट की आनुवंशिक विविधता के बारे में पता लगाया गया तथा उत्तर एवं पश्चिम भारतीय कीटों में उच्च आनुवंशिक समानता देखा गया और उन्हें एक क्लस्टर के रूप में इकट्ठा किया गया। राइजोक्टोनिया सोलानी (AG1-IA) वियुक्तों की आनुवंशिक विविधता की गई और उन्हें चार समूहों में बांटा गया। आईएसएसआर/यूआरपी मार्करों का उपयोग करते हुए फ्यूजेरियम फुजिकुरोई प्रजातियों के कीटों और आनुवंशिक विविधता विश्लेषण के संभोग प्रकार के बारे में पता लगाया गया। सालकाठी, पीटीबी-33, टीकेएम-6 किस्मों ने पीला तना छेदक के विरुद्ध वृद्धि अवस्था में प्रतिरोधिता का निरंतर स्तर दिखाया है। पत्ता लपेटक, कैनफलोक्रोकिस मेडिनालिस, फाल्स स्मट (उस्टिलाजिनोइडिया विरेन्स) और आच्छद विगलन (सैरोक्लेडियम ओराइजा) के खिलाफ क्रमशः सात, छह और ग्यारह जीनप्ररूप प्रतिरोधी पाए गए। हाइपरस्पेक्ट्रल बैंड (519, 670 और 718 एनएम) की पहचान ने लगभग 83.66% की अधिकतम सटीकता दी जिससे पता लगा कि चावल में भूरा पौध माहू का पता लगाने के लिए हरे, लाल और लाल किनारे वाले क्षेत्र ज्यादातर जिम्मेदार हैं। ट्रांसक्रिप्टोमिक्स विश्लेषण से पता चला है कि ट्राइकोडर्मा एरीनेसियम उपचारित पौधों में कुल 111 जीन अपस्ट्रीम एक्सप्रेशन दिखा रहे थे और 167 जीन डाउन स्ट्रीम एक्सप्रेशन थे। ट्राइकोडर्मा एरीनेशियम (एनआरआरआई-टी2) की डेनोवो सीक्वेंसिंग की गई और ग्लिमर एचएमएम द्वारा आकलन किया गया और विशिष्ट जीन की संख्या 18815 पाई गई। राइजोक्टोनिया सोलानी, आच्छद अंगमारी को रोगजनक का प्रोटिओमिक विश्लेषण से वायरल वियुक्त में 48 अलग-अलग प्रचुर मात्रा में प्रोटीन की पहचान हुई जिनमें से 27 प्रोटीन उच्च प्रचुरता के साथ थे और विषाक्त वियुक्त में 21 प्रोटीन कम थे। फंगस एस्परगिलस नाइगर और जीवाणु स्यूडोमोनास

फ्लोरेसेंस के निचोड़ का उपयोग करके सिल्वर नैनोकणों को संश्लेषित किया गया जो 50 पीपीएम पर प्रभावी था। जगतसिंहपुर (आरआरसी, इर्समा) को छोड़कर, साइटोफिलस ओराइजा की अन्य 11 संख्या फॉस्फीन के लिए प्रतिरोधी थी। एक अध्ययन से पता चला कि मेजबान सी. सेफेलोनिका में LC_5 पर फॉस्फीन-प्रेरित हार्मेसिस का प्रदर्शन से जो परजीवी एच. हेबेटर के बड़े पैमाने पर पालन की गुणवत्ता में सुधार करने में मदद कर सकता है। छोटी संख्या में कीटनाशकों की स्थानिक-अस्थायी परिवर्तनशीलता का अध्ययन किया गया और 20% और उससे अधिक की पहचान आवृत्ति के साथ सोलह कीटनाशकों का पता लगाया गया। कीटनाशक उपयोग चयन दबाव का आंतों के रोगाणुओं पर प्रभाव पड़ता है जो बदले में मेजबान कीट द्वारा ज़ेनोबायोटिक्स चयापचय में अपनी भूमिका निभा सकता है।

फसल शरीक्रियाविज्ञान एवं जैवरसायन कार्यक्रम के तहत, एक विशिष्ट वंश IC-516149 को परीक्षण करने पर सूखा, जलमग्नता और अवायवीय अंकुरण जैसे कई अजैविक तनावों के खिलाफ सहिष्णु पाई गईं। इसके अलावा, धान के 32 जीनप्ररूप को सूखा तनाव के प्रति अत्यधिक सहिष्णु के रूप में पहचाना गया और आठ जीनप्ररूप कम प्रकाश और सूखे के तनाव के प्रति सहिष्णु थे। ओ. निवारा अंतर्मुखी वंशावलियों से, जलमग्न सहिष्णुता के लिए चार स्थिर वंशों की पहचान की गई। यह देखा गया है कि चावल में प्रजनन चरण में लवण सहिष्णुता के लिए आयन बहिष्करण और ऊतक सहिष्णुता लक्षणों के सापेक्ष योगदान और पूरक महत्वपूर्ण हैं। यह पाया गया कि चावल के बीजों पर पोटेशियम नाइट्रेट और थियोरिया सहित छिड़काव करने पर सूखे और लवणता के तनाव को सहन करने में प्रभावी था। विविपेरस अंकुरण या पूर्व-फसल अंकुरण की क्षमता का विश्लेषण 450 चावल वंशावलियों में किया गया और उन्हें उनके सहिष्णुता स्तर के आधार पर विभिन्न समूहों में वर्गीकृत किया गया। लगभग 1400 जीनप्ररूपों को उनके जैवपदार्थ और अनाज की उपज दक्षता के लिए जांचा गया, जिसमें से 25 जीनप्ररूपों को आशाजनक पाया गया। एस. इटालिका एमई से एनएडीपी-एमई (एनएडीपी-निर्भर मैलिक एंजाइम) जीन के साथ उपज और प्रकाश संश्लेषक दक्षता ट्रांसजेनिक वंशों में सुधार के लिए विकसित किए गए। चावल में कार्बन डाइऑक्साइड-प्रतिक्रिया के लिए फसल सूचकांक, कुल जैवपदार्थ और पौधे की ऊंचाई के तीन महत्वपूर्ण लक्षणों की पहचान की गई। विभिन्न पोषण लक्षणों के लिए कई जीनप्ररूपों की जांच की गई और भूरा चावल में स्टार्च डाइजेस्टिबिलिटी लक्षणों, फाइटिक एसिड, एंटीऑक्सिडेंट और अमीनो एसिड मात्रा के लिए बेहतर वंशों की पहचान की गई। बिन-उसना और उसना चावल के दानों का इलेक्ट्रॉन माइक्रोग्राफ स्कैनिंग से पता चला है कि सीआर धान 310 के एंडोस्पर्म में अन्य किस्मों की तुलना में अधिक प्रोटीन मात्रा थी। विभिन्न प्रसंस्करण तकनीकों के तहत चावल के दानों के खनिज मात्रा का अनुमान लगाया गया और यह पाया गया कि कच्चे चावल में लौह और पके हुए चावल जस्ता की मात्रा सबसे अधिक थी। इसके अलावा, भंडारित चावल के दानों की आयु निर्धारित करने के लिए मिश्रित पीएच संकेतकों का उपयोग करके एक रासायनिक विधि विकसित और मान्य की गई, जिसके द्वारा रंग विविधताओं के आधार पर चावल की आयु का निर्धारण किया जा सकता है।

सामाजिक विज्ञान कार्यक्रम के तहत, एनआरआरआई विस्तार मॉडल इंस्पायर के दो रूपांतर (1.0 और 2.0) का उनके संभावित सत्यापन और देशव्यापी संस्तुति के लिए परीक्षण किया गया। वर्ष 2022 के दौरान देश के असम, आंध्र प्रदेश, बिहार, छत्तीसगढ़, झारखंड, मध्य प्रदेश, महाराष्ट्र, ओडिशा एवं पश्चिम बंगाल राज्यों के 26 जिलों में 927 किसानों के खेतों में लगभग 116 हेक्टेयर भूमि क्षेत्र में चावल की 28 किस्मों का प्रदर्शन आयोजित किया गया। अधिकांश प्रदर्शित किस्मों ने उसी पारिस्थितिकी में मौजूदा लोकप्रिय किस्मों से 51.22% तक अनाज उपज लाभ के साथ बेहतर प्रदर्शन दिखाया। एनईएमए डेटाबेस से निकाले गए अलग-अलग, क्रॉस सेक्शनल, घरेलू सर्वेक्षण आधारित प्राथमिक आंकड़ों के विश्लेषण से पता चला कि 28.42% सैंपल किसानों ने कम से कम एक एनआरआरआई किस्म को अपनाया है। नमूने में 12.16% किसानों द्वारा पूजा को सबसे लोकप्रिय किस्म के रूप में अपनाया गया है, इसके बाद ललाट (6.08%), सहभागीधन (3.55%), सरला (3.14%), और सावित्री (2.94%) का स्थान था। कुल आर्थिक लाभों के संदर्भ में चावल की दो किस्मों के सामाजिक मूल्य का आकलन करने के लिए आर्थिक अधिशेष उपाय का प्रयोग करने का प्रयास किया गया जिससे पता चलता है कि अध्ययन के तहत दो किस्मों ने क्रमशः लाभ के शुद्ध-वर्तमान मूल्य के रूप में लगभग 11.33 करोड़ और 5.48 करोड़ रुपये का उत्पादन किया है। निवेश पर लाभ के मामले में ये क्रमशः लगभग 18 गुना और 13 गुना था। विशेष चावल के लिए भुगतान करने की इच्छा के विश्लेषण से पता चलता है कि लोग विशेष चावल के साथ-साथ प्रीमियम बीज के लिए अतिरिक्त भुगतान करने को तैयार हैं; उच्च प्रोटीन चावल, सुगंधित गैर-बासमती चावल और प्रीमियम बीज के लिए समान श्रेणी के उत्पादों की दर से अधिक भुगतान करने की इच्छा में अधिकतम वृद्धि क्रमशः 18.75, 15 और 40 रुपये तक पहुंच गई। प्रवृत्ति स्कोर मिलान तकनीक का उपयोग करते हुए न्यूनतम समर्थन मूल्य के प्रभाव की मात्रा निर्धारित करने में, यह पाया गया कि जिन किसानों जिन किसानों के पास एमएसपी की पहुंच नहीं है उनकी तुलना में जिन किसानों के पास एमएसपी की पहुंच है, उन्हें एक क्विंटल धान के लिए अतिरिक्त 545 रुपये मिले हैं। कार्यक्रम-6 तनाव सहिष्णु किस्मों के विकास और छोटे और सीमांत किसानों के लिए उन्नत एकीकृत फसल उत्पादन और सुरक्षा पैकेज पर केंद्रित ऊपरी, तटीय और निचलीभूमि चावल पारितंत्र से संबंधित है। वर्ष 2022 के दौरान, झारखंड के वर्षाश्रित सूखा-प्रवण पारितंत्र के लिए चार किस्मों पर अध्ययन किया गया। इसके साथ ही, वर्षाश्रित परिस्थितियों में चावल की उपज में सुधार और स्थिर करने के लिए उत्पादन तकनीकों का मूल्यांकन किया गया है। आरपीए तकनीकों का उपयोग करते हुए चावल के रोगजनकों, फाल्स स्मट और टुंग्रो वायरस के लिए नए निदान विकसित किए गए हैं। चावल आधारित फसल प्रणाली में एकीकृत पोषक तत्व प्रबंधन विकल्पों की प्रभावशीलता का प्रदर्शन किया गया। उन्नत प्रबंधन विकल्प [संस्तुत उर्वरक की मात्रा (तीन भागों में नत्रजन + जिंक सल्फेट के रूप में जस्ता का प्रयोग (25 किग्रा/है)] ने सूखा-प्रवण उथली निचलीभूमि के तहत अनाज की उपज में महत्वपूर्ण सुधार प्रदान किया। तटीय चावल पारितंत्र के लिए अनुकूल प्रौद्योगिकियों को विकसित करने पर भी ध्यान केंद्रित किया गया है, आंध्र प्रदेश के तीन तटीय जिलों में सर्वेक्षण किया गया और चावल की फसल में कीट प्रकोप की घटनाओं (एमटीयू 1061 किस्म) को दर्ज किया गया। वर्षाश्रित निचलीभूमि के लिए चावल के आनुवंशिक सुधार और प्रबंधन पर ध्यान केंद्रित करते हुए, चावल के जननद्रव्य की 766 प्रविष्टियों को सुरक्षित रखा गया और 50% फूल आने के दिनों, पौधे की ऊंचाई, दौजियों की संख्या और अनाज की उपज पर आंकड़ा दर्ज किया गया। चावल की फसल की बकाने रोग के खिलाफ कवकनाशी की प्रभावकारिता का परीक्षण किया गया और देखा गया कि रोपाई के 15 दिनों के बाद प्रोपिकोनाजोल 2 मिली/लीटर पानी की दर से के छिड़काव से बकाने रोग की घटना सबसे कम हुई और उच्च उपज मिली। फरवरी के पहले पखवाड़े में रोपी गई फसल में धान के तना छेदक का प्रकोप सबसे कम (0.76%) दर्ज किया गया और देर से बोई गई फसल की तुलना में सबसे अधिक उपज दर्ज की गई।

NATIONAL RICE RESEARCH INSTITUTE

MAJOR RESEARCH AREAS

1
- Germplasm Exploration & Conservation
- Super Rice
- Hybrid Rice
- Bio-fortified Rice
- Climate Smart Varieties

2
- Input Management
- Resource Conservation Technologies
- Farm Mechanization
- Climate Resilience
- Harnessing Microbial Potentials
- Integrated Farming Systems

3
- IPM
- IDM
- Stored Grain Pests
- Pesticide Formulation
- Pesticide Residue Management

4
- Stress Tolerant Rice
- Low Glycemic Rice
- Grain Quality
- C_4 Rice

5
- Development and Testing of New Extension Models
- Socio-economic Studies
- Rice Value Chain
- Technology Dissemination
- Training and Advisory Services

6
- Climate Resilient Technologies:
- Rainfed Upland
- Rainfed Lowland
- Coastal Ecology

AT A GLANCE : YEAR 2022

NRRI IN NUMBERS

1. 12 New Rice Varieties Released
2. 4 Unique Rice Germplasm Registered with ICAR-NBPGR
3. 3 New Rice Varieties Submitted with PPV & FRA
4. 18 Technologies Commercialized and 1 Patent Granted
5. 144 Peer Reviewed Research Papers Published
6. 9 States Covered through Extension Activities
7. 20 New Rice Varieties Demonstrated in Farmers Field
8. 3304 Personnels including Farmers Visited the Institute
9. 115 Trainings Conducted & 5613 Persons Attended
10. 55 Agromet Advisory Bulletins Released
11. 24 Agro Advisory Services & 24 Video Barta Released
12. 215 Field Demonstrations Conducted

8 DECENT WORK AND ECONOMIC GROWTH | 10 REDUCED INEQUALITIES | 11 SUSTAINABLE CITIES AND COMMUNITIES | 12 RESPONSIBLE CONSUMPTION AND PRODUCTION | 13 CLIMATE ACTION | 15 LIFE ON LAND | 16 PEACE, JUSTICE AND STRONG INSTITUTIONS | 17 PARTNERSHIPS FOR THE GOALS

Introduction

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

Vision

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

Goal

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

Mission

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

Mandate

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

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

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

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

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

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

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

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

Linkages

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

Location

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

PROGRAMME-1

Genetic Improvement of Rice

The Crop Improvement Division of the Institute develops novel rice varieties, hybrids, and other technologies to enhance yield, improve nutritional quality, and alleviate diverse biotic and abiotic challengesin order to improve the socioeconomic status of rice stakeholders. The division with its cadre strength of 23 scientists and 19 technical staffs operates 11 institutional research projects and 36 externally funded projects. During 2022, 12 rice varieties were released and 11 of them were notified. (New release : CR Dhan 314, CR Dhan 414, CR Dhan 321, CR Dhan 103, CR Dhan 107 (Unnat Vandana), CR Dhan 415 and CR Dhan 804; Varital extension in Assam : CR Dhan 307, CR Dhan 310, CR Dhan 311, CR Dhan 801 and CR Dhan 802). In addition, 207 new promising entries were nominated in AICRIP trials. Furthermore, 29 wild rice germplasm accessions were collected and 2949 germplasm / elite lines / donors / varieties were supplied to the researchers. About 34.92 q nucleus seed of 90 varieties and 537.64 q breeder seed of 60 varieties were produced. Besides, *MQTL 3.1* was identified responsible for grain development. The QTLs for various traits such as, seed vigour, grain protein content, amylose content, seed germination percentage, seed vigour index II, root-shoot ratio, seed vigour index I, rate of root growth, root-shoot ratio, superoxide dismutase, flavonoids, anthocyanins, γ-oryzanol, ABTS, tiller number, panicle length, flag leaf width, root length, no. of fertile grains, grain yield and straw quality traits were identified. Further, donors for BPH resistance, anaerobic germination, multiple abiotic stresses, high grain Zn and Fe content, high photosynthetic rate, panicle length, heavy panicle, high grain number, large leaf area, high tiller number were identified. Eight genes responsible for multiple abiotic stresses (heat, drought, salinity, submergence and cold) were identified through machine learning model approach. The Melylome analysis identified two genes, *LOC_Os05g43860.1* and *LOC_Os02g36200*.1 in control and heat-treated samples of five rice varieties. The efficiency of *in vitro* mutation was proved by developing mutants with 28.5% height reduction in Kalajeera and glyphosate tolerance in Shaktiman. Genome edited lines targeting *IPA1, EPFL9* and *Gn1a* were evaluated for yield and drought tolerance. Some Isogenic lines for submergence and multiple stresses (submergence, BLB, drought) were also developed. MAS was used to develop BLB resistance in biofortified variety Swarnanjali and breeding lines CRL 22R, Pusa 33-30-3R, SRA 2-19, SRA 149-1-2, and SRA 3-41.

Managing Rice Genetic Resources for Sustainable Utilization

Exploration and collection of wild rice

An exploration was conducted in Raigad, Ratnagiri, and Sindhudurg districts of Maharashtra during 13-23 November, 2022. A total of 29 samples of 3 wild species, namely *O. nivara* (8 samples) (Fig. 1.1), *O. rufipogon* (5 samples), and *O. sativa* var. *spontanea* (16 samples) were collected. Very sparse distribution of wild rice in these area was observed which might be due to hilly region (Fig. 1.2). The passport information, collection list and GPS data were recorded and the samples were deposited in the gene bank.

Germplasm conservation and seed supply

Altogether 2973 rice accessions were characterized and conserved in MTS of NRRI gene bank. The conserved material includes, germplasm received from ICAR-NBPGR, New Delhi, DUS testing materials, newly collected cultivated and wild rice germplasm. Besides, 2949 accessions of rice germplasm / elite lines / donors / varieties were supplied to researchers. Among them, 157 accessions were shared with different institutes / organizations across the country with proper signing of MTA and revenue of ₹47, 800/- (Rupees forty-seven thousand and eight hundred only) was earned for the institute through sharing of rice germplasm.

Fig. 1.1 *O. nivara* in roadside ditch

Characterization and documentation of Northeast collections

A set of 356 germplasm accessions collected from Northeast (NE) region (Tripura, Sikkim, Nagaland, and Manipur) were morphologically characterized and documented. In qualitative traits, no variability was observed for ligule shape (all 2-cleft type) whereas, it was reported maximum for apiculus colour (Fig.1.2). In case of quantitative traits, maximum variability was observed for yield (39.44%) followed by tiller no. (22.09%). AC 44991 had shortest plant stature (43.33 cm), whereas it was longest in AC 44967 (158.33 cm) along with highest leaf length (72.33cm) and leaf width (1.90 cm). Among the yield contributing traits, maximum tiller (12.00) was observed in AC 9051 and longest panicle was observed in AC 39764 (29.33 cm). The highest fertility was observed in AC 45033 (98.49%). The highest 100-grain weight (3.30 g) and yield (39.44 g per plant) was observed in AC 44977.

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

Seed production and maintenance

The nucleus seed of 90 released varieties were multiplied in panicle-progeny row approach. After thorough rouging and rejection of probable variant in progeny lines, true to the type panicles were collected for next generation nucleus seed production. A total of 34.92 q nucleus seed of 90 varieties were produced (Fig. 1.4) which will be used for breeder

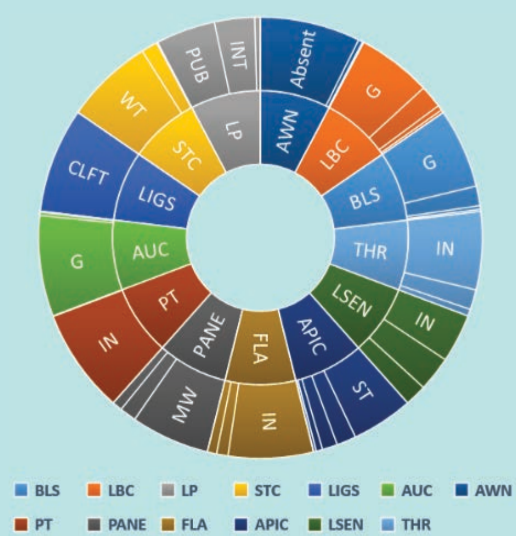


Fig. 1.2 Variation in qualitative traits

seed production. Similarly, as per DAC indent, total 537.64 q breeder seed of 60 varieties were produced (Fig. 1.3). In order to popularize new varieties, seed production of 7 varieties were taken up under farmer participatory mode and a total 466.55 q TL seed was produced (Fig.1.4).

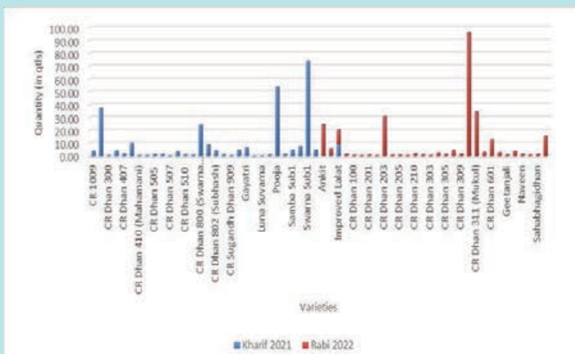


Fig. 1.3 Variety wise breeder seed production during the year 2021-22

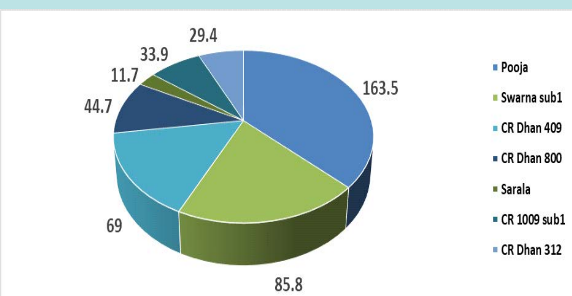


Fig. 1.4 Variety wise TL Seed Production during the year 2021-22

A new Meta-QTL for grain weight identified

Using QTL meta-analysis technique, we collated rice grain weight QTL information from numerous studies reported across populations and in diverse environments to find constitutive QTL for grain weight. The information from 114 original QTL spread over 12 rice chromosomes was used in QTL meta-analysis and discovered a total of 39 MQTL for grain weight on different chromosomes in rice genome. However, only three MQTL on chromosome 3 were found significant under different criteria with significant confident intervals. According to gene ontology, these three MQTL have 179 genes, of which 25 genes found annotated to developmental functions. MQTL3.1 includes the *OsAPX1*, *PDIL*, *SAUR*, and *OsASN1* genes, which are involved in grain development and have been discovered to play a key role in asparagine biosynthesis and metabolism, which is crucial for source-sink regulation (Fig. 1.5). Further, identified MQTL were validated using tightly linked peak marker on a set of genotypes with extreme phenotype. The MQTL3.1 was successfully validated using linked marker RM7197 which can be used in marker aided breeding programs. MQTL that have been identified and validated in this study has significant scope in MAS breeding and map based cloning programs for improving rice grain weight.

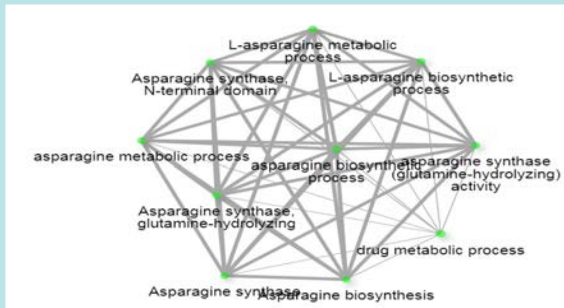


Fig. 1.5 Network display of five grain related genes underlying identified MQTL involved in asparagine biosynthesis and metabolism pathways having significant role in regulating source to sink relation in rice.

Optimization of genomic selection models using candidate gene markers in rice breeding

Nine genomic selection methods, including regression-based and machine learning-based models, were used to predict grain weight using a leave-one-out five-fold cross validation approach to optimize the genomic selection model with genic markers. Among nine prediction models, Kernel Hilbert Space Regression (RKHS) is the best among regression-based models, and Random Forest Regression (RFR) is the best among machine learning-based models. Furthermore, two multi-locus GWAS models, FarmCPU and mrMLM, along with a single locus mixed linear model (MLM), identified 28 significant marker trait associations. Genomic prediction accuracies with and without GWAS significant markers were compared to assess the effectiveness of markers. The rapid decreases in prediction accuracy upon dropping GWAS significant markers indicate the effectiveness of new genic markers in genomic selection (Fig. 1.6). Apart from that, the candidate gene-based markers were found to be more effective in genomic selection programs for better accuracy.

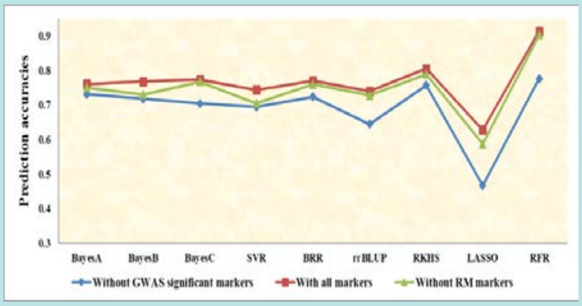


Fig. 1.6. Comparison of prediction accuracies of all the models considering all markers used in the study and dropping significant markers associated with grain weight identified in GWAS. The difference in prediction accuracies indicates the effectiveness of the identified markers associated with grain weight in predicting the grain weight.

Genome-wide association analysis using cgSSR marker revealed the genetics of seed vigour traits in rice

A mixed linear model with efficient mixed model analysis identified a total of 99 casual associations for seed vigor traits. Many of the associated markers were derived from different candidate genes in rice. The marker alleles derived from the genes *OsTDC3*, *OsPAP10C*, *THIS1*, *OsMIK,* and *GS3* were pleiotropically associated with different seed vigor traits. The new candidate gene markers identified to be associated with seed vigor traits possess a potential role in incorporating several causative alleles for improved seed vigor through modern breeding programs.

Elicitor seed treatment to improve the seed parameters of the rice varieties

The seed treatment effect of two widely known plant elicitors *viz.*, potassium silicate @ 1% and salicylic acid @ 50 ppm were tested. The effect on shoot and root length, shoot and root weight and seed vigour index in 25 different rice varieties were measured. The shoot and root length, shoot and root weight and seed vigour index were increased in treated seed than the untreated control seed across the varieties. An increase in 20% and 15% of shoot length, 16% and 11% of root length, 37% and 26% of shoot weight, 35% and 15% of root weight, and 38% and 34% of seed vigour index due to potassium silicate and salicylic acid treatment respectively were observed than the untreated control set. The elicitors showed a positive response on seed vigour parameters.

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

Identification of cross transferable markers for genus *Oryza*: Stepwise screening of 23,499 sequence-tagged microsatellite site (STMS) markers of rice in whole genome sequence of eight species of *O. sativa* complex lead to identification of 1005 core set of STMS markers. Total 96 accessions of *O. sativa* complex were characterized with a subset of 48 markers distributed across AA genome. In further studies with distant halophytic species *Oryza coarctata* genome sequence, 77 common markers with AA genome were identified. Twenty-nine robust polymorphic markers from the core set of these nine species were evaluated *in-vitro* in 12 other *Oryza* species. Overall, out of 21 *Oryza* species studied in a panel of 37 genotypes with the 29 markers, amplification was not achieved in average 1.66 cases per marker. Allele numbers per marker ranged from 2-7 in 3.5% agarose gel with mean value of 4.72 and PIC value of the markers ranged from 0.23-0.80 with average value of 0.65. The dendrogram constructed with 123 alleles of 27 markers classified the different species complexes as well as outliers of genus *Oryza* according to their taxonomic subgroups (Fig. 1.7).

Identification of trait specific wild rice germplasm: Multiple accessions of various wild *Oryza* species and *O. glaberrima* were characterized based on morphological descriptors, resistance to brown plant hopper and ability to anaerobic germination (Table 1.1). Valuable genetic resources for these four traits were identified among wild rice accessions. Induced dormancy under anaerobic germination stress was found as unique adaptive mechanism in various wild species.

Evaluation of wild rice germplasm for nutritional quality

Eighty-seven wild rice genotypes and 3 checks were evaluated for grain Fe and Zn content in de-husked rice. The Zn content ranged from 22.30 mg kg^{-1} (*O. sativa* var. CR Dhan 307) to 77.35 mg kg^{-1} (*O. rufipogon* AC 100098A), while Fe content ranged from 8.79 mg kg^{-1} (*O. sativa* var. CR Dhan 307) to 56.15 mg kg^{-1} (*O. glaberrima* IRGC 100983). *O. australiensis* recorded the highest average zinc concentration in grains (60.75 mg kg^{-1}). Similarly, *O. glumaepatula, O. latifolia, O. longistaminata and O. minuta* observed to have higher zinc content i.e. (>40 mg kg^{-1}) in comparison to cultivated genotypes. It was observed

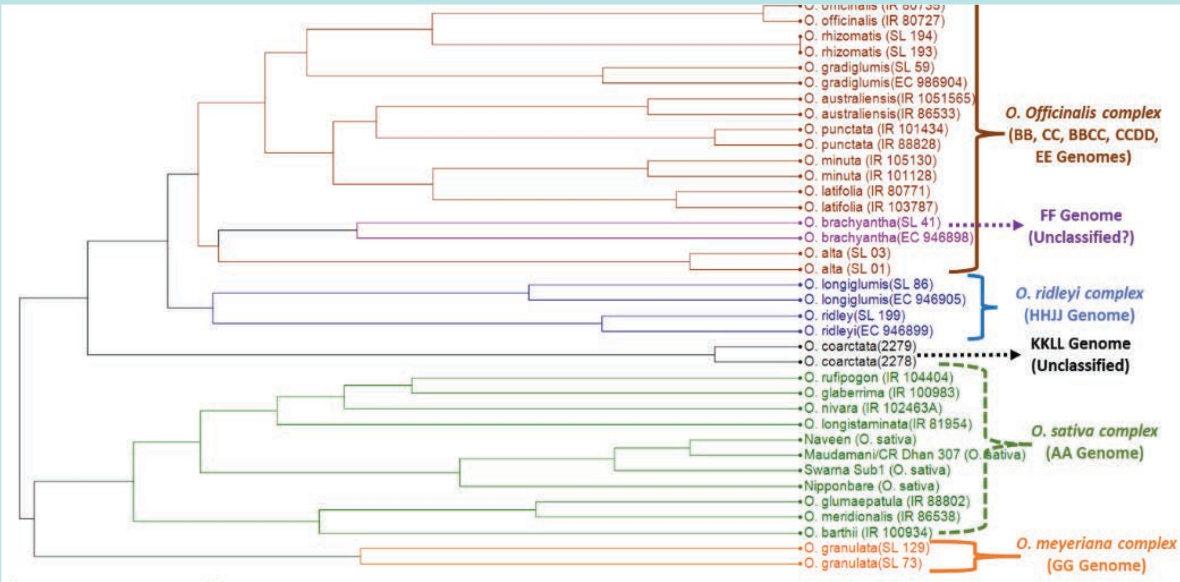


Fig.1.7 Dendrogram depicting genetic relatedness among the 37 accessions of 21 *Oryza*species based on amplification profile of 27 markers (IR – IRGC).

that all the wild rice accessions showed higher zinc concentration in grains than cultivated genotypes. In case of Fe concentration in grains, *O. latifolia* measured highest average grain Fe content (33.87 mg kg^{-1}) with a range of 30.36-37.37 mg kg^{-1} among the accessions. This is followed by *O. officinalis* (24.11-30.62 mg kg^{-1}) and *O. minuta* (23.98-27.41 mg kg^{-1}). The wild rice accession IRGC 80771 of *O. latifolia* was found to be a rich source for both iron (37.37 mg kg^{-1}) and zinc (60.20 mg kg^{-1}).

Identification of interspecific wide compatible rice genotype: Total 224 crosses were generated involving 14 *O. sativa* genotypes and 16 accessions of seven species from *O. sativa* complex and further advanced to BC_1F_1 generation using *O. sativa* accessions as female. The progenies were validated using cross transferable STMS markers. CR Dhan 307 was identified as a widely compatible genotype with different wild rice accessions.

Development of homozygous CSSLs: A cross of CR Dhan 307 and *O. rufipogon* (AC 100444) was tracked at whole genome level in various generations and finally homozygous chromosome segment substitution lines (CSSLs) were identified representing the whole genome of *O. rufipogon* in the background of CR Dhan 307 (Fig. 1.8).

Development of novel submergence tolerant near isogenic lines

Four stable and tolerant pre-breeding lines (NPS 17, NPS 18, NPS 71 and NPS 95) were identified from a set of 110 backcross derived introgression lines between *O. sativa* var. Swarna and *O. nivara* accession IRGC 81848. The lines were crossed further with Swarna as well as Swarna *Sub1* and mapping populations (BC_3F_5 equivalent) were developed. Submergence tolerant BC_4F_3 NILs with golden-brown husk colour like Swarna were developed using the line NPS95 (Fig. 3.4). The 'Swarna *Sub1*' variety developed earlier using the *Sub1* gene from FR13A is closely linked to inhibitor of brown furrow gene (*IBF1*) and thus husk colour of Swarna turns straw white. The sequence of *Sub1A* gene in NPS95 corresponds to

Table 1.1. Identification of novel trait in wild rice accession.

Germplasm Id/ Accession Number	Species	Trait for which identified	Resistance / tolerance level as per SES score
EC 946906 / IRGC 105690	*O. punctata*	Brown plant hopper resistance	Resistant
AC 100042	*O. nivara*	Anaerobic germination	Moderately tolerant

submergence susceptible allele *Sub1A2* and the NILs lacks quiescence mechanism of 'Swarna Sub1' for survival. The results indicate the QTL(s) /gene(s) / allele(s) for submergence tolerance in the NPS lines as novel (Fig 1.9).

Developing genetic solutions for enhancing input use efficiency in rice for rainfed and irrigated rice ecologies

Marker trait association for seed vigour related traits in rice

A total of 163 diverse rice genotypes were used to constitute association panel and genotyped with 295 SSR markers. The phenotypic data for two seed vigor related traits was measured. The BLUP values of all traits explained significant variation in the panel. The normal distribution of BLUP values for target traits indicated their quantitative inheritance pattern. The MLM approach coupled with EMMA algorithm identified a total of 6 marker-trait associations at p ≤ 0.01 for two traits which were short listed as highly significant explaining considerable phenotypic variation (Table 1.3).

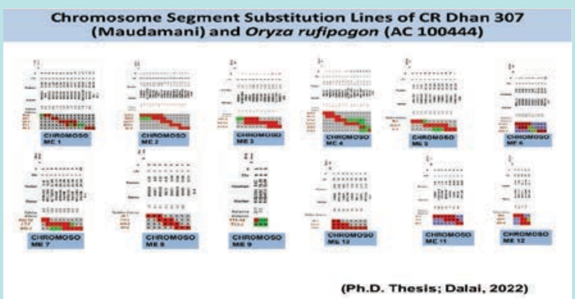


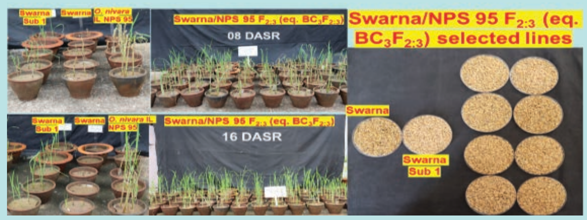
Fig. 1.8 HomozygousCSSLs representing whole genome of *O. rufipogon*in the background of CR Dhan 307

Evaluation and nomination of Breeding lines

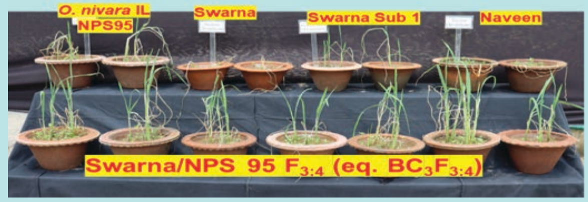
- 523 early to medium maturity breeding lines were evaluated in line stage testing (LST), out of which 335 were evaluated under direct seeded condition and 350 were evaluated under transplanted condition for creation of elite grouping of genetic materials.
- 25 high yielding lines were nominated in AICRIP trials for evaluation.

Development and release of CR Dhan 321

This variety has been recommended by CVRC for release for nine states *viz.,* Odisha, Bihar, Jharkhand, West Bengal, Uttar Pradesh (Eastern India), Tripura & Assam (North-eastern states) and Chhattisgarh & Maharashtra (Central part) of the country. The variety matures in 118-120 days under irrigated



Kharif 2021



Kharif 2022

Fig. 1.9 Submergence tolerant near isogenic lines of Swarna developed from NPS 95

Table 1.2 Significant Marker-trait associations identified for eight SVI related traits based on MLM model

Trait	Marker name	Gene name	Position	Chr no.	P value	R^2 %
SVI*	GY87F88R	RM11943	37851779	1	0.002	13.22
	SC32	OsTDC3	2270568	8	0.006	11.67
GI*	RM3643	RM3643	19948112	4	0.000	21.65
	RM3643	RM3643	19948112	4	0.000	21.65
	YD94	OsPAP10C	38120760	1	0.001	20.41
	Marker 94	THIS1	31527177	1	0.004	18.73
	YD57	OsMIK	30247380	3	0.006	18.16

*SVI- seed vigour index; GI- Germination inedx early transplanted ecology with plant height ranging from 95-108 cm, MS grain type, 68.2% HRR, 24.5 % amylose content and yield ranging from 5.5- 6.0 t ha^{-1}. It is moderately resistant to false smut, neck blast, leaf blast, brown spot and grain discolouration, and sheath rot. Also, it is highly tolerant to leaf folder and stem borer (dead heart) insect pests (Fig. 1.10).

IET 28084 (CR 3549 -6-1-1-3-1-1) is another medium duration (135 days) culture developed from the cross between ADT 43 and Annapurna. It has been identified as the Low nitrogen tolerant genotype after four years of testing in AICRIP over the locations. It yields around 5.4 t ha^{-1} at moderate N level of nitrogen i.e. 60 kg N ha^{-1} over the years across and locations (Fig. 1.11).

Evaluation of genotypes for their performance and agronomic nitrogen use efficiencies at various N levels

Twenty genotypes comprising of 10 improved nitrogen use efficient lines and 10 popular medium duration cultivars including N use efficient check Indira and non- efficient check Ratna were evaluated at 5 levels of nitrogen during dry season 2021-22 for their performance and agronomic nitrogen use efficiency (AE_N) using the formula Grain Yield in N fertilized plot (kg ha^{-1}) – Grain yield in N unfertilized plot (kg ha^{-1})/ kg of N applied/ha. Based on grain yield, AE_N and responsiveness, genotypes CR3783-1-3-2-1-1-2 followed by CR4311-2-2-2--1-2-2 and CR3580-3-1-1-1-1-1-2 were the most N use efficient and higher yielder; whereas Tapaswini followed by CR Dhan 308 and IR 64 were more N use efficient among the cultivars. The N use efficient check Indira is equally efficient and higher yielder while Ratna is poor yielder and non-efficient.

Fig. 1.10 Field view of CR Dhan 321 at flowering stage

Fig. 1.11 Qualification of IET 28084 as the most low nitrogen tolerant genotype AICRIP

Evaluation of rice genotypes for low phosphorus tolerance

A set of 57 accessions of rice germplasm, collected from NRRI gene bank, were evaluated for low phosphorus (P) tolerance in P control plot during Rabi, 2021 and data were recorded on days to 50% flowering, plant height (cm), number of tillers per plant, flag leaf length (cm), flag leaf width (cm), panicle length (cm) and single plant yield (g). The days to 50% flowering ranged from 95 (IC 459115) to 121 days (IC 15114). The plant height ranged from 62 (IC 46031) to 158 cm (IC 461825). The number of tillers per plant ranged from 6 (IC 215231) to 20 (IC 277228) and the flag leaf length ranged from 19.10 (IC 467627) to 56.30 cm (IC 555117). The flag leaf width ranged from 1.00 (IC 467627) to 1.20 cm (426097) and panicle length ranged from 16.20 (IC 311014) to 30.00 cm (IC 467627). The single plant yield ranged from 1.69 (IC 215231) to 20.10g (IC 467627). Thus the genotypes IC 467627, IC 426097 and IC 277228, which recorded high yield under P control can be used for improving low P tolerance in rice.

During 2021 AICRIP, the entries like IET 29236 (CR 3580-3-1-1-1-1-1-2 to AVT 2-IME), IET 29877 (CR4313-1-1-2-1-1-1) and IET 28523 (CR 3564-1-1-4-2-2-1) to AVT 1-IM; 5 in AVT 1-LNT *viz.,* IET 29573 (CR 3553-1-5-2-1-1-1), IET 29564 (CR 3511-7-1-1-1-1-2), IET 29578 (CR3756-2-4-2-1-1-1), IET 30273 (CR 3516-1-1-1-1-1-1), IET 30270 (CR 4358-3-3-1-2-1); 3 in AVT1 Aerob *viz.,* IET 29411 (CR 4161-5-6-IR14L572), IET 29424 (CR 4317-IR97034-21-2-1-3), IET 29446 (CR 3918-109-5-6-4-1) were promoted.

Breeding for rice, nutrition, and grain quality

Improvement of biofortified variety for biotic stress resistance

Improvement of high protein Swarna (Swarnanjali) was undertaken for resistance to bacterial blight through incorporation of *xa5*, *xa13* and *Xa21*.

Nominations in AICRIP

CR 4199-2-B-1-2-B, CR 4225-1-2-B-1, CR 4229-1-1-2-B-1, and CR 4103-B-1 with high Zn or protein content were nominated for AICRIP Biofortification trial-2022. CR 4169-200-52-1 with the positive alleles of bacterial blight resistant genes, *Xa21* and *xa5* (*snpOS00054* and *snpOS00061* markers) in the background of Swarnanjali has been nominated in AVT-NIL trial in 2022. CR 4351-14398-68-1 (Chakhaoamubi x Swarna *sub1*) purple rice and CR 4341-18266-1-4-2 (CR Dhan 801 x CR Dhan 310) *pup1* introgressed high protein line were nominated in 2021 AICRIP, IVT-Biofortification Program.

QTLs/ genes of quality traits

Two QTLs each for grain protein and amylose content were detected to be associated with the markers RM17600 and RM1272. RM8050 was associated with Fe content as well as kernel length/breadth ratio. Three hundred and seventy-four lines from 5 different crosses were genotyped using SNPs for Zinc content, waxy locus (cooking quality) and biotic stress tolerance (*Sweet1u3*). Sneha and Kalinga III contain favorable allele (*C*) and 37% lines with favourable alleles of *NAS3* showed higher Zn content.

PPV&FRA Registration of Biofortified high protein elite genotypes

CR 2829-PLN-98, CR 2829-PLN-32, CR 2829-PLN-23, CR2829-PLN-99, CR 2829-PLN-116 in Naveen background while CR 2830-PLS-124 and CR 2830-PLS-156 in Swarna background with high (11.78% to 12.86%) protein content in brown rice were registered under PPV&FRA.

Upscaling of the released biofortified varieties

MoUs were signed with seven FPOs from Uttar Pradesh with the help of Grameen Foundation, India, for popularization of high protein rice CR Dhan 310 and with M/s. Granova Naturals (India) Pvt. Ltd. Hyderabad, for popularization of two biofortified varieties CR Dhan 310 and CR Dhan 311 (Mukul). Breeder seed indent was received for 70q seeds of CR Dhan 310, 24q of CR Dhan 311 and 3q of CR Dhan 315.

Pigmented rice

Characterization of germplasm: Two hundred and ninety-three genotypes varying in grain pigmentation, collected from 14 districts of Odisha, were characterized for Fe and Zn content. These genotypes were classified into eight groups based on Fe and Zn content. Champeisiali (AC 43368) and Gedemalati (AC 34306) were observed with highest Fe (44.1 ppm) and Zn (40.48 ppm) content.

Characterization of breeding lines: One hundred and seventy-seven semi-dwarf, non-lodging breeding lines derived from Chakhao were characterized for antioxidant related traits (*kharif*-2021). Highest variability was observed for anthocyanin content (76.40%) and lowest for gamma-oryzanols (21.30%). Highest total anthocyanin (TAC) was observed in QCR 48-2-52; gamma-oryzanols (GA) in QCR 48-2-85 (115.31 mg $100g^{-1}$), total phenolics (TPC) in QCR 48-2-65 and QCR 48-2-65 was identified with highest (282.26 mg CE $100g^{-1}$) total flavonoids (TFC).

Aromatic rice

Marker Assisted Breeding for improvement of biotic stress tolerance in short grained aromatic rice varieties

Breeding populations to improve biotic stress tolerance of Nuakalajeera, Gobindbhog, CR Dhan 907, CR Dhan 910 and Geetanjali through MAS were developed using appropriate donors.

Characterization of NRRI Released varieties for quality parameters

Ankit, Satyabhama, Abhisek, Hazaridhan and Sahbhagidhan were identified to have superior grain quality with yield >4.00 t ha^{-1} under upland condition whereas; CR Dhan 304, Maudamani, CR Dhan 305, CR Dhan 313 with yield >6.00 t ha^{-1} under irrigated condition and; Pradhandhan, Gayatri, CR Dhan 508, CR Dhan 507, Savitri with yield>5.50 t ha^{-1} under lowland condition.

Breeding for superior grain type

Eight crosses were undertaken for combining MS grain type with higher yield, Sunakathi, Padmakeshari, J 509 and J400 were used as MS grain parents with J94 and K4 as high yielders.

Genetic improvement of landraces: Purified sorts of Gobindbhog were subjected to second year of sensory analysis and phenotypic characterization. GB type 4 was found to be quite distinct among all the sorts. Dwarfing of Gobindbhog through recombination breeding is in BC_1F_2 generation and EMS mutants are in M_3 generation. Baspatri, an aromatic and Sunakthi, a fine-grained landrace from Odisha were purified through pureline selection (Fig. 1.12).

Establishment, up-gradation, and operation of state-of-art quality assessment laboratory facility

Prices for analysis of 29 quality traits were fixed including DNA fingerprinting and are available on institute website.

Trials conducted

IVT-Biofortification, AVT1-Biofortification, IVT-MS, AVT1-MS and IVT-ASG trials were conducted during *kharif* 2021 with the demonstration of the released aromatic rice varieties.

Suitability of NRRI rice varieties for instant rice

For instant rice processing, 19 NRRI rice varieties varying in amylose content were studied. Three varieties, CR Dhan 508, CR Dhan 507, and CR Dhan 205, were determined to be suitable for immediate quick cooking.

Breeding for Glutinous Rice

Genes related to the glutinous trait were characterized among 78 rice landraces of Nagaland using functional polymorphisms at *Waxy* locus. Hybridization program for breeding of glutinous rice have been initiated using Aghnibora as the glutinous parent during *kharif* 2021. A cross was also made between Rülü x Sahbhagidhan.

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

Breeding towards climate resilient genotypes for rainfed shallow lowland

Three near isogenic lines (NILs) namely, CR 2538-20-14-24-2 (IET 29032), CR 2538-42-17-32-3-3 (IET 29026) and CR 2538-42-17-32-3-2 (IET 29026) were developed in the background of popular variety, Varshadhan and were superior over the checks under AVT-1, NIL trial in two years of testing. Selection, evaluation, and testing of the NILs were done with the objective to breed high yielding variety in the background of popular variety, Varshadhan with tolerance to submergence condition. One NIL line, CR 2538-20-14-24-2 (IET 29032) cross of Varshadhan*3/IR49830-7 was submitted to the State Variety Release Committee, Odisha for release.

Isogenic lines development carrying *Sub1* + *Xa21* + *xa13*+ *xa5* +*qDTY1.1* + *qDTY2.1* + *qDTY3.1* in the background of mega variety, Swarna was started during 2017-18. The BC_2F_1 plants carrying the desired gene combination of *Sub1*+*Xa21*+*xa13*+*xa5*+ *qDTY1.1*+*qDTY2.1*+*qDTY3.1* were selfed during *kharif* 2021 to produce BC_2F_1 seeds. About 10000 BC_2F_2 seeds were generated during wet season, 2022.

The candidate QTLs controlling a total of 17 reported QTLs *viz.*, *qGP8.1* for germination % (GP); *qSVII2.1*, *qSVII6.1* and *qSVII6.2* for seed vigour index II (SVII),

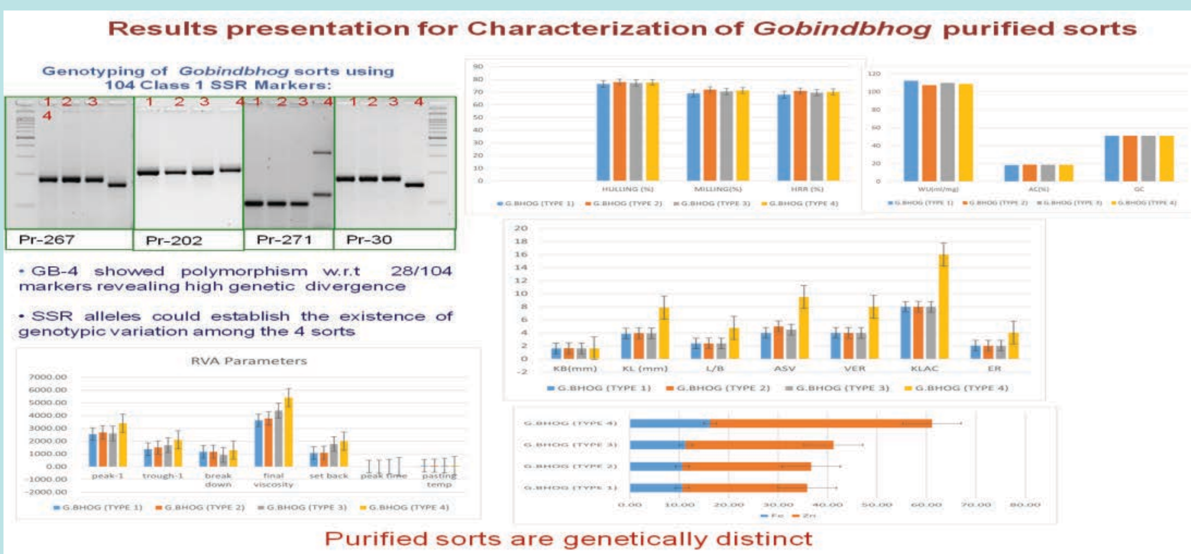


Fig. 1.12. Pictorial representation of results of quality testing and SSR marker based characterization of the four *Gobindbhog*sorts.

and *qRSR11.1* for root-shoot ratio (RSR) were validated in this mapping population. In addition, 13 QTLs regulating the physiological parameters such as *qSVI 11.1* for seed vigour index I; *qSVI11.1* and *qSVI12.1* for seed vigor index II; *qRRG10.1, qRRG8.1, qRRG8.2, qRRG6.1* and *qRRG4.1* for rate of root growth (RRG); *qRSR2.1, qRSR3.1* and *qRSR5.1* for root-shoot ratio (RSR) while *qGP6.2* and *qGP6.3* for germination % were identified. Additionally, co-localization or co-inheritance of QTLs, *qGP8.1* and *qSVI8.1* for GP and SVI-1; *qGP6.2* and *qRRG6.1* for GP and RRG, and *qSVI11.1* and *qRSR11.1* for SVI and RSR were detected. The QTLs identified will be useful for improvement of seed vigour trait in rice. The marker-trait association for growth parameters controlling the traits namely *qAGR4.1, qAGR6.1, qAGR6.2* and *qAGR8.1* for AGR; *qRSG6.1*, *qRSG7.1* and *qRSG8.1* for RSG while *qRGR11.1* for RGR were also detected in the population.

Three lines were promoted to final year of testing in AICRIP based on the performance in the AVT1 trial during *kharif,* 2021. The entry CR 3987-3-1-1-1-1 in rainfed shallow lowland trial (AVT1 RSL) of last year was promoted to AVT2 RSL. In addition, two lines viz., CR 3933-39-2-1-2-1 and CR 3145-4-1-3-2-1-2 were also promoted to AVT2 SDW trial. Besides, another 12 entries showing more than 5.5 t ha^{-1} under station trial were nominated to the 1^{st} year AICRIP lowland trials.

Mapping of antioxidant traits: superoxide dismutase, flavonoids, anthocyanins, γ-oryzanol and ABTS

Consumption of antioxidants rich rice has impressive health benefits. Five antioxidant traits *viz.,* superoxide dismutase, flavonoids, anthocyanins, γ-oryzanoland ABTS traits were mapped in a panel population using 136 SSR markers through association mapping. The panel consisting of 120 germplasm set, including genotypes from all the phenotypic groups of all antioxidant traits from the original shortlisted 270 rice genotypes. Donor lines rich in multiple antioxidant compounds were identified from the population (Fig. 1.13). The population was classified into four genetic groups and showed fair degree of correspondence with the antioxidants content. A total of 14 significant marker-trait associations for antioxidants were detected of which 3 QTLs namely *qANC3, qPAC12-2* for anthocyanin content and *qAC12* for ABTS activity were validated in the population.

Eleven putative QTLs such as *qTAC1.1* and *qTAC5.1* for anthocyanin content; *qSOD1.1, qSOD5.1* and *qSOD10.1* for SOD; *qTFC6.1*, *qTFC11.1* and *qTFC12.1* for TFC; *qOZ8.1* and *qOZ11.1* for γ-oryzanol and *qAC11.1* for ABTS were detected to be novel loci. Co-localization of the QTLs detected for *OZ11.1*, *TFC11.1* and *AC11.1* regulating γ-oryzanol, flavonoid and anthocyanin content, respectively while *PAC12.2* for anthocyanin content remained closer to *TFC12.1* for flavonoid content. These QTLs will be useful in the antioxidant improvement programs in rice (Fig. 1.14).

Phenotyping for seed germinability under high temperature (GUHT)

About 120 diverse rice genotypes were evaluated for their variability in germination under high temperature (Fig.1). Genotypes were subjected to three high temperature regimes (40^0C, 42^0C and 45^0C) (Table 1). At 40^0C germination ranged from 84.0% -96.0%, wheras, at 42^0C germination ranged from 68.17% to 85.67%. Only 46 genotypes could achieve ≥80% germination.Two genotypes Gondia champeisiali and Magura had germination of 75% at 45^0C, which is near to standard germination value of 80%. These two genotypes could suitably be used for breeding varieties resistant to high temprature at germination stage (Fig. 1.15).

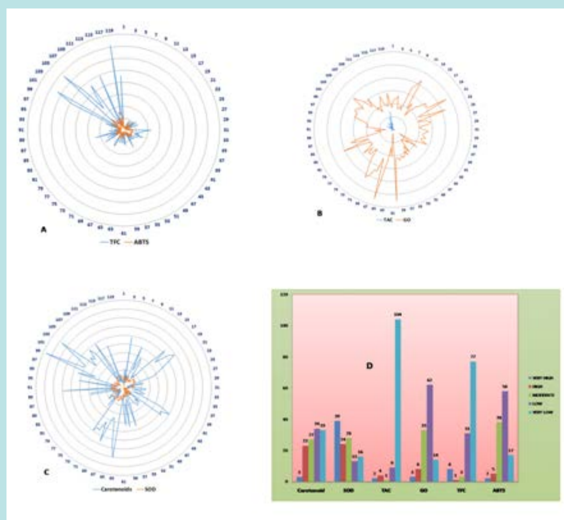


Fig. 1.13 Antioxidant content of 120 genotypes and their frequency distribution in the panel population. A. Spider graph showing the TFC content & ABTS activity. B. the TAC & γ-oryzanol content, C. Carotenoid and SOD content D. Frequency distribution of germplasm lines for carotenoids, superoxide dismutase, anthocyanins, γ-oryzanol, flavonoids, and ABTS in the panel population

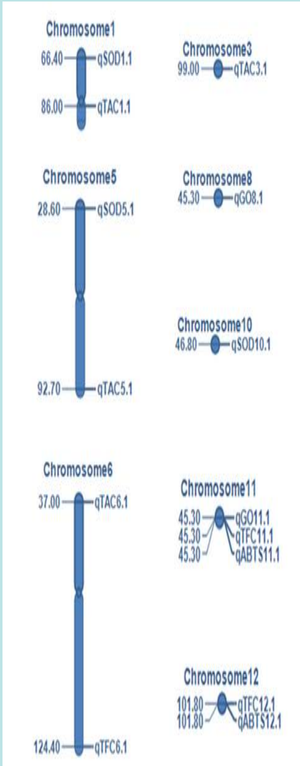


Fig. 1.14 Positions of the QTLs on the chromosomes for antioxidant content detected by association mapping in rice.

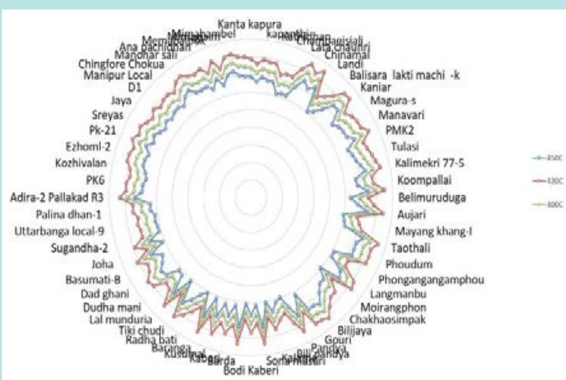


Fig.1.15 Variability in germination under high temperature.

Genetic Enhancement for Multiple Stress Tolerance in Rice for Coastal Ecosystem

Phenotyping and genotyping of mapping population for detection of QTLs for multiple stress tolerance

AC 39416a was identified as, a donor for tolerance to salinity, stagnant flooding, anaerobic germination, submergence, drought, and combined stress (salinity + stagnant flooding). RIL population derived from Savitri/ AC 39416a was phenotyped under stagnant flooding under saline water condition. Na+, K+ conc. in leaves, NDVI, SPAD, chlorophyll fluorescent, grain yield and yield attributing traits were taken. Introgressed lines with superior performance were identified (Table 1.3).

Most of the traits were showing normal distribution (Fig. 1.16). Genotyping of 150 RILs from Savitri/ AC 39416a was done using 50K SNP chip. 6075 Homo-polymorphic SNPs were identified. Rice Whole Genome Re-Sequencing of On Illumina Hiseq 2000/2500 was done for AC 39416a and Savitri and the pre-processed reads were aligned to the rice 93-11 reference genome.

Homo-polymorphic SNPs identified were 12747. Polymorphic SNPs located on known probable functional genes of multiple abiotic stresses identified were 130. Selected SNPs located on genes for multiple abiotic stresses tolerance (Salinity, stagnant flooding, drought, etc.) for marker and functional validation in RIL population was 29.

Phenotyping and genomics-assisted selection for multiple stress tolerance

Around 700 lines were phenotyped for salinity, submergence, and yield traits. Among them 374 genotypes were genotyped using SNP markers for salinity, grain number and biotic stress tolerance. These were *Saltol* –aus (*snpOS00397*), *qSES1-2_1* (*snpOS00405*), *qSES1-2_2* (*snpOS00409*), *qSES1-2_3* (*snpOS00410*), *qSES1-2_4* (*snpOS00411*), *sweet13* (*snpOS00482*). A few submergences tolerant lines such as CR 3483-1-M-4-B-Sub-7-S-1, CR 4214-M-2-2-2-S-3-3-Sub-3 were identified with most of the positive alleles and with salinity tolerance.

Variety with multiple stress tolerance for coastal saline areas

CR Dhan 414 derived from Gayatri/ SR 26B cross has been released and notified for cultivation in coastal areas of Odisha, West Bengal, and Andhra Pradesh (Fig. 1.17). It has multiple stress tolerance. It was found tolerant to moderate salinity stress (EC 4-7 dS m^{-1}) and moderately tolerant to stagnant flooding. It was also detected with higher ability to germinate in anaerobic condition and with osmotic stress tolerance in AICRIP Physiology trial. It has long maturity duration (145 days) with 115 cm plant height. The mean grain yield was found around 4.50 t ha^{-1}.

Table 1.3 Introgressed lines derived from Savitri/AC 39416a cross with superior performance under stagnant flooding with saline water

Lines	Yield (g) (non-stress)	Yield (g) (Stress)	Yield stability index
MP-11-172	26.567	17.364	0.654
MP-11-9	31.033	18.894	0.609
MP-11-171	26.733	16.047	0.600
AC 39416a	22.323	13.313	0.596
MP-11-143	28.527	16.045	0.562
MP-11-128	26.183	14.649	0.559
MP-11-38	28.961	16.008	0.553
MP-11-11	30.500	16.499	0.541

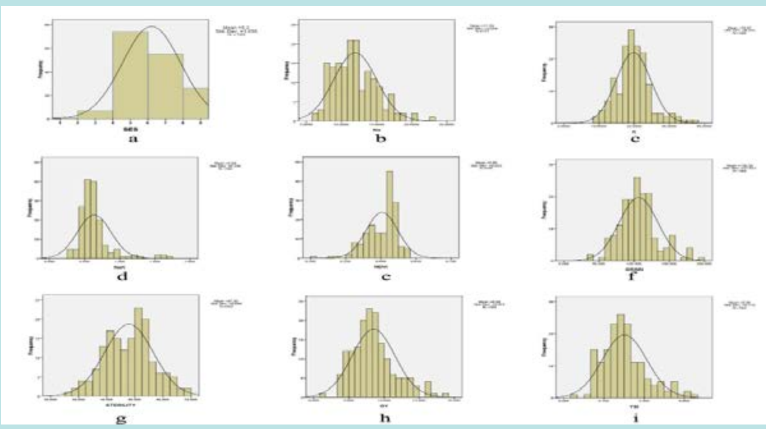


Fig. 1.16. Distribution of RILs derived from Savitri/AC 39416a cross for a. SES, b. Na+ concentration, c. K+ concentration, d. Na-K ratio, e. NDVI, f. Grain number/panicle, g. Spikelet Sterility (%), h. Grain yield, i. Yield stability index under combined stress (salinity and stagnant flooding) condition

Promising and elite lines

CR 4283-274-6-2-1-3 derived from CR Dhan 310/Getu cross has been promoted to AVT-1 CSTVT. Another 15 elite lines were nominated in AICRIP trials for coastal salinity in *kharif* 2022.

Hybrid rice for enhancing yield, quality, and sustainability

A source nursery with 1184 diverse parental genotypes were constituted, maintained, and characterized; out of these 16 lines harbouring Rf (*Rf3* and *Rf4*) genes were utilized in crossing programme.

Fig. 1.17. Field view of CR Dhan 414 - A multiple stress tolerant rice variety for coastal saline areas

Development of CMS, restorer, and hybrid combinations

Total 935 test crosses of nine CMS and 152 pollen parents (>5.0 GEBVs) were evaluated and 63 heterotic hybrids, 10 maintainers and 58 good restorers were identified.

Besides, 28 heterotic hybrids were re-evaluated under station trials. A medium duration CMS, CRMS58A (WA) (INH1001) was identified to have 38% out crossing (Fig. 1.18). In addition, 31 sterile backcrosses (BC_2 -BC_{10}) with enhanced seed producibility and sustainability for BLB, BPH resistance traits were advanced. Furthe, 72 aromatic genotypes (landraces, ABLs, varieties) were screened, and 11 of them were positive for *rf3* and *rf4* which were utilized in hybrid breeding.

Hybrid release/ New promising hybrid combinations

Promising hybrid, CR Dhan 704 (IET 28187) is nominated for release by SVRC, Odisha. CR Dhan 702 (IET25231) and CR Dhan 703 (IET25278) were evaluated in Bihar for state notification. Besides, two hybrids, CRHR 154 and CRHR 156 were promoted to AVT1-MS and AVT1-IM, respectively. Two more hybrids, CRHR105 (IET28124), CRHR150 (IET 28187) were evaluated under 2nd year of AICRP trials, under AVT-1-ETP and AVT-1-MS. respectively. Further, eight hybrids namely, CRHR 143, CRHR 150, CRHR 151, CRHR 153, CRHR 154, CRHR 155, CRHR 160 and CRHR 161 were tested in Bihar and five of them were promoted. Total 28 promising hybrids (6 mid early, 9-medium, 6-long duration and 7-MS grain type) were re-evaluated during *rabi* 2021-22. Among the hybrids evaluated under DSR and *boro* conditions in Odisha, CR Dhan 703 recorded the highest yield of 8.51 t ha^{-1} and 8.02 t ha^{-1}, respectively.

Trait development/ genetic diversification of parents and hybrids

The restorer lines, CRL 22R and Pusa 33-30-3R were pyramided with 4 BB resistant genes, *Xa4, xa5, xa13* and *Xa21*; introgression of salinity and submergence tolerance in IR42266-29-3R (restorer line) were advanced to BC_3F_3 generation. Introgression of BPH resistant hybrid Rajalaxmi was advanced to BC_2F_4 generation; and in CRL22 to BC_1F_1 generation. Twelve genetically fixed lines having long stigma were under conversion, population was advanced to BC_3F_1. Partial restorers Akshaydhan, Azucena (BC_3F_6), INH 10001 and NP 801(BC_2F_6) were introgressed with *Rf3* and *Rf4*. Introgression of WC genes in SR 11-3-1 (*indica x japonica*) was advanced to BC_2F_4 generations; and CR 1033 to BC_1F_1 generations.

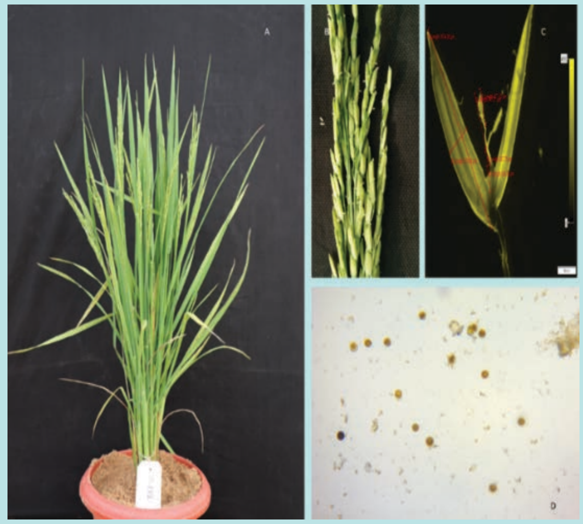


Fig. 1.18 CRMS 58A (BCN192) (a) single plant view, (b) panicle with stigmaexertion (c) single spikelet view, and (d) sterile pollens

Development of heterotic pool

Altogether 192 good combining and genetically diverse lines (48 maintainers and 144 restorers) were phenotyped and genotyped with 148 hypervariable SSR markers, the data will be utilized for development of heterotic groups.

Restorer and maintainer breeding

Total 5138 single plant progenies (F_3 to F_{12}) of 134 crosses (AxR, RxR and BxB) were evaluated, 15 of them were utilized in crossing. Six random mating populations (RMP) of parents (04-maintainers, 02 restorers) were advanced to 10th RMP and 02 inter-subspecific MAGIC (B and R; each with 10 parental genotypes) were advanced to IC_3F_2.

Speed breeding and breeding modernization strategy adoption

Under Field RGA, total 127 breeding populations (BC_2-BC_6) were advanced. Besides, total 240 ABLs (F_{7-8} generation) were genotyped and phenotyped over 4 locations. Among them, 26 ABLs recorded across locations >6.00 t ha^{-1} yield and >5.0 BLUP were utilized. Under line stage testing, 872 ABLs (F_6) were also evaluated.

Seed production of parents/ hybrids

A total of 1320 kg truthful labeled (TL) seeds of 42 hybrids were produced. Besides, 120 kg breeder seeds of 13 CMS; and nucleus seeds of released hybrids were produced. Further, agro-practices for seed production of eight new hybrid combinations were refined.

DNA fingerprinting of parent/ hybrid and mapping for QTLs

DNA fingerprints of 02 CMS (CRMS 57A and CRMS 58A) and three hybrids (CRHR 105, CRHR 150 and CRHR 129) were developed. Besides, 02 RILs populations of hybrids, CRMS31B/CRL 22R and CRMS31B/CRL 23R were phenotyped. These data will be utilized for excavating genomic region responding to heterosis in rice.

Evaluation of AICRIP trials

Altogether 4 hybrid rice AICRIP trials, IHRT-E (25 entries), IHRT-ME (31 entries), IHRT-M (26 entries) and IHRT-MS (16 entries) were evaluated, and data were submitted to the coordinator.

MoUs/ Consultancy services

Consultancy services for hybrid rice seed production were extended to four licensees, namely, Sansar Agropol, Delta Seeds, PAN seeds and Nath Biogene. Besides, under contract research project, suitability of three hybrids of M/s Bayer Bioscience Pvt. Ltd. Was evaluated under DSR.

Development of New Generation Rice (NGR) for enhancing yield potential

The NGRs with high photosynthetic rate (µmol m^{-2} sec^{-1}) (Pn) rate *viz.,* CR 4336-13-1-1-2 (27.78), CR 4030-3-3-3-1-1-1 (25.28) and CR Dhan 328 (24.18) were identified. Although, there was no correlation across the different genetic materials between Pn with seed yield, but there was a positive correlation and regression between Pn with seed yield and biomass in NGR lines (Fig. 1.19). Hence, photosynthetic trait has the potential to improve yield in NGRs.

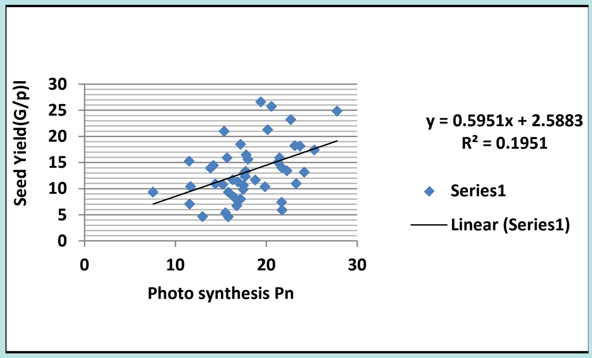


Fig. 1.19. Relationship between Pn and seed yield (G/P) using regression analysis

Evaluation of suitable donors

Trait specific donor lines were identified in a set of lines evaluated during *kharif* 2022. For panicle length (>30cm) the varieties Rambha, Sonamani, Mahanadi, Basmati 564, Pusa Sugandh 4 were identified, similarly for heavy panicle (>5.0g) the varieties were Pusa Sugandh 5, Golak, Jogen, Purnendu, Uphar, CR Dhan 501, CR Dhan 508, Maudamani, Padmanath and R-Mahsuri; for high grain number (>300) the varieties were WGL 32100, Sampad, CO-45, MTU 1075, ADT 39, ADT 45 and Maudamani ; for large flag leaf area the varieties were Lunishree, Nalini, Sonamani, Hanseswari; for high tiller number (>15) the varieties were ADT 39, Gayatri, MTU1075, Dhanlaxmi, PR 114, and Ranjeet.

Release of new variety

CR Dhan 314, an NGR variety was released and notified for cultivation in Odisha and Bihar. This variety is high yielder (avg. yield of 6.62 t ha^{-1} in eastern region: 7.20 t ha^{-1} in Odisha and 6.43 t ha^{-1} in Bihar). It is highly resistant to false smut, resistant to leaf folder and moderately resistant to stem borer (dead heart). It is moderately susceptible to plant hopper, leaf blast and neck blast. It has field resistance to major diseases and pests with good grain quality traits (Fig. 1.20).

Few of the lines were promoted to 2nd/3rd year of testing, *viz.,* CR 3969-24-1-2-1-1 performed well in AVT2 and found promising in Chhattisgarh and Maharashtra. Similarly, another 6 cultures were promoted to AVT 1 out of which the culture CR 3856-

Fig 1.20 Newly notified variety CR Dhan 314 in dough stage.

44-22-2-1-11-4-1-1 stood 1st and 3rd in Zone III in IVT IME (*kharif*) and *boro* respectively. In *boro* season, it recorded 13.14 t ha^{-1} followed by NGR culture CR 4334-2-1-1 with 12.30 t ha^{-1}. Out of 50 advance generation promising lines evaluated in *kharif* 2021 (PYT), CR 3856-44-22-2-1-11-4-1-1 (8.37 t ha^{-1}), C 772-105-1(7.61 t ha^{-1}), SBR 2-4-1(7.47 t ha^{-1}) and SR 48-2-1(7.45 t ha^{-1}) were found promising (23.1% to 9.56% yield advantage over very high yielding variety checks CR Dhan 307) in mid-duration. Similarly, in favourable late situation, SRB **5-1 (8.19** t ha^{-1}**)**, C 1418-1-1-1-1-1-3 (7.87 t ha^{-1}), C 1444-1-1-1-1-1-1-1 (7.85 t ha^{-1}), C 1404-3-2-3-1(7.58 t ha^{-1}) and C 1429-2-1-1-6 (7.49 t ha^{-1}) were found promising with 36.2 to 24.6% superiority over check Swarna. It has been observed that smaller number of tiller is a significant bottleneck in development of very high yielding lines along with heavy panicle. In a new strategy, improvement of tiller was focused with compromising the panicle size resulting in improvement of grain yield. These 2nd generation NGR lines also showed stable performance for yield and the lines C1407-3-2-1-1-1-1-1, C1418-4-3-1-2-5-1-2 and C1747-4-1-1-2-1-1 were identified for high yield potential of ~ 9.00 t ha^{-1}, during *kharif* 2022.

Some of the lines have been introgressed with 3-4 BLB resistance genes *viz.,* SRA 2-19, SRA 149-1-2, and SRA 3-41 were found with more than 7.0 t ha^{-1} grain yield, having yield superiority of ≥ 10.0% than recurrent parent CR Dhan 316.

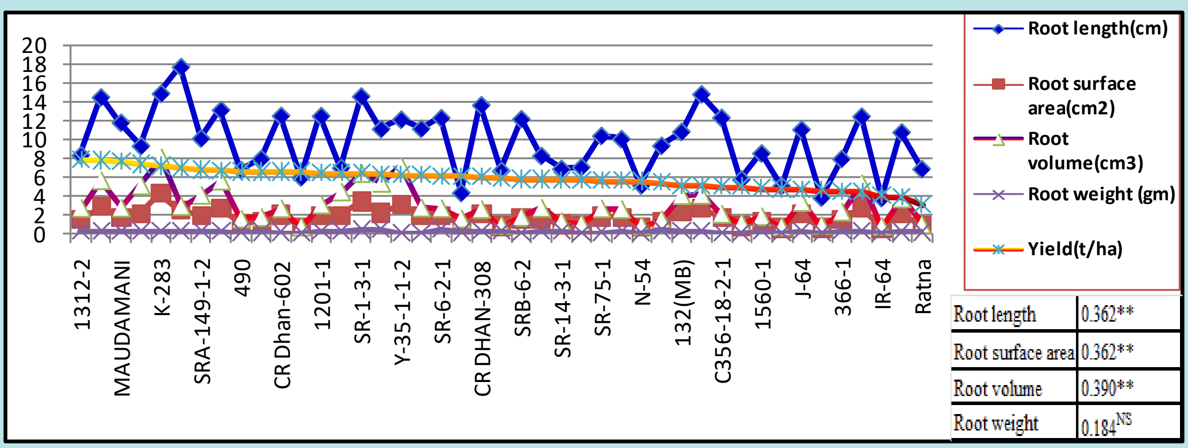
A set of rice genotypes (43 including NGR, NPT, N-responsive and HYV) were studied to assess 17 morphological traits including root traits. The root traits *viz.,* root length, root surface area and root volume showed significant correlation with grain yield. The yield contributing trait *viz.,* 'panicle weight' was having highest direct contribution followed by tiller number', No. of fertile grains', Flag leaf width and root volume. These were genotyped using 56 Indel and SSR markers for marker-trait association analysis using MLM model by GAPIT package of R software (Fig. 1.21).

Ten markers were found to be significantly associated with different morphological traits *viz., GS-5* indel-1(tiller No), *Sub1BC2* (Panicle length), *SCM2*-indel 1(Flag leaf width), RM25(root length), RM19 (No. of fertile grains), *GS5*- indel-1and *SUB1BC2* (No. of sterile spikelets), *Gn1A*-17 SNP, RM19 and *Sub1BC2* (Grain yield). The study validated two SSR markers, RM168 and RM5711 those were linked with grain yield and flag leaf width, respectively. Moreover, these genotypes were clustered into different groups and could be a good indicator for selecting diverse parents for hybridization.

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

Efficiency of developed androgenic protocol for generation of DHs

The potentiality of the androgenic protocol was proven by producing significant number of DHs from various hybrids (Arize 8433DT, Arize 6453, Arize Bold and Arize Gold) and inter-varietal crosses {IR20 x Mahulata, TCN (- RP-5599-312-63-5-1 x IR42266-29-R) and BCN (CRMS32B x *O. longistaminata*)} showing callus induction from 21.20% - 52.00% and regeneration of 41.60% - 85.90%. A total of 391 DHs and 282 DHs were developed from all the rice hybrids and inter-varietal crosses, respectively (Fig. 1.22).



Root length	0.362**
Root surface area	0.362**
Root volume	0.390**
Root weight	0.184^{NS}

Fig 1.21. Regression curve showing association of root traits with grain yield.

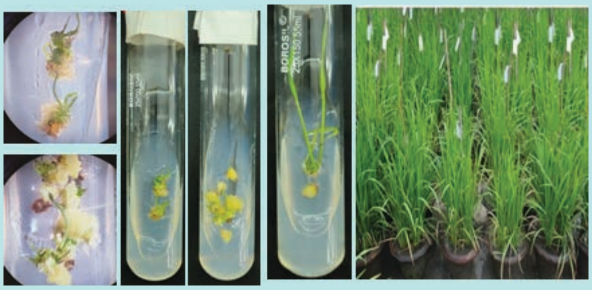


Fig.1.22. Androgenesis in generation of DHs from Arize 8433DT.

Utilization of DH technology in rice improvement

Introgression of multiple genes/QTLs

Androgenesis was employed to introgress multiple biotic and abiotic resistant/tolerant genes/QTLs into maintainer (*Sub1+Hd3a+xa13+Pstoll*) and restorer (*Xa21+ qHtsf 4.1+ xa 13+ TAC 1*) lines which were validated by functional markers through marker assisted selection (Fig.1.23).

Mining of multiple BB resistance genes from hybrid rice

Employment of androgenesis could produce 200 DHs from BS6444G. All 200 DHs were screened for the presence of BB resistance genes (*Xa4, xa5, Xa7* and *Xa21*) from which 8 DHs were identified carrying 4 gene combinations (*Xa4+xa5+Xa7+Xa21*); 3 gene and 2 gene combinations were found in 26 and 28 DHs respectively.

Yield evaluation of doubled haploids under station trial

Eighteen DH lines derived from the hybrids 27P63, and CR Dhan 701 were evaluated under replicated trial along with parents, out of which CRAC 3998-43-1 (6.95 t ha^{-1}), CRAC 3994-2-5 (6.75 t ha^{-1}), CRAC 3998-114-1 (6.55 t ha^{-1}) and CRAC 3998-325-2 (6.52 t ha^{-1}) recorded at par yield with parent hybrids. Besides, 09 DHs were evaluated under multilocation trials at four research stations of OUAT as well as in farmers' fields.

The DH line CR 3918-109-5-6-4-1 (IET29446) evaluated under AVT1-Aerob was promoted to AVT2-Aerob. Further, seven promising DHs were nominated for AICRIP evaluation.

***In vitro* mutagenesis for *indica* rice improvement**

- A mutant of Kalajeera (landrace of Koraput) developed through EMS-based mutagenesis in *vitro* showed 28.5% height reduction from the parent (140-150cm) (Fig. 1.24).
- Upon evaluation of Shaktiman mutants through *in vitro* and *in vivo* approaches, six lines were identified for tolerance to glyphosate (2ppm, 4ppm and 6 ppm) (Fig. 1.25).

Genotype independent robust regeneration protocol in *indica* rice genotypes

A genotype independent robust regeneration protocol was developed using 24 *indica* genotypes and 10 wild rice species which was found efficient with 100% callus induction and 75 to 100% regeneration efficiency.

Editing *IPA1*, *EPFL9, Gn1a* for improving yield and drought tolerance in rice through CRISPR/Cas9

- The stable maintenance of *IPA1* gene in heterozygous condition of Swarna was confirmed through genotype analysis which might be tandemly duplicated. This needs further confirmation through sequence analysis.

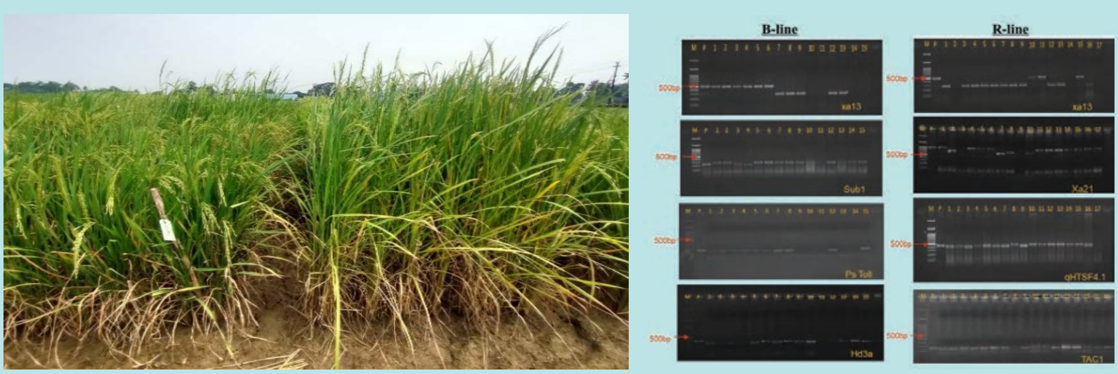


Fig.1.23. DHs carrying genes/QTLs in B-line (*Sub1+Hd3a+xa13+Pstoll*) and R-line (*Xa21+ qHtsf 4.1+ xa 13+ TAC 1*). Validation of various genes *Sub1, Hd3a, xa13* and*Pstoll* in B and *Xa21, qHtsf 4.1, xa 13* and *TAC 1* in R line

Fig.1.24 Height reduction in Kalajeera mutant

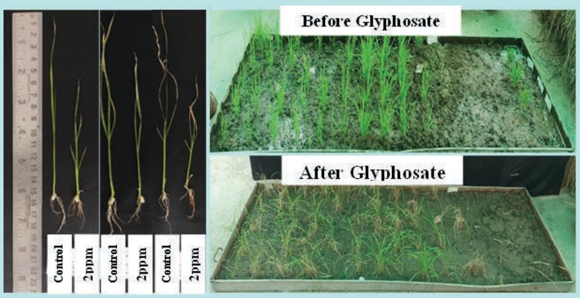


Fig.1.25 *In vitro* and *in vivo* evaluation of Shaktiman mutants for glyphosate tolerance

- Three putative regenerants were developed in Swarna by editing *Gn1a* gene.
- The Cas9 construct for EPIDERMAL PATTERNING FACTOR (*EPFL*) gene was developed targeting the exon region which was further mobilized into *Agrobacterium* strain LB4404 for transformation (Fig. 1.26).

Development of novel genomic resources for rice improvement

Whole-genome re-sequencing of donors and elite rice cultivars, and development of markers for desired genes

Five genotypes (CR 3006-8-2, Naveen, HP 2216, RIL 14 and Swarna *Sub1*) were re-sequenced with an average depth coverage of 26.74 (X) and alignment rate of 97.58%. Sequence data of Naveen and CR 3006-8-2 will be used for development of gene-

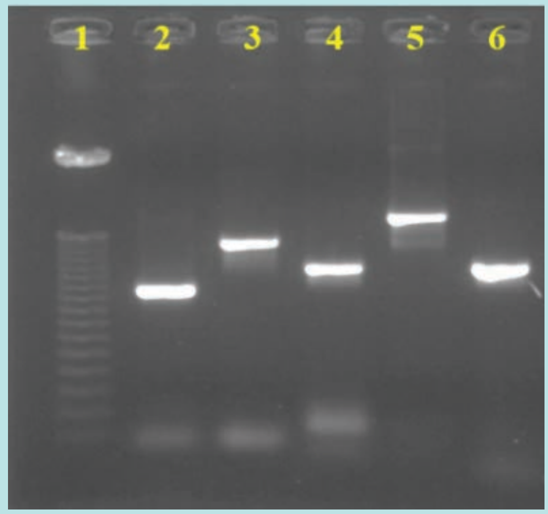


Fig.1.26 Confirmation of the plasmid harbouring sgRNA for target gene *OsEPFL9* into *Agrobacterium* strain LB4404 by colony PCR.

based markers for BPH resistance. HP 2216 and RIL 4 will be used for cloning blast resistance gene while Swarna *Sub1* will be used for comparative genome analysis with Swarna.

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

An association panel containing 144 genotypes (varieties and land races) was developed for mapping of *bakane* resistance at seedling stage. Mapping population of the cross Pooja (S)/ Thavalakannan (R) was advanced and genotyped with 20 polymorphic markers. A number of RILs ($F_{6:7}$) were found to be heterozygous. Hence, mapping population will further be advanced and then will be genotyped.

The association mapping panel consisting of 169 rice genotypes (landraces and varieties) was evaluated for spikelet fertility under high temperature stress condition. The association mapping panel was genotyped by GBS approach. Marker-trait association analysis with 16.7K high quality SNPs identified 10 SNP markers associated with spikelet fertility, explaining 11.75% -15.25% PVE (Fig. 1.27).

Another association mapping panel consisting of 189 rice genotypes (landraces and improved lines) was evaluated for straw qualities like dry matter, ash, silica and metabolizable energy (ME). These traits showed wide variations. The association mapping panel was genotyped with 295 SSR markers.

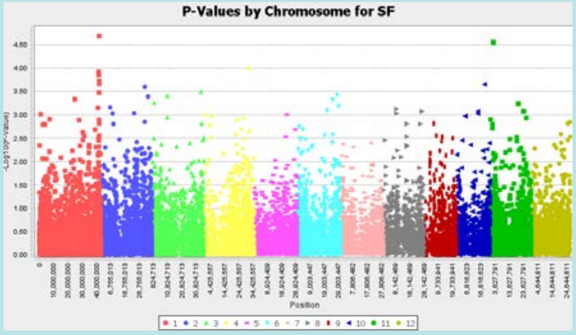


Fig. 1.27 Manhattan plot showing marker-trait Association for spikelet fertility under high temperature stress condition

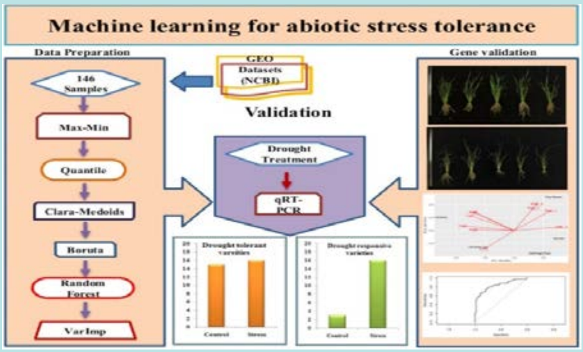


Fig. 1.28. Machine learning model approach to identify genes responsive for multiple stresses (heat, drought salinity, submergence and cold) using 142 microarray data related to abiotic stresses.

Marker-trait association analysis identified five markers associated with dry matter, ash, silica and metabolizable energy (ME), explaining 10% -39% PVE.

Gene prospecting and epigenetics for tolerance to abiotic stresses

One hundred forty-two (142) microarray data related to multiple abiotic stresses (heat, drought, salinity, submergence and cold) were downloaded from databases, grouped into control, and treated samples. Data were analyzed using machine learning models (Fig. 1.28). Eight genes responsible for multiple abiotic stresses (stresses: heat, drought, salinity, submergence and cold**)** were identified.

Methylation controls the gene expression, cell proliferation, cellular proliferation, embryonic development, etc. The expression of genes depends upon the level of methylation at promoter sites. Five varieties, JR201, HKR107, Pusa Basmati 6, N22 (T) and Naveen (S) were treated to heat stress (HS) at vegetative stage. Half of each control (C) and heat-stress treated samples were treated by sodium-bisulphite. Primers were designed for promoter regions of two identified genes, *LOC_Os05g43860.1* and *LOC_Os02g36200.1* and amplified from both samples. Melylome analysis was carried out. Non-amplification from sodium-bisulphite treated samples indicated that these genes not methylated in the promoter region, while amplification indicated genes are methylated in the promoter region.

Functional validation of putative candidate genes for resistance to biotic stresses (BPH)

Expression analysis of 10 putative genes from QTL regions in resistant (Salkathi and CR 3006-8-2 (Pusa44/Salkathi), susceptible (TN1 and Naveen) parents and 12 BILs identified eight genes, *LOC_Os04g02040*(NBS-LRR), *LOC_Os04g02510* (*ZOS4-01 - C2H2* zinc finger protein) (Fig. 1.29), *LOC_Os04g02920* (Leucine rich repeat family protein), *LOC_Os04g02860* (disease resistance protein RPM1) *LOC_Os04g21890* (Disease resistance protein RPM1), *LOC_Os04g022900* (Jasmonate-induced protein), *LOC_Os04g34250* (Serine/threonine-protein kinase receptor) and *LOC_Os04g34330* (serine theorine protein kinase) are likely to be candidate genes for BPH resistance which will again be validated.

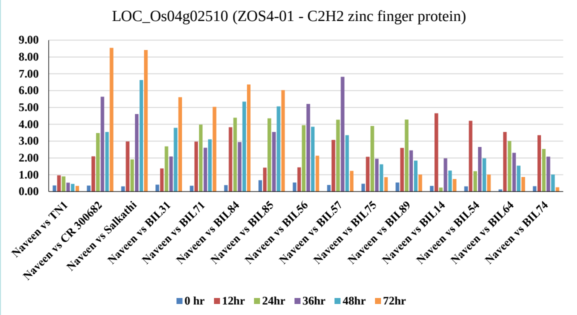


Fig. 1.29. Expression analysis of candidate gene (*LOC_Os04g02510*) in treated (12hr, 24hr, 36hr, 48hr and 72hr) and non-treated (0 hr) samples of BPH tolerant (Salkathi, CR3006-8-2, BILs) and BPH susceptible (TN1, Naveen, BILs) genotypes. Susceptible parents, BILs showed lower expressions while tolerant parents and BILs showed enhanced and higher expressions.

Conclusion

An intense research is being undertaken in Crop Improvement division under various projects to enhance rice plant to make it more resilient to changing environment and meet the growing socio-economic needs of the rice stockholders. Such research activities will help achieve the goals, breakthroughs, and anticipated product development in rice. The various technologies developed, including the varieties, hybrids, and methodology, would enable the rural rice farmers to be self-sustainable. New insight into genomics will help in precise product development, biofortified rice will provide nutritional food security to the nation. In addition to this, the division is tasked with producing and supplying high-quality rice seeds to meet ever-increasing demand of the farmers. The outcomes of these initiatives will certainly help policymakers at regional and national levels to make essential modifications in future agricultural policy planning to address the constraints linked to rice.

PROGRAMME-2

Enhancing Productivity, Sustainability and Resilience of Rice Based Production System

The sustainable rice production depends upon four major components viz., productivity, profitability, resource use efficiency and climate change resilience. In this context, the programme has been planned to develop, validate and disseminate innovative cutting edge technologies for enhancing productivity, sustainability and resilience of rice based production system. The main objectives of the programme are to (i) develop precision nutrient and water management framework using advanced digital, sensor based and nano technology for enhancing nutrient and water use efficiency in rice, (ii) site specific planning and development of cropping and farming system models and weed management strategy for enhanced productivity and profitability, (iii) economic and environmental friendly utilization of rice residues by resource conservation technologies and microbial intervention, (iv) customize new prototypes and improvement of identified machineries for small farm mechanization, (v) development and evaluation of rice-specific microbial formulation for nutrient, pest and residue management, (vi) impact assessment of land use and land cover change on ecosystem services from rice based cropping systems, and (vii) vulnerability analysis and prioritization of climate smart agricultural technologies for enhancing resilience in stress prone rice ecologies.

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

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

Calibration experiment to develop relationships for predicting yield of rice from in-season optical sensor measurements using Greenseeker (GS) was conducted with 6 N levels (0, 40, 60, 80, 100, 120 N ha^{-1}) and two varieties (Swarna and Naveen) during *kharif* season and five varieties namely, CR Dhan 312, Lalat, Shatabdi, and CR Dhan 206 during the *rabi* season of 2022. The relationship between the *in-season estimation yield* (INSEY) calculated from the NDVI sensed at 35, 53, 60 and 68 DAT and yield showed best fit to a power function equation as: $Yp_0 = a * (INSEY)^b$ at 60 DAT for Swarna and 46 DAT for Naveen and other varieties. The algorithm developed was generated to derive top dressing recommendation for different varieties at panicle stage. The validation of the GS based recommendation in the subsequent season resulted in 4.7 to 7.1% enhancement in yield as compared to blanket recommendation.

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

The nano-clay polymer composites (NCPC) were synthesized and loaded with three low molecular weight organic acids (LMWOA) (citric, malic and tartaric acids) and three sources of P (diammonium phosphate, DAP; single super phosphate, SSP and rock phosphate, RP) making nine combinations. It was observed that DAP, SSP and RP can be loaded maximum up to 10% w/w, 20% w/w and 10% w/w, respectively. Beyond this, there is an increase in polymerization time and sticky consistency of the final product at higher w/w of fertilizer. The release pattern of P from loaded NCPC in water and soil for both SSP and RP variants were studied. Power form of release was observed in all the cases. In case of release in soil, NCPC+SSP (20%)+TA and NCPC+RP (10%)+TA recorded the highest release of P. We also characterized polymer using Fourier transform infrared spectroscopy (FTIR) and scanning electron microscope (SEM). The FTIR peaks between 3800 and 3200 cm^{-1} represents -OH stretching vibrations of kaolin clay. Similarly, peaks at 1700 and 1600 cm^{-1}, 1100-1000 cm^{-1} and 1200-1050 cm^{-1} suggested C=O stretching of acrylic acid and acrylamide; PO_4^{3-} chemical groups and C=O stretching vibrations of COOH groups, respectively. In SEM, we found sheets like hexagonal structure of kaolinite. Round structures, rosette-shaped aragonite crystals and rough surface structure represented citric acid, malic acid and tartaric acid, respectively.

Synthesis and characterization of nano-silica from rice husk

Silicon (Si) may improve the plant cell membrane functioning and integrity and it may consequently increase the uptake and transportation of some nutrients (N, P, K, S, Zn) and minimize biotic and abiotic stress in rice. Rice husk is an agricultural waste material that need to be converted to wealth. However, rice husk is one of the most silica-rich raw materials containing about 90 to 98% silica. Thus, an experiment was designed to synthesize the Si nano particles (NPs) from rice husk. Raw rice husk was burned in an open environment to collect rice husk ash. Rice husk ash was mixed with milt acid and allowed to stand overnight. The treated RH ash was calcined in a furnace following standard protocol, which finally converted the Si into nano size. Finally, the produced Si nano particles were stored in a polythene zip bag in a dry place for further characterization. Characterization was done through a dynamic laser scattering particle size analyser (DLS). The particle size was 53.50 nm. Silica NPs have a wide array of applications in electronical, medical and agricultural sector. Rice husk could be a cost-effective source of Si nano particles.

Taxonomic and functional profiles of microbial community under 52 years' old LTFE paddy soil through whole metagenome

Microbial taxonomic profile of 52 years old LTFE paddy soils were analyzed from super kingdom to species level. Results revealed that soil viruses and eukaryotes were abundant in control (without fertilizer plots) compared to other 52 years old LTFE paddy soil, whereas fertilizer application either inorganic or organic or combinational might promote the abundance of bacteria and archae. Continuous application of N-alone over 52 years suppressed most of the cellular function of microbial community compared to other treatments.

Evaluation of organic nutrient management options in relation to C-N mineralization in rice-pulse system

Four N-responsive rice varieties, Naveen, CR Dhan 311, CR Dhan 308, Genotype 413-5 were grown during *kharif* 2021 under long-term organic nutrient management under eight distinct organic nutrient treatments for *kharif* rice: T_1-absolute control; T_2-FYM; T_3-Azolla; T_4-Green manure; T_5-Vermicompost; T_6-FYM+Azolla, T_7-FYM+green manure; T_8-FYM+Vermicompost to replace the dose of 80 kg N ha^{-1}either 100% or 50% combinations. Among the treatments, it was noticed that the inorganic-N varied in both 0-15 and 15-30 cm soil following the trend: T2>T6>T8 ranging between the values 131.6-139.4 mg kg^{-1} of soil (0-15 cm soil) and 122.4-130.9 mg kg^{-1} of soil (15-30 cm soil). Laboratory incubation was set up for 90 days for studying C-mineralization. The max value of C_{min} reaches up to 13.2 mg CO_2-C g^{-1} soil (0-15 cm) and 9.1 mg CO_2-C g^{-1} soil (15-30 cm). Among the treatments, T_7 and T_8 showed less C_{min} values as compared to T_2, T_3, T_4 and control. Combination of organic manures (T_6, T_7, T_8) proved beneficial for yield and biomass and the harvest index varied between 32-43%. In economic point of view, T_7 (FYM + Green manure) was found as the most promising one, with B:C ratio of 2.85.

Weed dynamics in 21 years of long-term organic nutrient management in rice-fallow system

The present experiment was conducted at the long-term (21 years) organic management experiment during *kharif*, 2021- *rabi*, 2022. Data were taken during maximum tillering and panicle initiation stage of rice both in *kharif* and *rabi* seasons. Organic fertilization was equivalent to 60 kg N ha^{-1} applied in all treatments except the control. A total of 11 weed species from 9 families were recorded. *Poaceae* was the predominant family, followed by *Sphenocleaceae* and *Marsileaceae* at the maximum tillering stage in the *kharif* season, while *Poaceae* and *Onagraceae* were the two predominant families at the panicle initiation stage in the *kharif* season. Weed density was comparatively lower during the panicle initiation stage, but increased during the fallow period in the *rabi* season. The highest density of weeds was observed in control when crop was at panicle initiation stage, while the lowest weed density was observed in Green manure + *Azolla* during cropping season. In terms of weed species, grasses dominated in all treatments at each growth stage, followed by broad leaves. Nutrient accumulation in weed species was higher in FYM + *Azolla* during fallow season, while lowest nutrient accumulation was noticed in control during fallow season.

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

Zonation and mapping of different rice ecologies

In this activity, estimation of the proneness to ponded water for certain duration in a cropping season has been done for Tangi Chowdwar block (Fig. 2.1). Hydrological and hydrodynamic models are broadly applied for flood assessment with respect to magnitude, extent, and frequency of floods. Multi-criteria decision analysis (MCDA) along with the application of analytical hierarchy process (AHP) method was used to identify the optimal selection of weights for the factors that contribute to ponding water in the study area. In this study, 7 parameters i.e. rainfall, distance to the river, digital elevation slope, land use and land cover, drainage density, flow length and soil clay map were used to map the proneness for ponding water based on review of different literatures. Landsat-08 OLI was used for land use land cover map, whereas Cartosat 2 DEM 2.5 m was used for generating elevation, drainage density, flow length and distance to river map. Rainfall data was procured from CHIRPS. For rainfall, new resources of satellite observations like gridded satellite-based precipitation estimates from NASA and NOAA have been used. Most of the area has elevation up to 30-50 meter except near foothills and hillocks. Most of the agricultural areas shows the slope up to 1.6% but in some foothills it reached up to 37%. The surface slope influences the velocities of overland flow and the concentration of flow. The probability of inundation/ponding increases as the slope of a region decreases, making it a good indicator for assessing inundation. All these maps layers were classified and weight assignment of the layers were done using Saaty's 1-9 scale. A (7x7) pairwise comparison matrix for the AHP was prepared. Among the 7

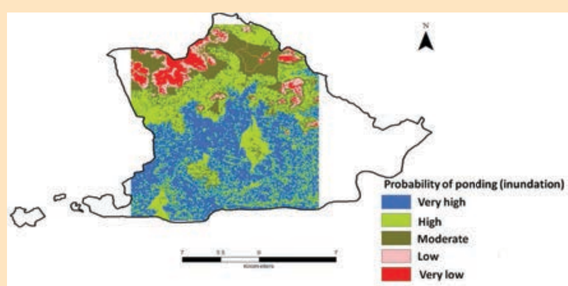


Fig. 2.1. Map of proneness to ponding water for Tangi Choudwar block of Cuttack district.

parameters the normalized principal Eigen vector was highest for rainfall (0.30). Similarly, consistency ratio for assessing the parameter ranking was also done and it was below 25%. Finally, the parameters were aggregated as per the assigned weightage and proneness to ponding water was generated, which was categorized as very high, high, moderate, low and very low.

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

Prioritization matrix for components of farming system model (FSM) was prepared using expert opinion. The weightage of the various indicators in Coastal Zone varied widely among which higher productivity (range 10-25 and average 18) and higher income (range 10-20 and average 16) received the highest weightage. The components of farming system models were also scored by the experts. Besides, the information from 308 farmers covering 20 villages and 5 blocks of Kendrapada, Bhadrak, and Jagatsinghpur districts of Odisha were collected. The specific adoption for crop (rice+ pulse/ oilseed/ veg) + dairy + pisciculture + mushroom was found 42.5%, which was higher than the other systems (2.3-11%). Adoption of the system crop (rice+ pulse/ oilseed/ veg) + dairy + pisciculture + mushroom showed some association with the training program (number), farming experience and cropping intensity. The reasons of poor adoption are laggardness (comfort zone), lack of risk taking ability, non-cosmopolitans and lack of innovativeness. However, our model had certain levels of errors, such as, endogenous, omitted variable bias and reverse causality.

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

Development of block wise drought vulnerability index for Dhenkanal district

Vulnerability refers to the possibility of being hit or propensity to be harmed by a stress or shock. It identifies what causes risk and how risk is managed. Vulnerability refers to the characteristics of a group in terms of its capacity to anticipate, cope with, resist and recover from the impact of disasters. Vulnerability assessment aims to identify vulnerable groups within a community and to determine ways to make the affected population less vulnerable. Less vulnerable means higher resilience and strong adaptive capacities. Drought vulnerability assessment frame work was developed which is comprising of the six steps. A database of all the indicators chosen for eight blocks of Dhenkanal district was created. The data on the indicators chosen were then normalized and combined into an index following the methodology followed in computation of Human Development Index (UNDP, 1999, 2006). The process of construction of vulnerability index involves normalization of all the indicators and then averaging these resultant normalized values. Highest vulnerability for drought was observed in Parjang block followed by Kankadahad. The higher vulnerability of Parjang is due to the high sensitivity and Kankadahad is due to low adaptive capacity. Due to low exposure, the vulnerability of Hindol block is low and for Odapada block low vulnerability is associated with low sensitivity and high adaptive capacity.

Standardized Precipitation Index of different blocks of Dhenkanal district

Assessing drought severity is an element of the drought monitoring. The assessment of severity and frequency of dry periods in a given severity class depends on the assumed criteria of drought. Using the series of precipitation records in the growing periods of 1990-2021 from Dhenkanal, Gondia, Odapada, Hindol, Kamakhyanagar, Bhuban, Parjang and Kankadahad blocks of Dhenkanal district, the standardized precipitation index (SPI) have been calculated. Standardized Precipitation Index (SPI) for all the blocks of the Dhenkanal district are under the mild drought category. The SPI for the Odapada and Kamakhyanagar blocks during July have a significantly negative trend which indicates that total rainfall during the month of July is decreasing in these blocks. The SPI for the Kankadahad block during July has a significantly positive trend which indicates that total rainfall during the month of July is increasing in this block.

Effect of different sources of silica to restrict Arsenic loading and enhance rice production

In this investigation, the interplays of the factors for mitigating arsenic (As) toxicity in rice was assessed using a contaminated paddy-rice system with seven amendment regimes involving $CaSiO_3$, SiO_2 nanoparticles, silica solubilizing bacteria (SSB), and rice straw compost (RSC). Tracing the translocation of As from soil-root-shoot-grain-polished to cooked rice, RSC and its combination with SSB was found as most effective in curbing As loading in rice grain (53.2%) (Fig. 1). The risk of dietary exposure to As was assessed by computing the average daily intake (ADI), hazard quotient (HQ) and incremental lifetime cancer risk (ILCR), and observed the ADI is reduced to one-third (0.24 µg kg^{-1} BW) under RSC+SSB treatments over control. An effective prediction model was established via random forest model and described the accumulation of As by rice grains depend on bioavailable As, P and Fe which explained 48.5, 5.07 % and 2.6% of the variation in the grain As, respectively. The model anticipates that to produce As benign rice grain, soil P and Fe should be more than 30 mg kg^{-1} and 12 mg kg^{-1}, respectively when soil As is more than 2.5 mg kg^{-1}.

Plant-mediated methane emission of rice cultivars influenced by redox potential gradients

In a field experiment plant-mediated methane emission of rice cultivars influenced by redox potential gradients was assessed. For this three varieties of contrasting heights and genetic backgrounds- V_1: Sahbhagidhan (plant height: 85-90 cm), V_2: Naveen (plant height: 105 cm) and V_3: Rajalaxmi (plant height: 105-110 cm) were grown with four management treatments *viz.,* Control (No amendments; N_0), Phosphogypsum (2.0 Mg ha^{-1}; N_1), Manganese oxide (MnO_2 @ 0.5 kg ha^{-1}; N_2) and Ferric oxide (Fe_2O_3 @ 10 mg kg^{-1} soil; N_3). The results revealed that in the experiment, crop growing period changes in the methane fluxes showed a general trend characterized by slightly increase at the maximum tillering stage i.e. from 32 DATs followed by significant increase at the panicle initiation stage of cultivation, and conversely, by a decrease at the maturity stage after the water drained out from the field. Maximum methane fluxes were recorded at about 67 days for Sahbhagidhan and Naveen cultivars whereas in case of Rajalaxmi it is at 74 days after transplanting. Among the management treatments, the methane flux from the soil significantly varied in a trend Control> Phosphopysum> Manganese oxide > Ferric oxide. The effect of ferric oxide also showed a prominent effect in increasing grain yield in a tune of 10-16% in three rice varieties, while var. Rajalaxmi recorded the highest yield (6.7 t ha^{-1}). Plant height of varieties showed a proportionate relationship with the aerenchyma size of stem, and thus impacts on plant-mediated CH_4 emission. This study revealed that plant morphology played a key role in determining the CH_4 emission under variable soil Eh, moderated by soil amendments.

Developing agronomy for new generation rice and rice based cropping system

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

Effect of age of seedlings, seed treatment and seeding density in nursery on yield and yield attributes of new generation rice (CR Dhan 314) was studied. The experiment was laid out in split-split plot design and replicated thrice. The treatments consist of age of seedlings in main plot (21 and 42 days old seedlings), seed treatment in sub plots (*Pseudomonas* @ 10 g kg^{-1} of seeds, *Trichoderma* NRRI formulation @ 10 g kg^{-1} of seeds and control) and seeding density in nursery in sub-sub plots (40, 50 and 60 g m^{-2}). Experimental findings revealed that age of seedlings has significant effect on yield and yield attributes of CR Dhan 314. Younger seedlings of 21 days increased the grain and straw yield by 4.4 and 4.6%, respectively over older seedlings of 42 days' seedlings. Seed treatment with biocontrol agents significantly increased the grain, straw and total biological yield. Application of *Pseudomonas and Trichoderma* (NRRI formulation) @ 10 g kg^{-1} of seeds as seed treatment produced comparable grain yield which was significantly higher than control. The increase in grain yield was mainly due to increase in number of panicles per unit area and grains per panicle. However, the seeding density on rice nursery did not influence the yield and yield attributes of new generation rice.

Standardization of major nutrient levels and development of INM for NGR

An experiment was carried out to assess the potential yield as well as to calculate the optimum dosage of N for NGR variety (CR Dhan 314). To conduct the experiment, six N doses *viz.,* 40 kg ha^{-1}, 80 kg ha^{-1}, 120 kg ha^{-1}, 140 kg ha^{-1} (20 kg N through FYM), 160 kg ha^{-1} (20 kg N through FYM) along with control were taken. Performance of CR Dhan 314 was compared with performance of standard check c.v. Swarna. Data revealed that CR Dhan 314 produced at par yield with Swarna. Highest grain yield of Swarna was achieved with Nitrogen level of 120 kg ha^{-1} where as in CR Dhan 314, it was achieved at 140 kg ha^{-1} (inclusive of 20 kg N through FYM). The grain yield of CRD 314 at 140 kg ha^{-1} (120 kg N ha^{-1} through Fertilizer + 20 kg N through FYM) was at par with grain yield of Swarna at 120 kg N ha^{-1}. The data indicated that the grain yield declined in Swarna beyond 120 kg ha^{-1} N application where as sharp decline in yield was recorded in CR Dhan 314 on additional N application after 140 kg ha^{-1} N.

Developing integrated nutrient management for nutrient dense rice

A field experiment was conducted to identify integrated nutrient management practices for nutrient dense rice. The experiment was conducted during *kharif* season with seven nutrient management treatments and six rice varieties. The different nutrient treatments were (a) T_1 = Control (No NPK) (b) T_2 = RDF (c) T_3 = RDF + FYM (5 t ha^{-1}) (d) T_4 = RDF + FYM (5 t ha^{-1}) + 25 kg ha^{-1} $ZnSO_4$. $7H_2O$ (e) T_5 = RDF + FYM (5 t ha^{-1}) + 25 kg ha^{-1} $ZnSO_4$.$7H_2O$ + Foliar Zn (0.2%) at MT (f) T_6 = RDF + FYM (5 t ha^{-1}) + 25 kg ha^{-1} $ZnSO_4$.$7H_2O$ + Foliar Zn (0.2%) at FL (g) T_7 = RDF + FYM (5 t ha^{-1}) + 25 kg ha^{-1} $ZnSO_4$.$7H_2O$ + 2 Foliar Zn (0.2%) at MT & FL and different varieties under examination were V1 = DRR Dhan 45, V2 = DRR Dhan 48, V_3 = DRR Dhan 49, V_4 = Zincose, V_5 = CR Dhan 311, V_6 = Naveen. Application of Zn as soil application @ 25 kg ha^{-1} and foliar application @ 0.2% at maximum tillering and flowering stage resulted in significantly higher (17-31%) grain yield as compared to no Zn application. The increase in grain yield due to external application of Zn was highest for high Zn varieties like Zincose and CR Dhan 311 (26-31% higher) as compared to low Zn variety like Naveen (20% higher). The increase in grain yield due to Zn application is mainly due to significant increase in filled grains per panicle and increased test weight.

Effect of system based phosphorus management on yield of rainfed rice – green gram cropping system

The effect of system based phosphorus management on crop productivity, profitability and nutrient uptake of rainfed rice-green gram cropping system was studied under medium land situation at ICAR-NRRI, Cuttack, Odisha. The experiment was laid out in a split plot design with four nutrient management practices in rice *viz.,* recommended dose of fertilizer (RDF), RDF+ 25% additional phosphorus(P) through FYM, RDF+ 25% additional phosphorus(P) through fertilizer and 75% of RDF (RDF_{75}) in main plots and five nutrient management practices in green gram *viz.,* Control, RDF, RDF+PSB inoculation(RDF+ PSB), RDF+ Foliar spray of 2% DAP (RDF+ FS) and RDF+ PSB inoculation+ Foliar spray of 2% DAP (RDF+PSB+FS) in subplots and replicated thrice. Effect of system based phosphorus management had significant effect on productivity, profitability and nutrient uptake by the system. Significantly higher system yield was recorded in rice when additional 25% P was applied through FYM (@ 5 t ha^{-1}) with RDF followed by RDF + PSB inoculation + DAP foliar spraying. Additional 25% P through FYM to rice had a significant effect on increasing the grain yield of rice in wet season and the seed yield of green gram in subsequent season. Grain yield of rice achieved under 25% additional P through FYM was on par with the yield under 25% additional P through fertilizer to rice but significantly higher than yield under RDF and RDF_{75}. Green gram applied with PSB and DAP foliar spray along with RDF produced higher seed yield irrespective of P fertilization to rice. Highest system grain yield (9.0 t ha^{-1}) was recorded with RDF + 25% additional P from FYM to rice followed by RDF + PSB application + DAP foliar spray to green gram in a rice green gram cropping system.

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

Assessing the impact of land use land cover (LULC) changes on ecosystem services during last three decades

This study was conducted to estimate the variation in ESV with respect to LULC change during 1992 to 2020 in three districts i.e. Jharsaguda, Bolangir and Gajapati of Odisha using satellite imagery for the year 1992, 1995, 2001, 2005, 2011(Landsat TM) and 2020 (Landsat 8 OLI). The satellite images were classified into six LULC classes i.e. rice area, forest, waterbody, wasteland and built-up (Fig. 2.2).

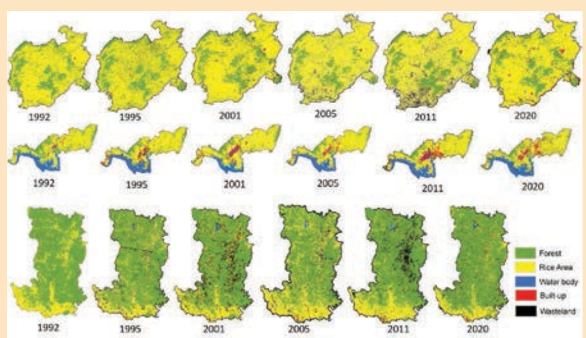


Fig. 2.2. Land use and land cover classification of six coastal districts of Odisha, India.

The highest (70.07%) forest cover of total geographical area of the district was found in Gajapati whereas; lowest (15%) in Jharsuguda. During the study period from 1990-2020, an overall increase in 9.0% forest cover was recorded in Jharsuguda, respectively, whereas a decrease 1.16% in forest cover was recorded in Bolangir. In case of rice crop area, an overall reduction was observed in Bolangir and Jharsuguda districts over the study period. But highest reduction in rice area recorded in Bolangir (28.60%) followed by Jharsuguda (26.82%) and an increase in 10.64% in Gajapati over the study period of 30 years. In case of built-up area, a continuous increasing pattern was recorded over 30 years for all districts. There was decrease in total ESV from 1990 to 2020 in all the districts over study period. Highest decrease (77%) was recorded in Jharsuguda followed by Gajapati (38%) and Bolangir (6%). ESV from rice crop land was estimated and similar pattern was recorded as estimated in total ESV. Highest decrease (81.8%) was recorded in Jharsuguda followed by Gajapati (39.5%) and Bolangir (18.7%) (Fig.2.3).

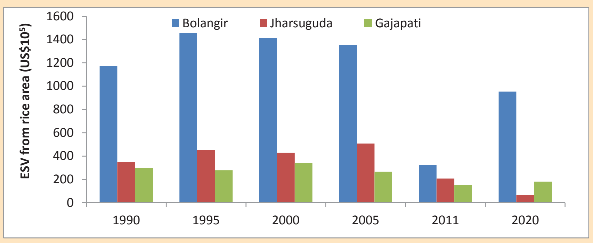


Fig. 2.3. Estimation of ESV from rice over study period from three districts of Odisha.

The overall ranking for the study period were estimated based on the average impact of individual ESVs on total ESVs. The ranking of ecosystem service functions in decreasing order is food production > soil formation > water supply > waste treatment > climate regulation > raw material > recreation> gas regulation. Food production is providing the largest contribution (47%) to total ESVs.

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

In India, rice straw production is around 126.6 million tonnes. Handling the straw is an issue and rice straw burning is spreading rapidly in India including eastern Indian states like West Bengal, Odisha, Bihar, and Jharkhand. Nearly 16% of crop residues are burnt on farms in India of which 60% is rice straw. Straw burning is of serious concern as it causes severe air pollution, nutrient and biodiversity losses. So, one activity was carried to make the residue burning map of Odisha (district wise), and in another activity, *in-situ* management of straw has been studied.

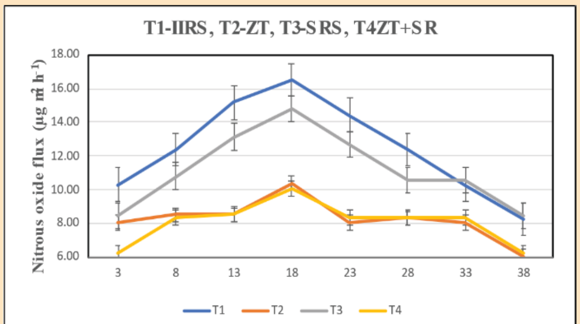
Rice straw burning scenario in Odisha

In a study of previous two years (2019-2021), it was observed that rice straw burning events occurred in between the months of December-March as per the base data of Terra and Aqua satellites, MODIS sensor. During 2019-2020, frequent burning events were observed in Bargarh (230, peak in December) and Nabarangpur (270; peak in February). Burning events expanded to more districts in 2020-2021 *viz.,* Bargarh (524), Nabarangpur (359), Baleshwar (247), Sambalpur (241), Kalahandi (234) in between December-March. Fire events data was further categorized into month-wise occurrence in the districts of Odisha. During 2020-21, few districts in Odisha accounted >100 fire events/month like Baleshwar, Kalahandi, Sambalpur, Subarnapur (in December), Bargarh (in January), and Nabarangpur (in February).

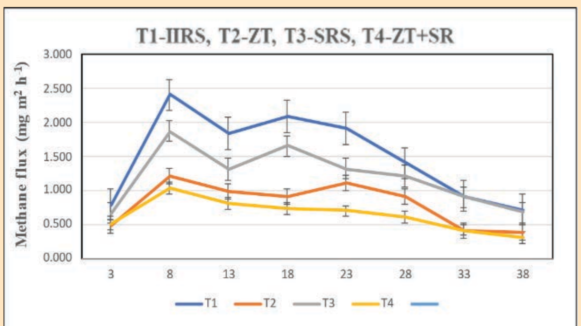
***In situ* straw management**

A field experiment was conducted at ICAR-NRRI experimental fields during *kharif* season 2022 for *in-situ* management of straw. Four treatments *viz.,* (i) Immediate incorporation of rice straw after harvesting (IIRS) (T_1), (ii) Zero tillage (with glyphosate spray) (T_2), (iii) Spreading of straw over the field (T_3) and (iv) Zero tillage with straw retention (T_4) (without glyphosate spray) were imposed in the field randomly with five replications (Table-2; Fig 2). The soil labile carbon pools- microbial biomass carbon (MBC); readily mineralizable carbon (RMC), enzymatic activities {β-glucosidase, dehydrogenase activity (DHA) and fluorescein diacetate activity (FDA)} and GHGs {carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O)} were estimated in all treatments after the imposition of the treatments at an interval of 3, 8, 13, 18, 23, 28, 33 and 38 days.

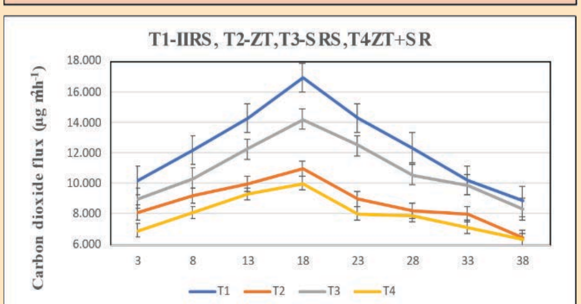
The readily mineralizable carbons (RMC) and microbial biomass carbons (MBC) were increased from 8th days of treatment imposition to 28th days then decreased at 38th days irrespective of treatments. The labile carbon and soil enzymatic activities (β-glucosidase, DHA and FDA) were found higher in IIRS (T_1), followed by SRS (T_3), ZT (T_2) and ZT+SR (T_4). The MBC and RMC values for IIRS, ZT, SRS and ZT+SR treatments were found to be 338.7, 305.9, 323.5, 285.7 μg Cg^{-1} and 243.6, 218.3, 230.5, 210 μg Cg^{-1}, respectively. The β-glucosidase activity for IIRS, ZT, SRS and ZT+SR was found to be 14.9, 11.9, 13.9 and 11.1, respectively. FDA and DHA for the same treatments *vis-à-vis* IIRS, ZT, SRS and ZT+SR were 4.2, 3.1, 3.7, 2.7 and 122.4, 100.9, 110.8, 94.3, respectively. The methane emission was higher in IIRS (T_1) followed by SRS (T_3), ZT (T_2) and ZT+ST (T_4) (Fig. 2.4). The CO_2 and CH_4 emissions were increased from 3rd to 18th days of treatment imposition and then decreased slowly. The CO_2 and N_2O (Fig. 2.4) emissions trends were the same. However, in the treatment of IIRS, the methane emission was higher than that of SRS. All the GHGs (CO_2, CH_4 and N_2O) emissions were relatively less in zero tillage (ZT).



Nitrous oxide flux after different treatment imposition



Methane flux after different treatment imposition



Carbon dioxide flux after different treatment imposition

Fig. 2.4. GHGs flux after different treatment imposition in different days interval.

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

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

A field experiments was conducted to study the efficacy of herbicide mixtures and suitable weed control technology by integrating chemical and manual methods in dry direct seeded rice (D-DSR) with cv. CR Dhan 312. The treatments included POST pre-mix Trifamone + Ethoxysulfuraon; POST Trifamone + ethoxysulfuraon followed by (fb) one manual weeding (1MW); POST pre-mix Florpyrauxifen-benzyl + cyhalofop butyl; POST Florpyrauxifen-benzyl + cyhalofop butyl fb MW; PRE Oxadiargyl fb Trifamone + Ethoxysulfuraon; PRE Oxadiargyl fb Trifamone + Ethoxysulfuraon fb 1 MW; PRE Oxadiargyl fb Florpyrauxifen-benzyl + cyhalofop-butyl; PRE Oxadiargyl fb Florpyrauxifen-benzyl + cyhalofop-butyl + 1MW; Oxadiargyl fb bispyribac-sodium with weed free and weedy check. Altogether eleven treatments were evaluated in randomized complete block design with three replications.

Mixed population of grasses, sedges and broadleaved weeds were observed in the experimental plots. Among the grasses, the dominant species were *Echinochloa colona* and *Leptochloa chinensis* contributed together about 39% of total weed population. Major sedges were *Cyperus difformis* and *Fimbristylis miliacea* that contributed 23% of total weed population. Among the broad-leaved weeds, *Sphenoclea zeylanica, Eclipta prostrata* and *Alternanthera philoxeroides* were the major species occupied 28% of total weed population. Other species recorded in the growing season were *Digitaria sanguinalis, Cyperus iria, Phyllanthus niruri* and *Ammannia baccifera*.

The highest yield (5.57 t ha^{-1}) was recorded in weed free check. Among the herbicide treated plots, the highest yield was achieved in the plots treated with pre-mix application of Florpyrauxifen-benzyl + Cyhalofop-butyl (25+125 g ha^{-1}) followed by manual weeding at 40 DAE (5.41 t ha^{-1}) but it was comparable with the treatment of pre-mix application of Trifamone + Ethoxysulfuraon (45+22.5 g ha^{-1}) followed by manual weeding at 40 DAE (5.34 t ha^{-1}). Though, little phyto-toxicity was found in plots of pre-emergence application of Oxadiargyl followed by post application of Trifamone + Ethoxysulfuraon with one manual weeding and pre-emergence application of Oxadiargyl followed by post application of Florpyrauxifen-benzyl + Cyhalofop butyl with one manual weeding, but they were found equally effective as reflected from comparable grain yield with pre-mix application of florpyrauxifen-benzyl + cyhalofop-butyl followed by manual weeding and pre-mix application of trifamone + ethoxysulfuraon followed by manual weeding at 40 DAE (5.28 t ha^{-1}). There was significant reduction in grain yield (47%) due to weed competition in weedy plots over weed free check.

Thus POST application of herbicide mixtures *viz.,* Florpyrauxifen-benzyl + Cyhalofop-butyl or Trifamone + Ethoxysulfuraon at 12 DAE combining with one manual weeding found effective for controlling weeds in dry direct seeded rice. PRE application of herbicide (3 DAE) combining with POST application of herbicide mixture (21 DAE) combining with one manual weeding resulted very good control of broad spectrum of weeds but it showed phyto-toxicity at early vegetative stage that resulted in reduction in yield attributes and finally reflected in yield reduction.

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

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

Mixed population of weed flora including grasses, sedges and broadleaved weeds were recorded in the experimental plots. Among the grasses, *Echinochloa colona* was found to be the dominant weed species at early vegetative while *Leptochloa chinensis* was recorded at late vegetative stage, together contributed about 41% of total weed population in weedy plots. *Cyperus difformis* and *Fimbristylis miliacea* were the major sedges contributed 24% of total weed population. Among the broad-leaved weeds, *Sphenoclea zeylanica*, *Ammannia baccifera, Alternanthera philoxeroides* and *Eclipta prostrata* were the major species occupied 27% of total weed population. Other species recorded in the growing season were *Digitaria sanguinalis*, *Cyperus iria, Marsila quadrifoliata* and *Phyllanthus niruri.*

From the experimental results, it was found that the rice variety, CR Dhan 602 produced significantly higher yield (4.78 t ha^{-1}) i.e., about 16% more than CR Dhan 206 (4.02 t ha^{-1}). It was found that significantly higher yield was obtained in the weed free plots in both the varieties of CR Dhan 602 and CR Dhan 206 i.e., 5.51 and 4.75 t ha^{-1}, respectively. Pre-mix application of Trifamone + Ethoxysulfuraon and Florpyrauxifen-benzyl + cyhalofop butyl combining with mechanical weed control by power weeder produced comparable yield in both the varieties indicating that both the herbicide mixtures are equally effective for controlling broad spectrum of weeds irrespective of rice varieties of different duration in direct seeded rice.

Among the weed control treatments, significantly highest yield (5.22 t ha^{-1}) was recorded in weed free plots. Both the herbicide mixtures *viz.,* Trifamone + Ethoxysulfuraon (Pre-mix) and Florpyrauxifen-benzyl + cyhalofop butyl (Pre-mix) combined with mechanical weed control by power weeder recorded comparable yield so far weed control was concerned. These two herbicide mixtures showed 9% yield enhancement over the recommended practice of early POST application of Bensulfuron methyl + pretilachlor followed by mechanical weed control by power weeder at 35 DAE. There was significant reduction in grain yield due to weed competition in weedy plots over weed free check and it was 44% with rice variety CR Dhan 602 and 48% with rice variety CR Dhan 206.

Thus, establishment of direct seeded rice crop by medium duration variety CR Dhan 602 (125 days) performed better under favourable shallow lowlands than early medium duration variety CR Dhan 206 (110 days). POST application of herbicide mixtures *viz.,* Florpyrauxifen-benzyl + Cyhalofop-butyl or Trifamone + Ethoxysulfuraonat 12 DAE combining with mechanical weed control by power weeder found effective over the recommended practice of early POST application of Bensulfuron methyl + pretilachlor followed by mechanical weed control by power weeder at 35 DAE for controlling broad spectrum of weeds in dry direct seeded rice during wet season.

Sensitivity analysis of barnyard grass (*Echinochloa crus-galli*) as pre evaluation for herbicide resistance

An over-reliance on herbicides has resulted in a huge increase in the number of resistance occurrences in weeds. Despite the threat herbicide resistance poses, not much research has been done in India regarding the monitoring and systematic reporting of herbicide resistance in rice weeds. A study was conducted to evaluate herbicide resistance in *Echinochloa crus-galli* accessions. Four accessions of *Echinochloa crus-galli* (NRRI Farm, Kandarpur, Bargarh and Hubli) were treated with three herbicides (Bispyribac sodium, BPS; Penoxulam, PNX; and Fenoxoprop-p-ethyl, FPE) at five doses of each herbicide - 0X (control), 0.25X, 0.5X, 1X, 2X, 3X, where X being the standard recommended dose of application in the field. The data were analyzed in Split plot design using SAS software.

The results reveal that the Bargarh accession had significantly higher fresh weight, dry weight and plant height, whereas lowest were recorded in Hubli accession. Hubli and NRRI farm accessions recorded the highest herbicide damage to the extent of 76.94% and 76.59%, respectively. The herbicide efficacy for Bargarh accession followed the order: BPS>PNX>FPE indicating that the FPE is least effective among the tested herbicide. NRRI farm accession and Kandarpur accession recorded herbicide efficacy in the following order: FPE>PNX>BPS indicating that two accessions are likely to develop resistance against BPS. The Hubli accession was highly sensitive to all the tested herbicides and, it may be inferred that the accession is unlikely to develop resistance in near future to the tested herbicides. It may be concluded that among the tested accession, the Bargarh accession was only controlled by the bispyribac sodium and showed least susceptibility to the other herbicides. It may be concluded that this accession is likely to develop resistance in future if proper strategy *viz.,* herbicide rotation, crop rotation/ diversification, IWM is not followed.

Harnessing microbiome for enhancing rice productivity and improving soil health

Study the effect of AM fungi on different aerobic rice under different levels of soil P

This experiment was conducted with following selected aerobic varieties *viz.,* CR Dhan 201, CR Dhan 204, CR Dhan 205, CR Dhan 207 with P tolerant (Kasalath IC 459373) and susceptible (IR 36) checks under low (2.68 ppm), medium (8.81 ppm) and high (12.84 ppm) P levels of soil. The results indicated that application of AM fungi significantly increased total root length (cm), surface root area (cm^2), projected root area (cm^2), root volume (cm^3) and number of root tips (nos), per cent root colonization, uptake of P in most of the varieties under low soil P as compared to high P soil. The mycorrhizal responsiveness was found superior in CR Dhan 201 followed by CR Dhan 207. Among the different P transporter genes *OsPT*11 had differential pattern of gene expression across different levels of P, whereas *OsPT*13 showed proportionate decrease with an increase in P level in CR Dhan 207 and Kasalath IC 459373. Among all the varieties the higher expression of phosphate starvation response gene (PHR2) was observed in CR Dhan 201 followed by CR Dhan 204 and CR Dhan 207 under low soil available P condition.

Evaluation of *B. thuringiensis* against rice leaf folder under field condition

Two liquid formulations of *B. thuringiensis* (NRRI-CPD-BIOCB7 and NRRI-CPD-BIOCB8) were evaluated against rice (TN 1 variety) leaf folder for last three years (2020, 2021 and 2022) under field condition. It was found that the biocontrol potential of both strains were significantly at par with chemical spray for controlling leaf folder and enhancing yield as compared to un-inocualted control. Based on three years of field evaluation, Bt (NRRI-CPD-BIOCB8) has been included AICRP, Bio-control, NBAII, Bengaluru for further validation under different ecological regions.

Tech NRRI Decomposer for *ex-situ* decomposition of paddy straw

It is carrier based formulation containing two efficient ligno-cellulolytic fungi and one actino-bacterial strain and systematically validated for *ex-situ* decomposition of paddy straw. Application of 1.0 kg of Tech NRRI decomposer with 0.5% (w/w) urea with 1.0% (w/w) cow dung maintaining 55-60% moisture content in composting pile could decompose (CN ratio 16:1 to 19:1) paddy straw (one ton) within 45-50 days under *ex-situ* condition. This technology has been released for commercialization.

Homology modeling and in silico characterization of cytochrome c nitrite reductase (NrfA) in three model bacteria responsible for DNRA

In silico modeling of NrfA was analyzed in three model DNRA bacteria (*Escherechia coli, Wolinella succinogenes* and *Shewanella oneidensis*) (Fig. 2.5). *In silico* analysis showed four number of highly conserved Cys-X1-X2-Cys-His motif and one C-X1-X2-C-K haem-binding motif in NrfA. Eleven identical conserved amino acids sequence was identified between serine and proline in NrfA. The alpha helix in NrfA dominated in *E. coli* due to higher abundance of alanine core. Ramachandran plot revealed that Modeller was the most acceptable *in silico* pipeline for NrfA.

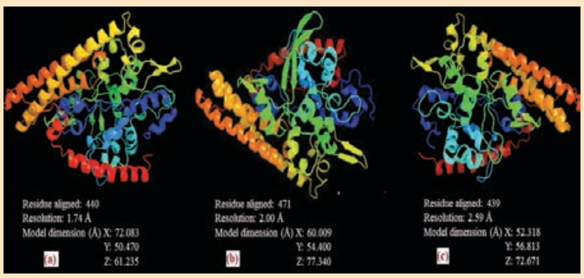


Fig. 2.5. NrfA protein model through Phyre2 server (confidence and identity 100%) of three dissimilatory nitrate reduction to ammonium (DNRA) bacteria, a. *Escherechia coli* (1GU6), b. *Wolinella succinogenes* (1FS9), and c. *Shewanella oneidensis* (3UBR). Rainbow image appeared in this figure represents N→C terminus.

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

Optimization of extrusion process parameters for the development of fortified rice extruded products

A Twin-screw extruder is to be used in the development of rice based extruded products. Optimization of extrusion process parameters especially the barrel temperature, screw speed and also the moisture content of the formulation were optimized to develop extruded products with good quality characteristics. Optimization was done based on the functional properties i.e., expansion ratio, bulk density, hardness and its physical dimensions. Factorial design was used to optimize these parameters. Numerical as well as graphical optimization was also carried out to optimize the process parameters. The optimization was carried out under certain applied constraints. The optimized conditions were also validated. From the results, it was observed that the barrel temperature was 115°C, screw speed was 350 RPM and moisture content was 5%.

Optimization of formulation of fortified extrudates with better functional properties and protein content

Optimization of formulation of extrudates fortified with maize and dal flour was done with the aim of improving its nutritional profile especially protein content with similar functional properties as obtained from the control sample. The parameters studied were: thickness (cm), breadth (cm), degree of expansion, bulk density, water absorption index, water solubility index, hardness, protein content and color values. Rice varieties varying in amylographic properties were taken and fortified with protein sources to improve its nutritional profile were studied. The result showed that among the parameters, analysed protein content and hardness was found to be significant for both the formulations (rice with maize as well as rice with dal).

Nutritional and proximate analysis of rice based products developed by hydrothermal treatments

Effect of pasting properties of rice flour on the functional properties of rice noodles

The different pasting properties of the fortified rice noodles were studied and compared with the nutritional properties of vegetable fortified rice noodles. The range of final viscosity was varied from 3842 to 5719 cP. It was found that the fortified rice noodles with improved nutrients were found to be harder than the market samples.

Development of low GI ready to cook rice products

Optimization of the levels of ingredients for the development of rice noodles fortified with vegetable powder

Swarna variety was taken for the study, while carrot powder as a source of vitamins and minerals were taken. Additional ingredients such as maize flour and hydrocolloid were used as a source of protein and also to give the binding property to the noodles.

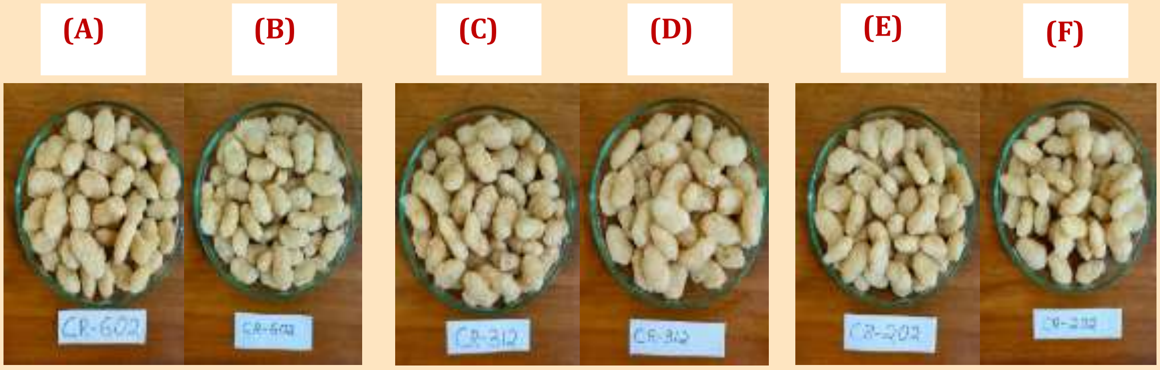


Fig. 2.6. (A-F): Rice extrudates fortified with maize and dal.

Fig. 2.7. Rice pasta fortified with vegetable powder.

Fig. 2.8. Fortified rice noodles (A). Beetroot, (B). Moringa, (C). Carrot

So optimization of these ingredients with respect to the functional properties like optimal cooking time, cooking yield, cooking loss and water uptake ratio were done. Formulations proposed by the software were run with 3 replications. Among the cooking quality parameters studied, optimal cooking time ranged from (5.1 to 7.5 min), cooking yield from (190-280%), cooking loss from (2.1 to 5.5%) and water uptake ratio (0.9 to 1.9%). Based on the sensory score, rice pasta incorporated with the optimized levels of carrot powder, maize flour and hydrocolloid were tastier and highly preferred with high overall acceptability in comparison with other formulations based on the sensory score.

Analysis of nutritional and functional properties of fortified rice noodles

Three rice varieties namely Swarna, CR-Sugandha Dhan and Lal Basanna were taken for the development of rice fortified noodles. Three vegetables namely carrot, moringa and beetroot were used for the study. All the vegetables used were purchased from market and processed in lab. Different combination of formulations was studied. Levels of the ingredients were optimized with respect to the functional quality characteristics of the developed noodles. The nutritional analysis of the optimized formulations showed that the protein content ranged from 5-9%, iron content was about 37 ppm in the moringa incorporated noodles, zinc content about 46 ppm, sugar about 53 mg/g and antioxidant activity of 88% inhibition.

Enhancing water use efficiency in rice based cropping system

Identification of optimum soil water potential for enhancing water productivity in rice varieties under changing climate scenario

A field experiment was conducted using split plot design with six irrigation treatments as main plot and six rice varieties as sub plot treatment. The different irrigation treatments were: (a) fully irrigated condition as the control, (b) re-irrigation at -20 kPa soil water potential (SWP), (c) re-irrigation at -30 kPa SWP, (d) re-irrigation at -40 kPa SWP, (e) re-irrigation at -50 kPa SWP, and (e) re-irrigation at -60 kPa SWP and different varieties under examination were V_1 = DRR Dhan 44, V_2 = Swarna Shreya, V_3 = IR 64, V_4 = CR Dhan 801, V_5 = CR Dhan 802, V_6 = Swarna. Under different soil water potential based irrigation treatments, there was a significant saving in irrigation water ranging from 20 – 57% as compared to continuous flooded condition (Fig. 2.9). Under moderate stress (-40 kPa), the decline in grain yield varied from 21-35% in introgressed varieties but for non-introgressed varieties the yield decline was up to 60%. However, under severe stress (-60 kPa), the decline in grain yield for introgressed varieties varied from 47-51% but for non-introgressed varieties the yield decline varied from 77-82%.

In all the varieties, tiller number and fertile grains per panicle decreased as the level of stress increased, however the quantum of decrease was more in susceptible varieties as compared to tolerant varieties. Water productivity of varieties introgressed with drought QTL was 39-60% higher when irrigation scheduling was done at -40 kPa soil water potential as compared to continuous flooded condition.

The effect of different levels of water deficit stress on activity of osmolyte like proline and antioxidant enzymes like peroxidase and catalase was also studied. We recorded a significant difference in the activity of osmolyte (proline) and antioxidant metabolites (peroxidase and catalase) activities under different treatments. The activity of all the antioxidant enzymes and osmolytes increased with increase in the level of water deficit stress in all the genotypes and highest activity of the metabolites were recorded under -50 and -60 kPa. Among different growth stages, highest activity of these metabolites was recorded under heading stage. At all the growth stages, the activity of osmolytes and antioxidant metabolites was highest for varieties introgressed with drought QTLs as compared to the varieties having no drought QTL.

Evaluation of efficacy of different soil amendments under water limited conditions for enhancing crop and water productivity

The effect of different soil amendments like biochar, fly ash and steel slag on plant growth and yield was tested under moisture deficit condition. Addition of biochar, fly ash and steel slag either alone or in combination has the ability to arrest the yield decline under WDS (-40 kPa). The main reason of increased grain yield was significant increase in filled grains per panicle and test weight.

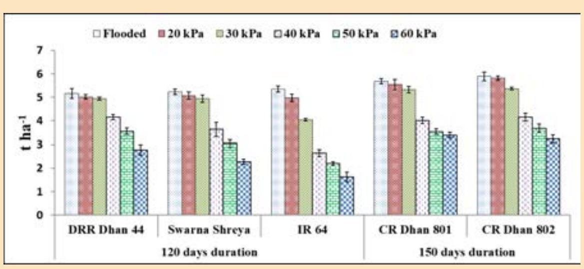


Fig. 2.9. Grain yield of different rice varieties under different levels of soil water potential.

Evaluating the water productivity of prominent rice cultivars under variable moisture regimes with drip irrigation system and residue mulching

A field experiment was carried out at the research farm of ICAR - National Rice Research Institute, Cuttack, India to identify rice varieties with higher water productivity under drip irrigation system. The experiment was laid out in split-split plot design. The main plot treatments consisted of 2 irrigation regimes i.e. irrigation at -10 kPa and irrigation at -30 kPa, two moisture conservation techniques i.e. rice straw mulch @ 4 t ha^{-1} and no mulch were used as sub plot treatments. In the sub-sub plot treatments, there were six rice varieties i.e. three stress tolerant/aerobic varieties *viz.,* Sahbhagidhan, CR Dhan 200, CR Dhan 205 and three irrigated varieties DRR 44, MTU 1010 and CR Dhan 304. All the treatments were replicated twice. The soil in the experimental plot was clayey and moderately fertile. The crop was fertilized with a uniform dose of 80: 40: 40 N, P_2O_5 and K_2O kg ha^{-1} with a spacing of 15 x 15 cm. Each plot was irrigated with 50 mm of water through PVC pipe at five days of interval to avoid any water deficit during crop establishment up to 15 days after sowing. After that irrigation was given based on the Tensiometer readings as per treatments till maturity.

Grain yield was measured at 14% moisture from a net plot leaving border rows and converting to per hectare yield. Significantly higher grain and straw yield was obtained with straw mulching and irrigating the rice crop at -10 kPa. Aerobic moisture regime of irrigating the crop at -30 kPa increased the grain yield by 14.3% compared to near saturation regime. Grain yield of rice was increased by 8.9% with straw mulching. Highest grain yield was recorded with variety CR Dhan 304 followed by DRR 44 and CR Dhan 205. Highest water productivity of 0.53 kg m^{-3} was achieved with the variety CR Dhan 205 followed by DRR 44 (0.49) and CR Dhan 200 (0.49). Irrigating the crop at -30 kPa increased the water productivity by 28.6% compared to - 10 kPa. Straw mulching increased the water productivity of rice by 13.6% compared to non-mulched plots.

Different research activities undertaken through Crop Production Division could identify nano-clay polymer composites for smart delivery of phosphate fertilizers. A cost effective method for synthesis of Silica nano particle from rice husk was developed. Prioritization matrix for components of farming system model was prepared using expert system/models. An effective prediction model was established via random forest model and described the accumulation of As by rice grains depend on bioavailable As, P and Fe which explained 48.5, 5.07 % and 2.6% of the variation in the grain As, respectively. The effect of system based phosphorus management on yield of rainfed rice – green gram cropping system was studied and it was found that highest system grain yield (9.0 t ha^{-1}) was recorded with RDF + 25% additional P from FYM to rice followed by RDF + PSB application + DAP foliar spray to green gram in a rice - green gram cropping system. A carrier based formulation (NRRI decomposer) containing two efficient ligno-cellulolytic fungi and one actino-bacterial strain was systematically validated for *ex-situ* decomposition of paddy straw.

PROGRAMME-3

Biotic Stress Management in Rice

Primary objective of the Crop Protection Division is to provide strategies for controlling rice pests to the various stakeholders. The division is currently focusing on identification of donors for multiple pest resistance, pest population dynamics under changing climate scenarios, identification of key chemicals or mechanisms in the interaction between hosts, pests, and natural enemies, the use of new tools for pest monitoring and forecasting, and identification of new management tools utilising existing pesticide molecules and natural resources. The division is prescribing Good Agricultural Practices (GAP) through Integrated Pest Management (IPM) tools.

A Patent filed on "Efficient portable insect collector with automated counter (Application number: 202211047342)"

The product is an insect collector, and more specifically, relates to a hand-held battery-operated insect collector (Fig. 3.1). It is a compact apparatus with minimum accessories and enables collection and counting of insects. The apparatus is portable and consumes less energy and time. There are enough safeguards for the health of user involved while collecting the moths.

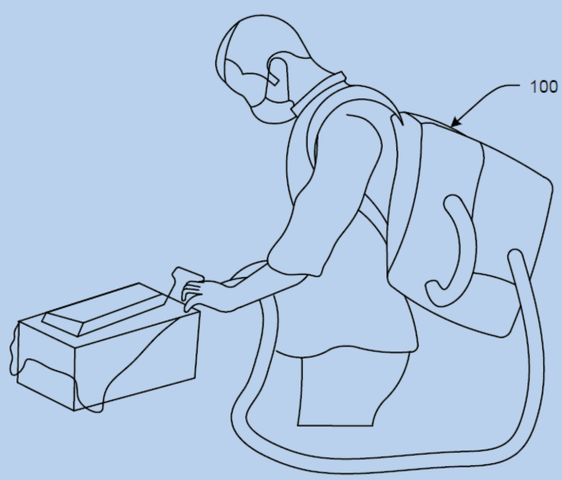


Fig. 3.1. Diagram of the apparatus

Identification and characterization of donors against biotic stresses

Identification of new source of resistant donor against Brown Plant Hopper (BPH) and White Backed Plant Hopper (WBPH)

Out of 188 genotypes screened against BPH & WBPH under controlled conditions, only one genotype (IC 342366) was moderately resistant (score 3) against BPH. Whereas, three genotypes (IC 465314, IC 323789, IC 342366) were moderately resistant (score 3) against WBPH. Entries through AICRIP screening namely, IC 322922, IC 75881, IC 426149, IC 426139, IC 256515, IC 273558, IC 426148, IC 426126, IC 256545, IC 346890 were resistant (score 1) to BPH. Seventeen gene differentials evaluated under planthopper special screening trial (PHSS) of AICRIP, only two differentials *viz*., PTB 33 (*with bph2+Bph3+unknown factors*) and RP 2068- 18-3-5 (*Bph33(t) gene*) were found promising with 1 score (resistance) against Cuttack BPH populations.

Population structure and genetic diversity of BPH, *Nilaparvata lugens* (Stål.) in India

Twenty-two *N. lugens* populations collected from 22 hotspot regions of India and diversity was studied with simple sequence repeats (SSR) markers. Results revealed that mean genetic diversity was 0.319 and polymorphic information content (PIC) was 0.270 in the 30 selected SSR markers. In cluster and population structure analysis, all the 22 population were sub-grouped into three groups. Interestingly, north and west Indian population showed high genetic similarity and assembled into one cluster. The east and south Indian populations were evenly segregated into rest two clusters. Similarly, north and west Indian population occupied separate compartment in Principal coordinate analysis (PCoA). This variation could be associated with the *N. lugens* migration due to wind movement of south-west monsoon in two branches viz. Arabian sea branch and Bay of Bengal branch.

Genome-wide association analysis of NRRI Rice varieties for gall midge resistance

A study of 92 NRRI rice varieties with 274 markers (210 candidate gene markers and 64 random rice SSR markers) revealed that the allelic diversity of these markers was ranged from 0.00 to 0.94 and major allele frequency was ranged from 0.14 to 1.00 (Fig. 3.2). The ΔK value was 2 and observed two subpopulations, largest sub-population consisted of 68 individuals while the smallest subpopulation had 24 individuals. On chromosome 12, one putative gene for gall midge resistance was identified, which is associated with marker RM28564.

Phenotyping for Yellow Stem Borer (YSB) resistance and elucidation of basis of resistance

Salkathi, PTB-33, TKM-6 along with 16 other varieties had consistent level of resistance at vegetative stage against YSB. The silica content of these varieties was significantly and negatively correlated with the dead heart damage. Salkathi, with the lowest dead heart damage, recorded the highest silica content. Thus, silica content may have influence on the resistant character of a variety in the seeding stage against rice yellow stem borer.

Identification of varieties resistant to leaffolder, Cnaphalocrocis medinalis

Out of 40 Assam Rice Collections (ARC) genotypes, 7 genotypes *viz.,* ARC 10416, 10884, 10960, 10827,

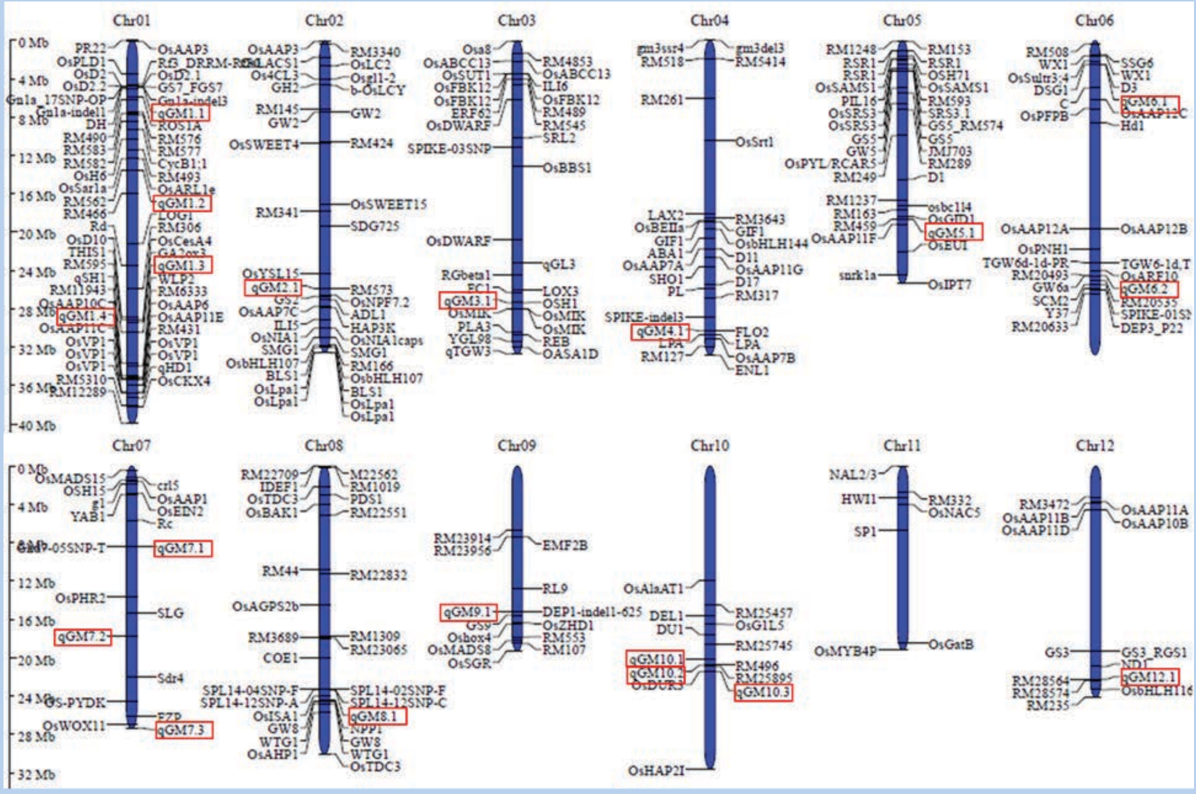


Fig. 3.2. Distribution of markers over all the 12 rice chromosomes.
The colored boxes represent identified QTL for gall midge resistance.

10342, 10281 and 10317 were found resistant and 11 genotypes namely, 10753, 10878, 10446, 11651, 446, 139, 12768, 10471, 10857, 10392 and 10451 were found moderately resistant to *C. medinalis*.

Phenotyping for sheath blight (causal organism, Rhizoctonia solani) disease resistance

Sixty-six NRRI, 40 OUAT released varieties, 53 Assam Rice Collections, 12 New Generation Rice lines and 10 Double Haploid lines were screened for resistant to *R. solani* and 8, 3, 4, 2 and 2 entries, respectively were found as moderately resistant. A total of 338 NSN1, 571 NSN 2, 112 NHSN, 114 NSN-H and 229 DSN entries were screened under AICRIP-Plant Pathology Trials to check the resistance against sheath blight disease, and 9 entries of NSN 1, 14 NSN2, 3 NHSN entries, 4 NSN-H and 6 DSN entries were found moderately resistant.

Genetic diversity of Rhizoctonia solani (AG1-IA) isolates using ISSR primers

Genetic diversity among twenty *Rhizoctonia solani* isolates was determined using 11 ISSR primers. A total of 35 bands were produced, and all these bands were polymorphic in nature. The gene frequency of these loci varied between 0.65 and 0.94. All the isolates were clustered into four groups, Group A had three isolates SHR-2, SHR7, SH13; Group B had 11 isolates, namely SHR12, SHR17, SHR22, SHR26, SHR28, SHR31, SHR36, SHR30, SHR18-1, SHR32-1, SHR32-2, SHR34; Group C included two isolates SHR-10, SHR-11; and SHR-3, SHR8 and SHR14 were included in group D.

Screening for resistant donor to False Smut (Ustilaginoidea virens) and Sheath rot (Sarocladium oryzae) pathogens

Twenty-four promising ARC accessions (selected from previous years of screening) were grown for screening against *U. virens (FSm)* and *S. oryzae* (*ShR*) under artificial inoculation conditions. Six (ARC-5786, 5982, 6006, 6596, 6606, 6609) and 11 (ARC-5769, 5776, 5786, 5937, 5982, 6006, 6596, 6609, 6628, 7048, 7085) accessions were found highly resistant (score 0) against FSm and ShR, respectively. ARC-5786, 5982, 6006, 6596, 6609 were resistant to both FSm and ShR diseases. IET 29511, 28789 (R), 27077 (R), 29430, 28017, 29356, 29246, 28366, 28631, 29256 entries of NSN1 were resistant to ShR disease at NRRI and across India. VPD2, VPD10, RP-Bio Patho -4, CB17135, 251-3-3-2, MS-ISM-DIG-8, VPD6, NPK83, RNR 39025 of DSN entries were resistant to ShR disease at NRRI and across India.

Multiple disease resistant entries

Analyzing the data from NSN1 and DSN entries, following entries were found resistant to more than one diseases like sheath blight (ShB), sheath rot (ShR), leaf blast (LB), neck blast (NB), bacterial blight (BB) and rice tungro disease (RTD): IET 28366 (ShB & ShR), 29268 (LB & ShR), 29356 (ShR & RTD) and 29430 (LB & ShR), 251-3-3-2 (BB & ShR), RNR 39025 (LB & ShR), RP Bio Patho-4 (LB, NB & ShR), VPD10 (ShB & ShR) and VPD5 (ShB & ShR) at NRRI and across India.

Evaluation of farmer's rice varieties for slow blighting characters

Out of 145 farmers' rice varieties screened for slow blighting characters both under laboratory (detached leaf and tiller method) and field conditions, 7 varieties found to have slow blighting characters. These lines possess maximum incubation period, least number of sclerotia/plant, long duration to form sclerotia, least vertical disease spread (%), and least AUDPC and apparent infection rate. They performed better than susceptible check Tapaswini and TN-1.

Evolutionary dynamics of rice tungro disease (RTD) causing virus

The field survey conducted during *kharif* season (2020) at experimental farm of ICAR-NRRI, Cuttack revealed widespread occurrence of tungro-like symptoms and occurrence of both RTBV and RTSV viruses were confirmed through PCR and RT-PCR assays. Most of the tungro isolates from eastern India, including Cuttack isolate, have been collected and characterized ten years back during 2010-11. Sequence comparison showed 97.0-98.0% nucleotide identity with previously reported Indian isolates (South Asian isolates). RTBV-Cuttack showed only 69-70% identity with South-East Asian isolates reported from Philippines, Thailand, Malyasia. The phylogenetic tree obtained after alignment of the nucleotide sequences of genomic DNA showed a distinct separation between RTBV isolates from southeast Asian (SEA) and south Asian (SA) type by forming two major clusters, RTBV-Cuttack clustered within South Asian group (Fig 3.3).

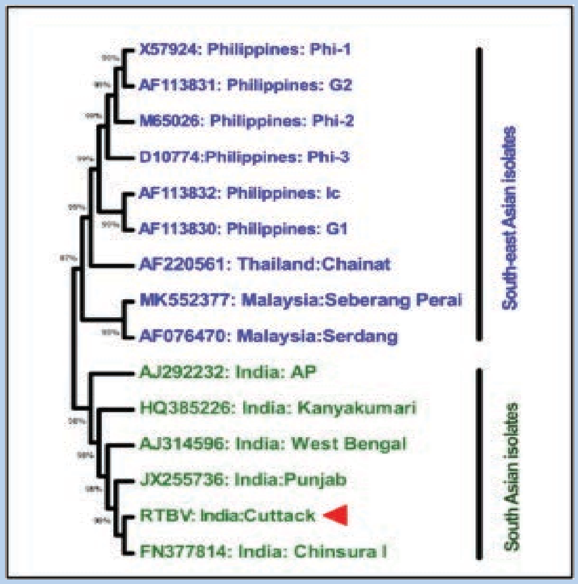


Fig. 3.4. Phylogenetic tree showing clustering patterns of RTBV viruses from SEA and SA countries.

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

Community structure of various hymenopteran parasitoids under different rice ecologies

Explorations were done in the Cuttack district to study the association of parasitoid species with the paddy crop. The parasitoid species, *Brachymeria excarinata* Gahan, 1925 (Hymenoptera: Chalcididae) was recorded for the first time from rice growing areas as hyper-parasitoid of *Charops bicolor*, a larval parasitoid of paddy yellow stem borer, *Scirpophaga incertulas.*

Biochemical changes in the BPH induced rice plants under salinity and moisture stress

Brown plant hopper (10 per hill) infested rice plants (var. Tapaswini) subjected to different abiotic stresses i.e. moisture stress @ 60KPa and salinity stress @ 8 dsm/m were analyzed for volatile compounds released and plant enzymatic patterns. The BPH suppressed leaf enzymes (peroxidases, superoxide dismutase and catalase) during tillering stage, and the suppression of enzymes was higher in salinity stressed plants than moisture stressed plants. Similarly, less population of BPH (2 per hill) on salinity stressed plants was recorded than moisture stress rice plants (4 per hill) and the normal plants recorded high population of BPH (10 per hill) indicating that BPH survived more in irrigated conditions than moisture stress conditions whereas, under saline conditions, the BPH couldn't reproduce successfully.

Fate of potassium silicate and chitosan application on rice plants at different temperature

The application of elicitors' potassium silicate and chitosan shown lesser dead heart damage caused by rice yellow stem borer (YSB) in TN-1 susceptible rice variety. The efficacy of these elicitors was tested at different temperatures *viz.*, 27 and 37 ºC. It was found that application of potassium silicate and chitosan improved superoxidase (SOD), peroxidase (PO) and catalase (CAT) activities and its gene expression level. Application of these elicitors could be a viable eco-friendly management option against YSB.

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

Identification of sensitive bands for brown planthopper in rice using hyperspectral remote sensing

Field experiments were carried out during the *rabi* season in an experimental rice field at ICAR-NRRI research farm. Different damage levels (Level 5, 7, 9 in Taichung Native 1) of brown plant hopper (BPH) infestation were created in 45-days old rice seedlings (Fig 3.4). Combination of derivative approach of continuum removal (CR) using ENVI software package, and sensitivity analysis (SA) were used to identify peaks and dips in the sensitive region. A dip was identified at 543 nm (SA) and a peak at 670 nm (both for SA and CR). Six bands 519, 543, 670, 718, 786 and 812 nm were found sensitive to BPH damage. The variation in carotenoid and anthocyanin content were correlated with the sensitive spectral bands. It was found that 519 and 543 nm showed higher correlation with carotenoid and 670 nm showed higher correlation with anthocyanin content. The band at 718 nm in the red edge region was most responsible for change in Leaf Area Index (LAI). Bands at 786 and 812 nm were neglected to avoid the noises from higher wavelengths. Out of all the machine learning algorithms, the RELIEFF algorithm showed best accuracy results when combination of sensitive bands was done. Bands at 519, 670 and 718 nm gave maximum accuracy of about 83.66 percent, which indicates that the green, red and red edge region, were mostly responsible for the detection of BPH in rice.

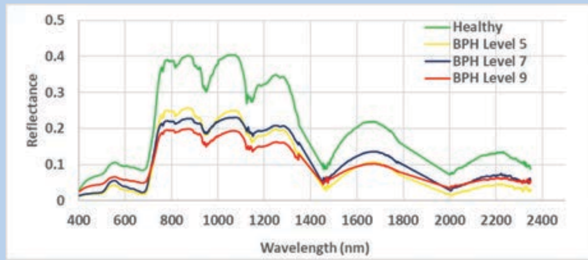


Fig. 3.3. Spectral signature of Healthy vs BPH at different damage level.

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

Mechanism of biocontrol and growth promotion in rice by Trichoderma sp.

Transcriptomics analyses was performed to unravel the mechanism of biocontrol and growth promotion by *Trichoderma* in Naveen treated with *Trichoderma erinaceum* (NRRI-T2). The RNA Seq profile revealed that 16486 genes were expressed in both the treated and untreated plants, whereas 654 and 690 genes were expressed only in control and the treated one, respectively (Fig 3.5). A total of 111 genes were showing upstream expression in treated plants and 167 genes were showing down stream expression (Fig 3.6). Functional Enrichment Analysis (KEGG Pathway) showed (i) up regulation of Plant-pathogen interaction, alpha-Linolenic acid metabolism, Nitrogen metabolism, Phenylalanine metabolism pathway genes; (ii) down regulation of Plant hormone signal transduction, Monobactam biosynthesis, Lysine biosynthesis pathway genes.

Denovo sequencing of Trichoderma erinaceum (NRRI-T2) showed the following observations:

The number of unique genes predicted by Glimmer HMM were 18815. Tandem Repeat Finder identified 5532 micro/mini satellite loci which is 1.53% of the genome. The results are similar to that of previous studies indicating the scarcity of transposable elements in *Trichoderma* genomes. Protein prediction for the identified genes with Blast2GO Pro version 5.2.5 resulted in 13,877 genes (74%) and 1219 genes being mapped to proteins of which 62 (5%) were mapped to predicted proteins and rest 95% were annotated. From these top hits, proteins were mapped onto 44 different fungal species including 10 species of *Trichoderma*. A total of 1182 genes were mapped to fungal proteins and rest to

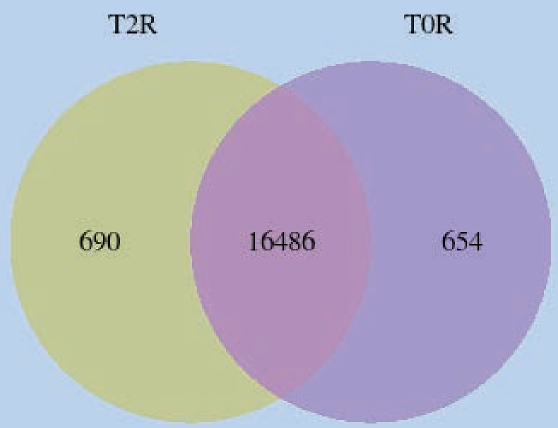


Fig 3.5. Genes expressed exclusively in treated (T2R) and control plants (T0R).

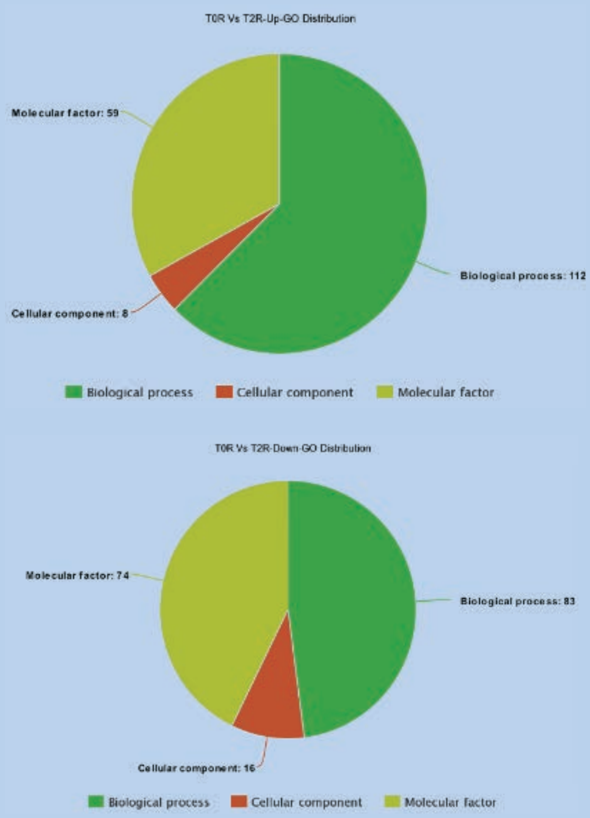


Fig 3.6. Distribution of differentially expressed genes as per their functional categories.

non-fungal proteins. The maximum number of hits were mapped to *Trichoderma gamsii* (53%) followed by *Trichoderma atroviride* (25%).

Comparative proteomic analysis for Rhizoctonia solani isolates and validation

A quantitative LC MS/MS-based proteomic analysis of *R. solani*, the sheath blight pathogen, was performed to identify the differentially expressed proteins that promote virulence. The isolate, RS15 of *R. solani* was found to be the most virulent and RS22 was identified as a less virulent isolate. A total of 48 differentially abundant proteins were observed in the virulent isolate; out of which 27 proteins were with higher abundance and 21 proteins with lower in abundance in the virulent isolate. Quantitative Real-Time PCR (qRT-PCR) was used to validate changes in differentially expressed proteins at the mRNA level for selected genes. The abundances of proteins and transcripts were positively correlated.

Elucidation of salicylic acid/ROS signaling components during Oryza sativa-Xanthomonas oryzae pv. oryzae interaction

Detailed elucidation of oxidative burst and anti-oxidative mechanisms on time scale has been performed during rice-elicitor/pathogen interaction in 5 rice cultivars, *viz.,* TN-1, Shatabdi, Naveen, Annapurna and Tapaswini against two elicitors (Salicylic acid, SA and Chitosan, CH) and bacterial blight pathogen *Xanthomonas oryzae pathovar oryzae* (Xoo). The H_2O_2 concentration were higher in Shatabdi when plants were treated with salicylic acid as well as Xoo. In case of Superoxide Dismutase (SOD) along with SA and Xoo chitosan also showed the similar expression level. Similar result was obtained when phenolic content was compared.

Elucidation of mating type of Fusarium fujikuroi species complex and genetic diversity analysis using ISSR/URP markers

Twenty isolates of *Fusarium* spp. were subjected for MAT analysis using specific primer sets (Gf-MAT-1 & Gf-MAT-2). Ten *Fusarium fujikuroi*, six *Fusarium proliferatum*, one *Fusarium verticilloides* and three *Fusarium sacchari* isolates were taken for the study. The results indicated that, out of ten *Fusarium fujikuroi* isolates, seven were belonged to MAT-1 and three to MAT-2 (Table 3.1). Similarly, out of six *F. proliferatum* isolates, two belonged to MAT-1 and rest four to MAT-2 group. Whereas, MAT primers could not detect any mating type in *F. verticilloides* and *F. sacchari.*

Population structure analysis was done to understand the genetic relationship among these 20 *Fusarium* isolates based on ISSR and URP markers data by using STRUCTUREv.2.3.4; a model-based population structure analysis program. The K= 3 separated the total 20 isolates into one larger cluster with nine

Table 3.1. Distribution of mating types among the putative *Fusarium* isolates.

Sl. No.	Species	MAT-1	MAT-2
1	*Fusarium fujikuroi*	7/10	3/10
2	*Fusarium proliferatum*	2/6	4/6
3	*Fusarium verticilloides*	ND/1	ND/1
4	*Fusarium sacchari*	ND/3	ND/3

isolates and two smaller cluster containing 6 and 5 isolates, respectively. The grouping of isolates based on location of their collection indicated their non-structured distribution across geographical locations with respect to pathogenicity and genetic diversity.

Molecular characterization of hymenopteran parasitoids associated with paddy leaf folder

DNA barcodes of 4 species of parasitoids using mt COI were generated and submitted to NCBI to confirm their identity at molecular level at various taxonomic levels. The species belong to three families *viz.,* Ichneumonidae, Braconidae and Eulophidae. Accession numbers of submitted parasitoids are *Xanthopimpla flavolineata* (OK314995), *Telenomus dignus* (MZ816950), *Cardiochiles philippinensis* (OM967485) and *Tetrastichus schoenobii* (ON007280).

Plant protection molecules: efficacy, distribution, toxicity and remediation

Biosynthesis of silver nanoparticle using fungal and bacterial extracts for controlling sheath blight disease of rice

Metallic nanoparticles like silver nanoparticles (AgNP) are known to have antimicrobial potential and could control *Rhizoctonia solani*. Silver nanoparticles were synthesized using extracts of fungus, *Aspergillus niger* and bacterium, *Pseudomonas fluorescens*. The UV-Vis spectrometry showed maximum absorption at 435 and 432 nm for fungal and bacterial synthesized AgNPs, respectively, confirming the synthesis of AgNPs. Dynamic light scattering (DLS) analysis showed that the fungal and bacterial synthesized AgNPs were having particle sizes of 42 nm and 74 nm, respectively. In laboratory conditions, 50 ppm concentration of AgNPs could inhibit 73.52% growth of *R. solani*. Application of 50 ppm concentration of AgNPs had least disease index (25.93%) in the *in-vitro* assay and the treatment was superior in all the morphological and yield attributes of rice crop (Fig 3.7).

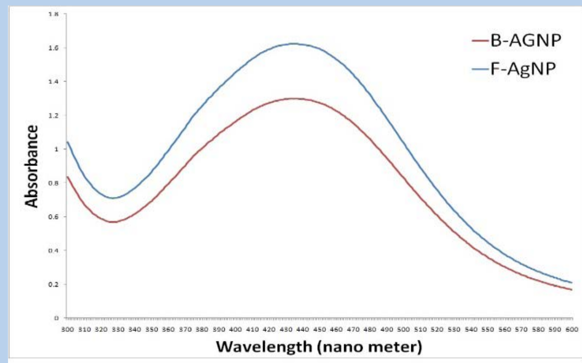


Fig 3.7. UV-Vis spectrum of fungal (F-AgNP) and bacterial (B-AgNP) extract synthesized silver nanoparticles.

Relative toxicity and resistance ratio of Sitophilus oryzae populations against phosphine

The main destructive stored grain pest in India is rice weevil (*Sitophilus oryzae)*. However, frequent and acute or chronic doses of phosphine exposure led to the development of genetic and morphological resistance to the insect. Except Jagatsinghpur (RRC, Erasama), other 11 populations were found to be resistant to phosphine. The laboratory population had a LC_{50} value of 0.004 mg/L. Population from Chhata (Kendrapara) had a LC_{50}value of 0.038 mg/L, and it was 9.50-fold more resistant in comparison with the laboratory population.

Effects of sublethal phosphine fumigation on Corcyra cephalonica and response of parasitoid, Habrobracon hebetor

Hormesis is well documented in pest insects, but for natural enemies of pests, limited efforts have been made. The study reports the consequences of sublethal (LC_5), low lethal (LC_{25}), median lethal (LC_{50}) of phosphine and untreated control for two continuous generations (G1 to G2) on rice moth, *Corcyra cephalonica* (Stainton) (Lepidoptera: Pyralidae). Stimulatory effects were observed for different biological traits of *C. cephalonica* like the adult duration, oviposition days, moth emergence, and increased egg hatchability when exposed to LC_5 of phosphine. The total protein, lipid, and carbohydrate contents of *C. cephalonica* were also found to be significantly influenced by LC_5 in both generations. GC-MS characterization of larval body volatile profile revealed 10, 16, 10 and 15 compounds specific to LC_5, LC_{25}, $LC_{50,}$ and untreated control treatments, respectively. Parasitoid, *H. hebetor* made the significant number of entries towards larval body extract and spent the highest time when compared to untreated control for all the treatments. The microbial diversity of LC_5 treated larval gut was higher and found to be different from the rest of the treatments (Fig 3.8). This is the first study to show that hormesis to fumigant insecticide. Overall, the present study comprehensively establishes the mechanisms and demonstrated phosphine-induced hormesis at LC_5 in the host *C. cephalonica*, which might help improve the quality of mass rearing of the parasitoid *H. hebetor*.

Monitoring of Pesticides in small streams adjacent to paddy fields of Odisha

High intensity of rainfall coupled with the uncertainties due to vagaries of monsoon, could play a crucial role in causing non-point pesticide pollution of small streams adjoining the paddy fields through run off and leaching. Therefore, the present work was planned to study the spatio-temporal variability of pesticides in small streams. Sixteen pesticides were detected with a detection frequency of 20 per cent and above. Pretilachlor was the most frequently detected pesticide (80%) followed by Tricyclazole (60%). Pesticide found with the maximum concentration was Thiamethoxam followed by Triflumezopyrim.

Dissipation of Tetracycline and Streptomycin from rice soil

Bacterial Leaf Blight in rice caused by *Xanthomonas oryzae pv. oryzae* can be controlled by an antibiotic, Streptocycline, a mixture of Tetracycline (10%) and Streptomycin (90%). Applied antibiotics may enter into soil and interfere with the natural microbiota. Antibiotics were extracted from soil samples and were quantified in liquid chromatography- mass spectroscopy (LC-MS). Tetracycline residues existed in soil up to 9 days in half the recommended dose (HRD at 75 mg L^{-1}) & 14 days in recommended dose (RD at 150 mg L^{-1}) and double the recommended dose (DRD at 300 mg L^{-1}) treatments. Streptomycin residue decreased from 57.6 µg kg^{-1} to 14.9 µg kg^{-1} in HRD on day-14, 108.2 µg kg^{-1} to 13.5 µg kg^{-1} in RD on day-21 and 223.4 µg kg^{-1} to 14.7 µg kg^{-1} in DRD on day-30 of the experiment. The results suggested that application of antibiotics in rice may not cause residue build-up over long run. We found adverse impact of

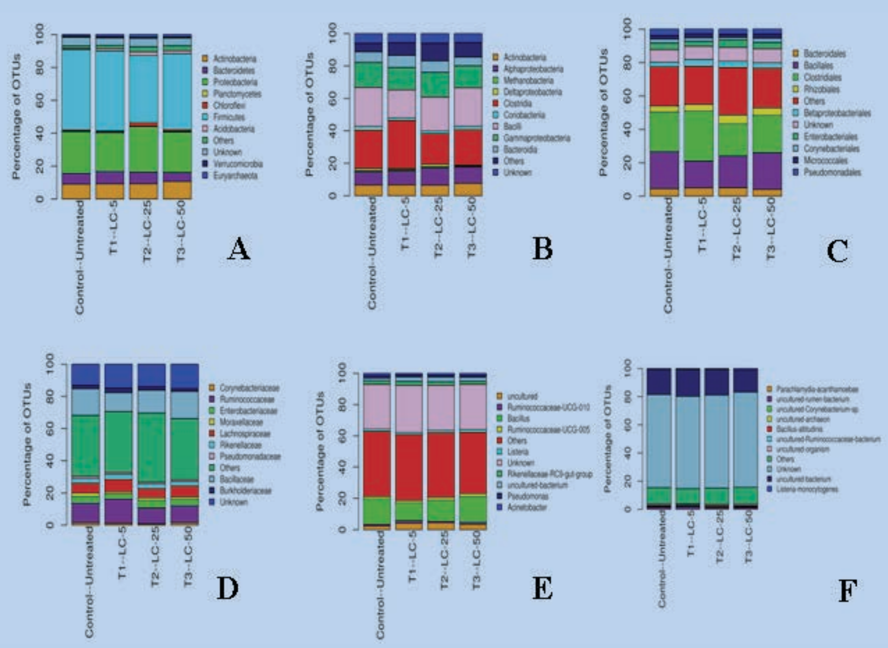


Fig 3.8. Relative abundance of OTUs at different taxa level when *C. cephalonica* was exposed to sublethal phosphine. Phylum level (A); Class level (B); Order level (C); Family level (D); Genus level (E); Species level (F)

antibiotics on some of the microbial parameters. This may alter the soil biochemical properties in long run, which is yet to be investigated.

Gut bacteria of rice stem borer and insecticidal degradation

Apart from the host plants, insect gut microbiome diversity significantly influenced by the respective insect species, its physiology and ecological functions, requirements and adaptation. Three rice stem borers *viz.,* Striped Stem Borer (SSB), *Chilo suppresalis,* Yellow Stem Borer (YSB), *Scirpophaga incertulas* and Pink Stem Borer (PSB), *Sesamia inferens* although collected from the same host (Varshadhan) at the same time, markedly differed in composition of gut bacterial microflora. Further, rice stem borers gut isolated bacteria were utilized for *in-vitro* degradation efficiency of three insecticides *viz.,* Chlorpyriphos, Chlorantraniliprole and Thiamethoxam. It was found that degradation efficiency of Chlorpyriphos was in the range of 65.32-74.34%, the degradation efficiency of Chlorantraniliprole was in the range of 66.56-71.24% and the degradation efficiency of Thiamethoxam was in the range of 10.65-20.50% (Table 3.2). The result shows that very commonly used insecticide is degraded more than the other insecticides. Thus, insecticide usage selection pressure has its effect on gut microbes which in turn can have its role in xenobiotics metabolism by the host insect.

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

Evaluation of the efficacy of natural zeolite formulation against Oryzaephilus surinamensis

Laboratory studies were conducted to test the efficacy of natural zeolite formulation against *Oryzaephilus surinamensis* at different dosages *viz.,* 0.25, 0.50, 0.75, 1.00, 1.25 and 1.50 g kg^{-1} of grain stored*.* Natural Zeolite formulation registered 94% mortality when treated @ 1.5 g kg^{-1} grain indicating very good control of test insect.

Plant Growth Promoting Rhizobacteria (PGPRs) against Rhizoctonia solani

The induced resistance activities due to treatment of bacterial biocontrol agents were studied after artificial inoculation with *Rhizoctonia solani.* From this experiment, rice plants inoculated with *R. solani* were found to overproduce defense related biomolecules and enzymes such as phenols, peroxidase and catalase etc. There was a significant increase in activities of all these enzymes when treated with bio-control agents in comparison to untreated control. As far as phenols activity was concerned, the maximum phenol concentration (83.16 mg g^{-1} of tissue) was recorded in RB-31 followed by RB-29. The least phenol concentration was recorded from untreated control (37.76 mg g^{-1}). All the bio-control treatments significantly recorded higher concentration of phenols compared to control. Similarly, the activities of peroxidase were recorded, where there were no significant activities observed among the treatments. But maximum concentration was recorded in treatment RB-31 (4.11 mg g^{-1} of protein). Least peroxidise activity was observed in untreated control (2.13 mg g^{-1} of protein). The activities of catalase were also studied, and the results found that, maximum catalase activity was recorded in RB-31 (37.52 Unit activity/Min/g of FW) followed by RB-28 (34.63 Unit activity/Min/g of FW). Whereas, untreated control recorded least catalase activity (24.00 Unit activity/min/g of FW).

Genome organization and comparative evolutionary mitochondriomics of rice earhead bug Leptocorisa oratoria (Fabricius)

The complete mitochondrial genome of rice earhead bug, *Leptocorisa oratoria* (Fabricius, 1794) from India was sequenced for the first time. The mitogenomes of *L. oratoria* are 17 584 bp long with 73.57% AT content (Fig. 3.9). *Leptocorisa oratoria*

Table 3.2. *In vitro* degradation efficiency of gut bacteria mix of rice stem borers

Insecticide	YSB (Q_1)	PSB (Q_2)	SSB (Q_3)	Mean (P)
Chlorpyriphos (P_1)	65.32 (53.92)	74.34 (59.56)	71.53 (57.75)	70.40^{A} (57.08)
Chlorantraniliprole (P_2)	68.45 (55.82)	71.24 (57.56)	66.56 (54.66)	68.75^{B} (56.02)
Thiamethoxam (P_3)	20.50 (26.92)	15.65 (23.30)	10.65 (19.04)	15.60^{C} (23.09)
Mean (Q)	51.42^{b} (45.55)	53.74^{a} (46.81)	49.58^{c} (43.82)	

mitochondrial genomes include 37 genes and one control region. Sliding window, genetic distance, and Ka/Ks ratio analyses revealed purifying selection of 13 protein-coding genes, with *cox1* and *nad2* having the lowest and the highest evolutionary rates, respectively. Phylogenetic analysis was reconstructed using 65 pentatomid mitogenomes with maximum likelihood and Bayesian inference methods. The results indicated that the Coreoidea superfamily differentiated from Lygaeoidea, Aradoidea, and Pentatomoidea. Family-level phylogenetic analysis yielded two topologies when rooted with Coreidae + Rhopalidae + Alydidae in one clade; the remaining families of Pentatomomorpha formed another clade. Further, *L. oratoria* from the present study formed a separate subclade from previously reported *Leptocorisa* sp. This study was the first attempt to provide a reference mitogenome for *L. oratoria* that may be applied to study the population genetics, individual differences, and phylogeography of hemipterans.

Performance of Trichogramma japonicum under field conditions as a function of the factitious host species used for mass rearing

The objective of this study was to compare, parasitoid, *T. japonicum* reared in different factitious hosts. Three commonly used factitious host eggs, *Corcyra cephalonica* (Stainton), *Ephestia kuehniella* Zeller and *Sitotroga cerealella* Olivier were tested under laboratory conditions and then in the field over a yellow stem borer, *Scirpophaga incertulus* (Walker) of rice. The highest parasitism by *T. japonicum* was observed on *E. kuehniella* eggs. The parasitoid's highest emergence (88.99%) was observed on *S. cerealella* eggs at 24 h exposure, whereas at 48 h it was on *E. kuehniella* eggs (94.66%) (Fig 3.10). *Trichogramma japonicum* females that emerged from *E. kuehniella* eggs were significantly long-lived. The days of oviposition by hosts and the host species were significant individually, but not their interaction. Higher proportions of flying *T. japonicum* were observed when reared on *E. kuehniella* and *C. cephalonica* eggs. Field results showed that *T. japonicum* mass-reared on *E. kuehniella* showed higher parasitism of its natural host, *S. incertulus* eggs. Hence, by considering these biological characteristics and field results, *E. kuehniella* could be leveraged for the mass rearing of quality parasitoids of *T. japonicum* in India, the Asian continent and beyond.

Gut bacteria of rice stem borers and lower temperature survival

Studied the emergence pattern of rice stem borers and found that majority of rice yellow stem borer larvae emerge in the initial period, whereas striped stem borer larvae emerges in the later period i.e., summer months. Insect gut microbiome diversity significantly influenced by the respective insect species namely, Striped Stem Borer (SSB), *Chilo suppresalis,* Yellow Stem Borer (YSB), *Scirpophaga incertulas* and Pink Stem Borer (PSB), *Sesamia inferens.* Growth curve study of the gut bacterial consortia of YSB, PSB, SSB at 15 ºC, 20 ºC, 25 ºC, and 30 ºC showed that YSB gut bacteria had better growth at all the temperatures, whereas SSB gut bacteria had shown better growth at higher temperature. These signals towards some possible role of the stem borer gut bacteria on the overwintering behaviour of the host and survival of insect.

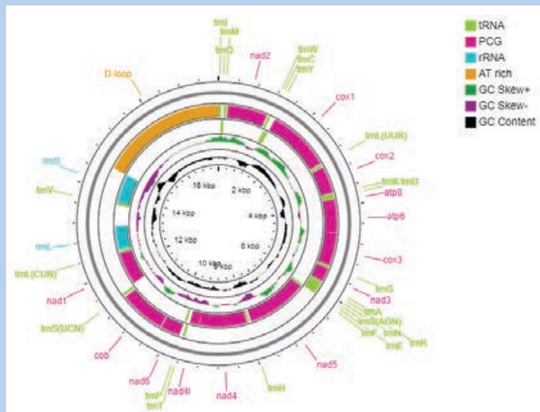


Fig 3.9. *Leptocorisa oratoria* mitochondrial genome map (PCGs, rRNA, tRNAs and CR) is indicated in the first outer circle. GC content and GC skew is represented in second and third circle, respectively.

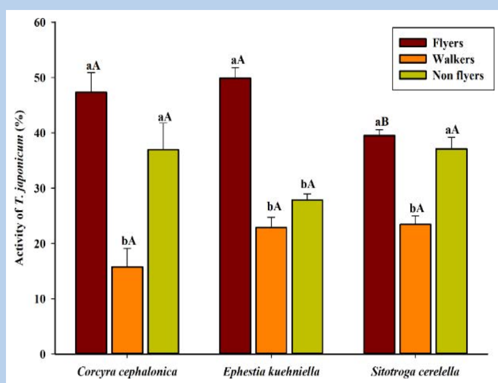


Fig 3.10. Flight propensity of *T. japonicum* emerged from the eggs of different factitious hosts.

In a nutshell, more than 1900 entries were tested against various rice pests to identify the resistant donors. The population dynamics and genetic diversity of BPH and sheath blight populations were studied. *Brachymeria excarinata*, a parasitoid species, was identified for the first time. The detection of BPH in rice may be done using the hyperspectral bands at 519, 670, and 718 nm. *Trichoderma erinaceum* was sequenced *de novo*. For the first time, the entire mitochondrial genome of the rice earhead bug was sequenced. Host *C. cephalonica's* phosphine-induced hormesis may aid in the mass rearing of the parasite *H. hebetor*. Demonstrations of various IPM techniques were conducted and trainings were given to various stakeholders to produce safe and quality rice with optimum input use.

PROGRAMME-4

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

Rice is grown under diverse ecosystems and under changing climatic conditions. Some germplasm lines or native land races though poor yielder, have potential to tolerate the abiotic stresses with many mechanistic alterations. To sustain per capita rice consumption at present rate it may be required to produce 50% with decreasing rice area. Besides, rice grain quality is the most important factor for evaluation of a variety as well as millers, consumers and farmer's point of view. It includes physico-chemical, nutritional and sensory qualities. Various biochemical factors (resistant starch, amylose, phytic acid) and heat processing (parboiling) affect starch digestibility and glycemic index of rice based food or its products. These problems are being addressed by three different institutional projects and four externally aided projects through the active participation of eight scientific and seven technical staffs of the division.

Photosynthetic efficiency and productivity of rice under changing climate

Rice genotypes evaluated for their biomass production and grain yield

Selected rice genotypes were evaluated for their biomass and grain yield efficiency under field condition. Out of 138 selected lines over 3 seasons in a set of 1400 genotypes collected from different sources, 25 were observed to be promising genotypes on the basis of their better performance in terms of higher biomass, grain yield, HI, grain filling % and Leaf area index at flowering stage (Table 4.1).

Improvement of photosynthetic efficiency of rice trough transgenic approaches

ME-transgenic lines showed reduced leaf malate content and enhanced performance of photosynthesis under water deficit conditions. *NADP-ME* (NADP-dependent malic enzyme) is an important photosynthetic C4-specific enzymes present in the mesophyll cells of C4 plants. To evaluate the effect of C4 enzymes in rice, we developed transgenic rice lines by introducing *Setaria italica ME* [*SiME*] gene constructs under the control of the green tissue-specific maize *PPDK* promoter (Fig. 4.1A). Rice lines for both constructs were screened using the polymerase chain reaction (PCR), Southern hybridization, and expression analysis. The best transgenic lines were selected for physiological and biochemical characterization. The results from qRT-PCR and enzyme activity analysis revealed higher expression and activity of *NADP-ME* genes compared with the non-transformed and empty-vector-transformed plants. The average photosynthetic efficiency of transgenic plant lines carrying *NADP-ME* genes increased by 12%, and was positively correlated with the increased accumulation of photosynthetic pigment. *SiME*-transgenic plants displayed reduced leaf malate content and superior performance under water deficit conditions (Fig. 4.1B). Interestingly, the trans-genic plants showed yield enhancement by exhibiting increased plant height, panicle length, panicle weight and thousand grain weight.

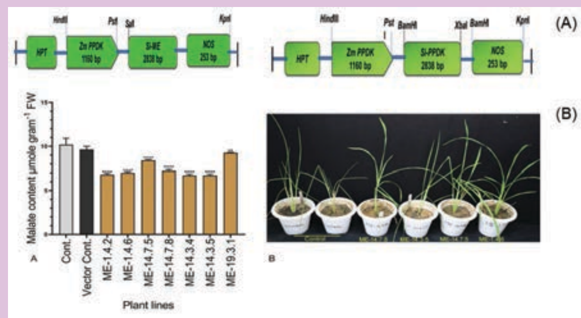


Fig. 4.1. *SiME* gene constructs under the control of the green tissue-specific maize *PPDK* promoter (A) and *SiME*-transgenic plants displayed reduced leaf malate content and superior performance under water deficit conditions.

Table 4.1. Performance of best ten rice genotypes for each studied parameters at harvesting stage.

Sl. No.	Variety	TDM ($t\ ha^{-1}$)	Variety	Gr. Yld ($t\ ha^{-1}$)	Variety	HI	Variety	Grain filling (%)
1	IC 516313	13.82	IC 465340	5.82	BAM785	0.53	N22	94.64
2	Azucina	13.58	Tapaswani	5.72	Satabdi	0.52	Kameh	92.88
3	IC 516149	13.53	SUWEON	5.52	BAM2680	0.51	Suraja Mukhi	91.89
4	IC 465340	13.03	Sasyasree	5.43	D206	0.51	GP 168	91.62
5	IC 516611	13.01	IC 516611	5.39	Konark	0.51	Anjali	91.36
6	IC 516366	12.98	Naveen	5.35	Anjali	0.51	Tchampa	90.75
7	Maudamani	12.76	IC 380534	5.30	GP 129	0.51	IC 211548	90.23
8	Kuan chin	12.63	Naveen	5.21	Sasyasree	0.51	BAM2680	90.04
9	IC 465615	12.57	Khitish	5.20	DT-14	0.50	Anjali	89.65
10	IC 464096	12.49	EC 306311	5.18	Tapaswani	0.50	Khitish	89.49
	Mean	**13.04**		**5.41**		**0.51**		**91.25**

Identification of genotypes and physiological traits responsible for elevated CO_2 response in rice

To identify the elevated CO_2-responsive genotypes and morpho-physiological traits governing high CO_2-response, a total of 25 rice genotypes belonging to four maturity groups *viz*., early (3), mid-early (6), medium (7) and late (9) were evaluated under normal and elevated level of CO_2 conditions (e[CO_2]). We observed a difference of ~1.8 °C between chambered (CC) and un-chambered control (UC) during the crop growth period. On average, >25% yield enhancement was observed in early duration cultivars (Satabdi, Vandana, Sahbhagidhan, etc.), followed by a 17% increase in mid-early cultivars (Abhishek, IR64, MTU1010). There was not much yield benefit observed in medium and late duration varieties on average, but some cultivars like Varshadhan, Pusa 1121 and Ajay responded better. Considering all the genotypes it was found that 'Harvest Index', 'Total Biomass' and 'Plant Height' are the three most important traits which were influenced by e[CO_2] treatment in rice.

Identification of rice genotypes with higher cellular level tolerance to heat stress by employing temperature induction response

Six rice genotypes *viz.,* HT-20 (AC 34975), Lalat, Naveen, HT-18 (AC 34973) including two checks *viz.,* N 22 (Tolerant) and IR 72 (Susceptible) were used for study. A novel technique called Temperature Induction Response (TIR) was used to phenotype diverse rice genotypes for tolerance at cellular level. Significant variability was observed for tolerance at cellular level (TCL) in the rice genotypes for different physio-biochemical parameters. Contrasting rice genotypes differing in TCL were identified. Identified HT-20 and HT-18 as the genotypes with better expression of stress-responsive genes that brought about intrinsic differences in heat stress tolerance (Fig. 4.2)

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

Evaluation of rice genotypes for multiple abiotic stress tolerance

About 70 genotypes were screened for seedling stage drought and submergence tolerance and their anaerobic germination potential (AGP) for two consecutive years. After two years testing 49 genotypes were found highly drought tolerant, 18 genotypes were tolerant to two weeks of complete submergence with >60% survival and four genotypes having >50% AGP (Fig. 4.3). The genotypes *viz*., IC 516149, AC 38209, AC 35678, IC 516008 were identified to have both drought and submergence tolerance, while IC 516149 was found possessing tolerance against all three stresses.

Identification of new source(s) of drought & lowlight tolerant genotypes

Thirty-five diverse set of drought tolerant genotypes were exposed to 50% of Normal Light stress following standard protocol (50% LL stress imposed 15 days after transplanting till maturity). Grain yield reduced by 48.4% and Total Biomass by 35.5% under low light. Relative yield reduction was lowest in Check Swarnaprabha (20%), followed by Satyabhama (24%) and IR72 (30%). However, another seven genotypes: Apo, MTU1010, Satabdi, Brahman nakhi, Naveen, Parijata and BVD 109 had RYR of 30-40% and eight genotypoes (Pathara, Black gora, Khitish, Annada, Lalat, Rasi, Vandana, Kamesh) had RYR of 40-50%, which may be considered as lowlight

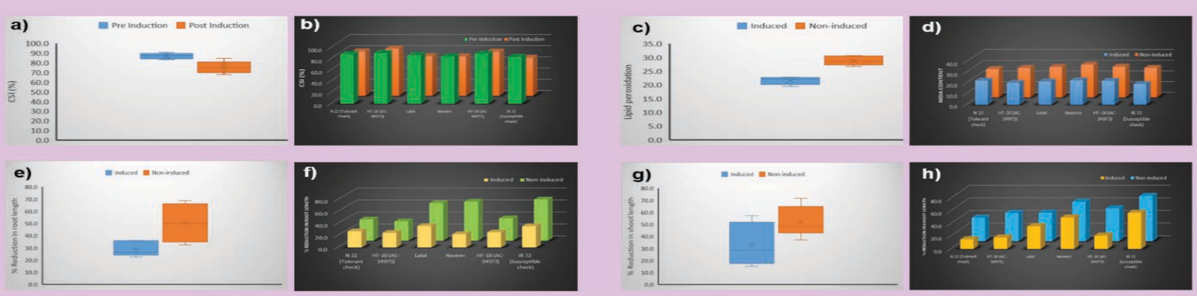


Fig. 4.2. Genetic variability among rice genotypes for a) CSI; c) lipid peroxidation; e) reduction in root length; g) reduction in shoot length and Response of rice genotypes at cellular level to TIR with regards to b) CSI; d) MDA content; f) reduction in root length; h) reduction in shoot length.

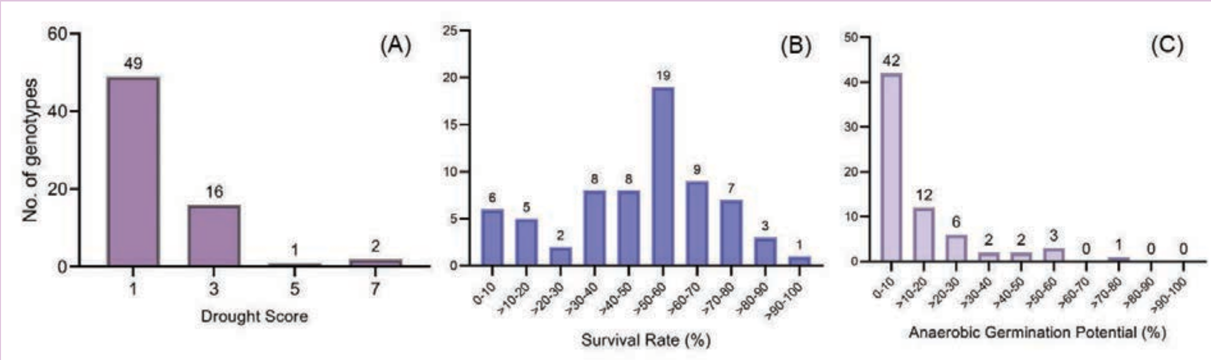


Fig. 4.3. Response of 70 rice genotypes against seedling stage drought (A), complete submergence (B) and anaerobic germination (GSOD) stresses.

tolerant genotypes having vegetative stage drought tolerance.

Identification of submergence tolerant introgression lines of *Oryza nivara*

A set of 110 backcross derived introgression lines between *O. sativa* var. Swarna and *O. nivara* accession IRGC 81848 (named as NPS lines) were obtained from ICAR-IIRR, Hyderabad. The lines were evaluated using standard evaluation system for four years and subsequently in multilocation trials in AICRIP. Four stable and tolerant lines (NPS 17, NPS 18, NPS 71 and NPS 95) were identified. The genotype NPS 95 was tall with dark reddish-brown husk colour. Enhanced leaf gas film thickness was recorded in all the four lines. The genotypes are now being used to develop mapping populations as well as submergence tolerant near isogenic lines of Swarna with its original golden-brown husk colour.

Mechanistic comparison of salt tolerant accessions of *Oryza nivara* and *Oryza sativa*

Two previously identified *O. nivara* accessions W118 (AC 100042/ IC 336715), W119 (AC 100042A) showing considerable salt tolerance (12 dS m^{-1}) at seedling stage were tested against FL478 and IR29, the tolerant and susceptible lines, respectively from *O. sativa*. Based on the leaf sodium (Na^+) and chlorophyll concentrations, and chlorophyll a fluorescence behaviour, we found W118 and W119 accumulated high amount of Na^+ in leaves as compared to FL478, but still able to maintain maximum efficiency of PS II (F_v/F_m), which is at par with FL478 (Fig. 4.4). It suggests, W118 and W119 members allowing the movement of Na^+ to the upper portion of leaves, yet could maintain a high PS II efficiency. Further we found that W118 and W119 higher tissue tolerance ability which help them to compartmentalize Na^+ into vacuoles, therefore, not hampering the cellular functions under stress.

Understanding the differential tolerance mechanism at seedling and reproductive stage

Rice shows considerable variability toward salinity stress at the seedling and reproductive stages. Though ion exclusion (IE) is one of the most important tolerance strategies, some good ion-excluders do not necessarily show an expected level of tolerance at the reproductive stage. We took rice genotypes having stage-specific variations in salt-tolerance ability and also studied the contribution of the tissue tolerance (TT) trait to understand its stage-specific influence on salinity tolerance. Tissue Na^+ and K^+ concentrations, and the values of selective transport of K^+ over Na^+ suggested that FL478 and AC 41585 were very good ion excluders, while Rashpanjor and IR 29 were moderate and poor ion excluders, respectively (Fig. 4.5). The gene expression profiles of different Na^+/H^+ transporters; high-affinity K^+ transporters, K^+ uptake channels/pumps, and H^+-pumps indicate very high IE behaviour of FL478 and AC 41585, which perfectly resembles the phenotypic manifestation of salt tolerance at the seedling stage. But, even with such dominating IE, FL478 failed to show a similar level of tolerance, while AC 41585 could. Interestingly, IR 29 showed the highest TT, followed by Rashpanjor and AC 41585, while it was the least in FL478. We conclude that only IE, without much contribution of TT, could be enough for seedling stage tolerance, however, may not be sufficient for the reproductive stage tolerance. Rather a fine balance between IE and TT is crucial for prolonged salt tolerance at the reproductive stage (Table 4.2).

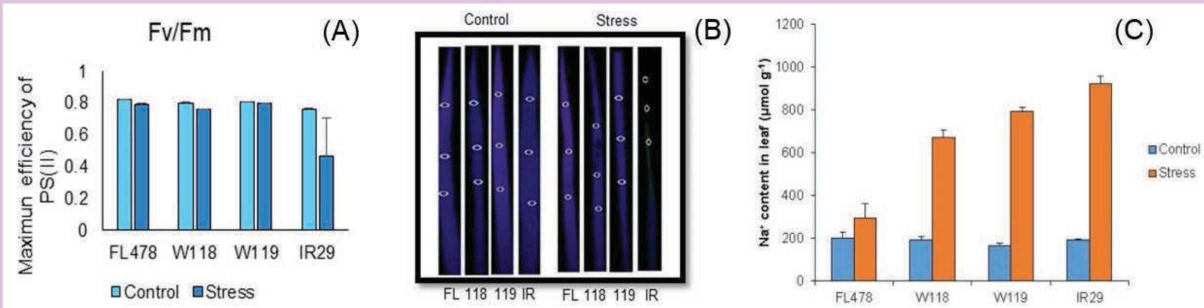


Fig. 4.4. Differential response of *O. nivara* and *O. sativa* accessions for seedling stage salt tolerance in terms of their maximum efficiency of PSII (A), F_v/F_m images (B) and leaf Na^+ concentration (C).

Table 4.2. Relative contribution of ion exclusion (blue circles) and tissue tolerance (green circles) traits in four rice genotypes and their phenotypic response towards salt stress at seedling and reproductive stages.

Genotype	Relative Contribution of Traits (● = Ion exclusion; ● = Tissue tolerance)	Phenotypic response towards salt stress: Seedling Stage	Phenotypic response towards salt stress: Reproductive Stage
AC41585	●●●●●● (blue) ●●●● (green)	+ + +	+ + +
FL478	●●●●●●●● (blue) ●● (green)	+ + +	– –
Rashpanjor	●●●● (blue) ●●●●●● (green)	+ +	+ + +
IR29	● (blue) ●●●●●●●●● (green)	– – –	– – –

Root anatomical study related to water uptake under stress condition

Seven different root anatomical traits - maximum root length (MRL), root section diameter (RSD), late metaxylem number (LMXN), late metaxylem diameter (LMXD), aerenchyma formation (no), stele diameter (SD), and ratio of stele diameter to root diameter (SD/RSD) were varying significantly for drought tolerant and susceptible genotypes. Dissected rice root segments with anatomical measurements imaged using Leica DMi8 inverted microscope revealed that genotypes Ampi and AC 42997 maintained highest LMXN and stele diameter under water stress (Fig. 4.5). Aerenchyma cell formation was lowest in Ampi and AC 42997 helping to enhanced water uptake efficiency under stress compared to IR 64 (susceptible check).

Standardization of effective concentrations of Plant Bio-Regulators (PBRs) to improve vegetative stage abiotic stress tolerance in rice

A study was conducted to standardize the effective concentrations of PBRs *viz.,* Thiourea (TU) and potassium nitrate (KNO_3) to improve the seedling stage drought and salinity tolerance in selected rice genotypes. Different concentrations of thiourea *viz*., 0, 100, 200, 300, 400, 500, 600, 700, 800, 900 and 1000 ppm; KNO_3 *viz*., 0, 1, 2, 3, 4 and 5% along with absolute control were evaluated in both susceptible (Drought- Naveen; Salinity- IR 29) and tolerant (Drought- Vandana; Salinity-FL-478) genotypes of rice for seedling level drought (withholding irrigation) and salinity (150 mM NaCl) tolerance. Treatments were imposed at five leaf stage. After seven days of the treatment, seedlings were sampled to measure various growth parameters like root length, shoot length, seedling fresh weight and seedling dry

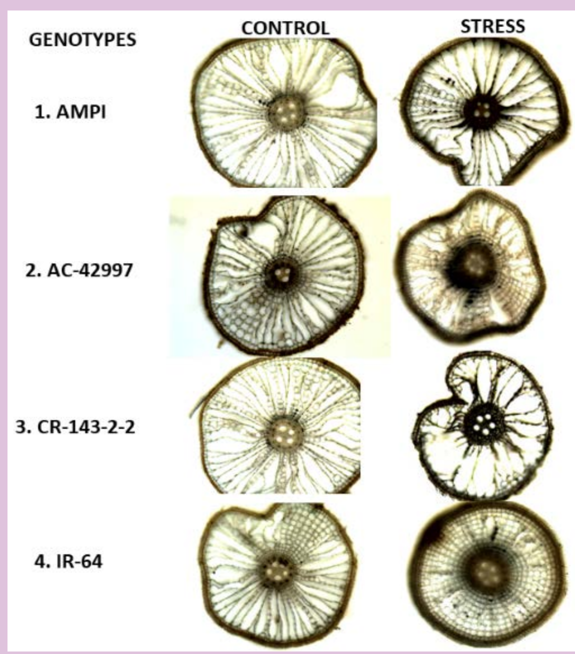


Fig. 4.5. Cross-sections of roots showing root diameter, metaxylem number, metaxylem diameter, stelediameter of four rice genotypes with varying degree of drought tolerance.

weight to assess the impact of foliar applied PBRs in combating abiotic stress tolerance. Results from the present study established that spraying the seedlings with KNO_3 (5% for drought and 2% for salinity) and Thiourea (500 ppm for drought and 1000 ppm for salinity) were more effective in improving seedling growth of susceptible genotypes.

Evaluation of rice genotypes for vivipary/Pre Harvest Sprouting (PHS) resistance

Evaluated 450 rice genotypes comprising of 150-Germplasms/Landraces (Assam Rice Collections (ARC), PB accessions (IC accessions from Western Odisha)); 100 Popular released rice cultivars; and 200 mapping panel including very high yielding NGRs, moderately yielding and low yielding cultures with biotic stress resistance for vivipary/pre-harvest sprouting (PHS) resistance under field and laboratory conditions. Based on the percentage germination upon vivipary treatment, the genotypes were grouped as highly resistant (0-3%), moderately resistant (3.01-5%), highly susceptible (>15%) and moderately susceptible (5.01-15%) (Fig. 4.6).

Mechanistic understanding of vivipary/ Pre Harvest Sprouting (PHS) resistance or susceptibility in contrasting rice genotypes

To understand the underlying mechanism of PHS, quantitative (Fig. 4.7A) and qualitative analyses were performed which showed that increased alpha amylase activity was associated with PHS in susceptible genotypes (Fig. 4.7B). Since alpha amylase activity stimulates germination via starch breakdown, we observed that resistant genotypes exhibited very little or no alpha amylase activity at any of the flowering phases. Reactive Oxygen Species (ROS) influence in the GA/ABA regulation there by regulating dormancy and germination, the present work also showed that post vivipary treatment, susceptible genotypes had much higher levels of H_2O_2, O_2^-, and MDA in their leaves and seeds, whereas resistant genotypes had significantly lower levels.

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

Characterization of rice genotypes for lower starch digestibility

Biochemical characterization of ~200 rice genotypes (IG: landraces, pigmented and aromatic rice; ICP: core set of irrigated rice) was done for starch digestibility parameters [Glycemic index (GI), Resistant starch (RS) and Amylose content (AC)]. In case of IG genotypes, large variation was found in the value of GI (52.49-63.00), RS (0.74-2.54%) and AC (3.82-24.52%). Among the genotypes studied, IG 23 showed lowest GI (52.49) and high RS (2.28%) followed by IG 33 which had the highest RS content (2.54%) with GI value 53.24. For AC, IG 40 (24.52%) had the highest and IG 53 (3.82%) had the lowest content. Regarding ICP genotypes, again large variation was found in the value of GI (55.66-60.95) and RS (0.75-1.82%) where ICP 58 showed lowest GI (55.66) and high RS (1.60%) while the highest GI (60.95) was found in ICP 50 with low RS (0.81%). Highest RS was found in ICP 9 (1.82%) with GI value 57.58. Among the genotypes studied, ICP 21 (23.70%) had the highest and ICP 42 (6.15%) had the lowest AC.

Characterization of rice genotypes for phytic acid content in brown rice

Phytic acid content was estimated in the brown rice of ~200 rice genotypes already characterized for starch

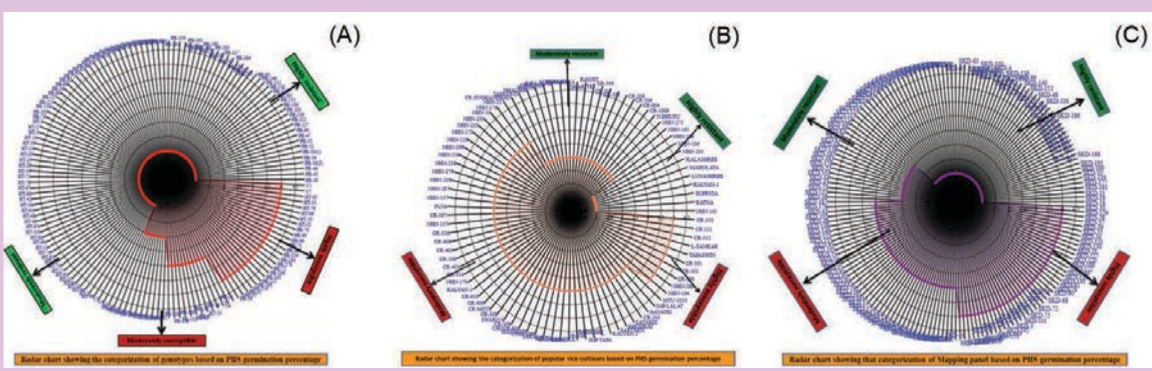


Fig. 4.6. Vivipary/PHS response of rice germplasm consisting of Assam Rice Collections and landraces from western Odisha (A), released cultivars from Odisha, AP and West Bengal (B) and mapping panel including high yielding NGRs and moderate and yielding lines (C).

Fig. 4.7. (A) α-amylase activity as observed in the PHS susceptible genotypes at 20, 30 and 40 DAF (B) Starch-agar halo disc assay for detecting α-amylase activity in rice.

digestibility parameters. Large variation of PA was found in the IG (0.54-1.96 g/100g) and ICP (0.72-2.00 g/100g) genotypes. Among the genotypes studied, IG 123 showed lowest PA (0.54 g/100g) while the highest PA (2.00 g/100g) was found in ICP 16.

Scanning electron micrographs of non-parboiled and parboiled rice grains under different stages of processing

The endosperm of CR Dhan 310 showed the higher protein content than other varieties and the aleurone layer (AL) of the rice after parboiling (indicated by arrows) showed high content of protein bodies while AL of rice before parboiling (indicated by arrows) showed smaller amount of protein bodies. It is suggested that the proteins of rice migrated to the endosperm of the grain, which corroborates well with the crude protein content. The SEM of raw rice endosperms showed polyhedral compressed starch granules with proteins distributed around the surface of starch granules while in case of parboiled rice, the starch granules are gelatinised and showed indefinite shape and size. (Fig. 4.8).

Minerals content of rice grain under different processing techniques

In this experiment Fe and Zn content of eighteen rice samples were estimated through atomic absorption spectroscopic method and their concentration observed to be varied significantly (6.30 to 17.17 ppm for Fe and 14.07 to 37.51 ppm for Zn) amongst the samples. The highest Fe content was obtained from the Treatment 1 i.e. raw rice of Naveen (17.17 ppm) whereas lowest was found from the parboiled fermented rice of CR Dhan 310 (6.30 ppm). For Zn content, highest was observed in the Treatment 6 i.e. cooked rice of Manipuri Black (37.51 ppm) while lowest was observed from the Treatment 17 i.e. parboiled fermented rice of CR Dhan 310 (14.07 ppm). Considering six levels of grain processing, the average Fe and Zn content were varied from 7.83 to 13.59 ppm and 19.27 to 24.16 ppm respectively and the highest was recorded from raw rice (for Fe) and cooked rice (for Zn) whereas lowest was found from the fermented raw rice (for Fe) and fermented parboiled rice (for Zn).

Characterization of rice genotypes for improved physico-chemical and nutritional properties

Fifty germplasm of Kerala have been analyzed for total antioxidant and Amino acid content. Two germplasm *viz.,* White Rice (AC 44302) and Kunje Kunje (AC 39534) were found to be high in antioxidant content while Amballavalaya (AC 44311) was found to possess high protein with moderate antioxidant content.

The rice genotypes of North-East India have wide variability but remains nutritionally uncharacterized. Fifty germplasm of Arunachal Pradesh have been analysed for total phenol content, total flavonoid content and total antioxidant activity (CUPRAC, DPPH, ABTS, FRAP Assay). AC 9135 and AC 9175 have been identified to possess high antioxidant content.

Twenty germplasm from Nagaland were quantified for nutritional quality traits. Pawnhi (IC 0635893) was found to possess higher antioxidant content with high Zn and moderate Fe content.

Development of mixed pH indicator-based method to identify the approximate age of rice grain

A chemical method was standardized and validated using mixed pH indicators to determine the age of rice. Six different rice varieties were analyzed at every 15 day's intervals till eight months for the

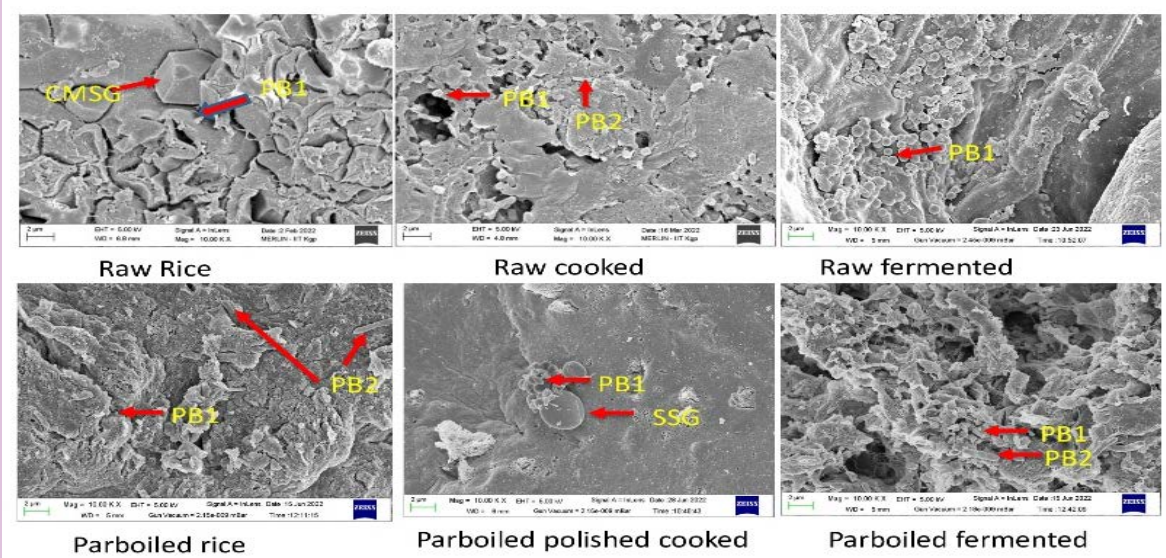


Fig. 4.8. Scanning Electron Micrograph (SEM) of rice grain after different degree of processing.

aging study. A mixed pH indicator was used to see the change in colour as the age of rice increases. One gram of milled rice was mixed in 10 ml of diluted mixed pH indicator and mixed for 1 minute in vortex and kept for 10 minute at room temperature. The change in colour was recorded (Fig. 4.9) and interpreted as follows: The colour of solution changes in following sequence; green (0-1 month) - olive green (1-2.5 months)-yellow (2.5-4 months)-orange (> 4 months). The age of raw milled rice can be easily determined by using this method which will help to differentiate between new and old rice.

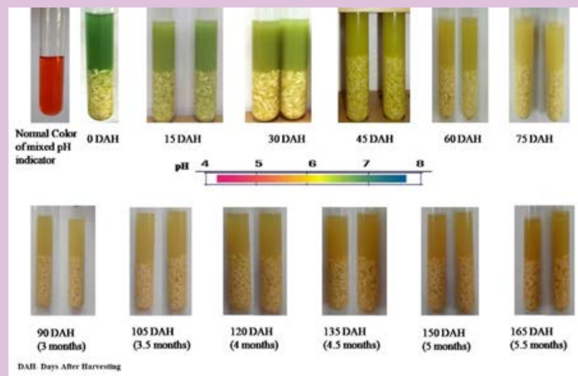


Fig. 4.9. Pictorial representation of change in colour of mixed pH indicator at different duration of storage.

Conclusion

Apart from identification of photosynthetically superior rice lines, transgenic rice lines with improved photosynthetic ability and grain yield were developed. Besides, several abiotic stress tolerant rice accessions from *O. sativa* as well as *O. nivara* were identified through different on-going research activities of the division. Among them four unique rice germplasm were identified and registered with PGRC, NBPGR, New Delhi as novel sources of multiple abiotic stress tolerant lines. Critical root anatomical structures contributing to seedling stage drought tolerance were characterized. Further, the mechanistic differences of seedling and reproductive stage salt-tolerance in rice were elucidated. Many lines were evaluated for genotypes for vivipary resistance to understand the mechanism of viviparous germination in rice. Several genotypes were screened for grain and nutritional qualities like glycemic index, resistant starch, phytic acid and grain mineral contents. Besides, grain physico-chemical and nutritional properties were studied in terms of total protein, amino acids, phenol and flavonoids contents. Also, a simple mixed pH indicator-based method was developed to identify the approximate age of rice grain.

PROGRAMME-5

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

The Social Sciences Division is on the forefront in developing and testing new extension models, approaches and strategies for technology transfer and socioeconomic research in rice sector. Major thrust of the Division is outreach activities for rapid dissemination of recent technologies to the end users and providing feedback to technologists. The Division with a total staff strength of (six scientists, eleven technical staff and one administrative staff) caters to its research mandates through two institute research projects and eight externally aided projects. During the year 2022, a total of 28 newly released rice varieties by the institute were demonstrated through 927 farmers' field demonstrations in nine states in close convergence with both state government and non-government stakeholders apart from participating farmers using INSPIRE 1.0 and INSPIRE 2.0 models. Eighty-seven training programmes of various durations were organized for 3577 participants comprising farmers, extension officials, administrative personnel and other rice stake holders. The Division conducted study on adoption of rice varieties in Eastern and North-Eastern states of the country; share of NRRI varieties in overall varietal replacement by the states; identified problems faced by the farmers in rice farming. The Division working on estimation of economic value of NRRI varieties, specialty rice, premium seed varieties; preference by consumers in rice consumption; trends in rice production; impact of minimum support price. The Division showcased the NRRI technologies by participating in exhibitions at various parts of the country, extended advisory services to the visitors, and provided agro-advisory services via different means. Rice database management for time-bound generation and submission of report has been quite efficiently being undertaken by the Division. The Division also played the crucial role in disbursing various kinds of benefits to a wide range of beneficiaries especially the marginalized ones through Scheduled Caste Sub-Plan (SCSP), Tribal Sub-Plan (TSP), Farmer FIRST Programme and *Mera Gaon Mera Gaurav* (MGMG) Programme.

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

Testing and validation of NRRI extension models

The project envisages testing and validation of three novel linkage-based extension models conceptualized at the Institute - INSPIRE 1.0, INSPIRE 2.0, and Climate Smart Model Village (CSMV). The evaluation methodology comprised multi-location on-farm minikit demonstrations and cafeteria demonstrations of 28 newly released improved varietal technologies developed by ICAR-NRRI, Cuttack with a sample size of 927 farmers (n=927) across 26 locations spanning 116 hectares of land. The entire locale of model-testing and validation encompassed 26 districts from nine states - Assam, Andhra Pradesh, Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Maharashtra, Odisha, and West Bengal. The assessment mechanism leveraged distribution of critical inputs (4638 kg paddy seeds in the form of 5 kg minikits) through *Krishi Vigyan Kendras* (KVKs) and state agriculture departments, technical guidance through follow up visits, relevant literatures, mobile calls and other digital modes, and crop cutting experiments-cum-field days. Among the key performance indicators (KPIs), yield and crop growth parameters were studied during the period under report. A majority of the demonstrated varieties outperformed the existing popular varieties in the same ecology with a grain yield advantage up to 51.22% (CR Dhan 307). CR Dhan 800 (= 6.2 t ha^{-1}), CR Dhan 307 (= 6.2 t ha^{-1}), CR Dhan 801 (= 5.8 t ha^{-1}), CR Dhan 505 (= 5.5 t ha^{-1}) and CR Dhan 409 (= 5.3 t ha^{-1}) were found to be the best performing varieties under farmers' field conditions (Table 5.1).

Table 5.1. Five best performing NRRI varieties under farmer's field condition.

Variety	Average yield (t ha^{-1})	Average grain yield advantage (%)
CR Dhan 800	6.2	29.17
CR Dhan 307	6.2	51.22
CR Dhan 801	5.8	20.83
CR Dhan 505	5.5	14.58
CR Dhan 409	5.3	10.42

Diffusion analysis of NRRI varieties in Eastern and North-eastern parts of India

An analysis of disaggregated, cross sectional, household survey based primary data extracted from the New Extension Methods and Approaches (NEMA) database revealed the state of diffusion of popular NRRI varieties in the Eastern and North-eastern states of India - Assam, Bihar, Chhattisgarh, Jharkhand, Odisha and Tripura. The sample of the study comprised 1464 rice farmers (n=1464). Findings indicated that 28.42% of the sampled farmers adopted at least one NRRI variety (Table 5.2). Share of NRRI varieties was highest in the state of Odisha (65.97%), followed by Jharkhand (45.79%), Tripura (21.1%), Assam (1.16%), and Bihar (0.21%). The average acreage of NRRI varieties in the adopter farmers' fields was highest in the state of Jharkhand (3.15 acre), followed by Odisha (2.81 acre), Assam (1.13 acre), Bihar (1 acre), and Tripura (0.7 acre).

Table 5.2. Adoption of NRRI varieties in Eastern and North-eastern states under study (n = 1464).

State	Sample size	Number of adopter* farmers	Percent adopters	Crop area under study (in acre)	Rice area under study (in acre)	Share of rice area (in %)
Assam	378	8	2.12	895.62	785.22	87.67
Bihar	212	1	0.47	542.59	484.34	89.26
Chhattisgarh	200	0	0.00	983.71	983.71	100
Jharkhand	176	86	48.86	607.9	592.52	97.47
Odisha	418	293	70.10	1382.66	1247.18	90.20
Tripura	80	28	35.00	93.36	93.36	100
All	1464	416	28.42	4505.84	4186.33	92.91

*farmers cultivating NRRI varieties

Varietal replacement potential of NRRI varieties in Eastern and North-eastern parts of India

A study was undertaken with 1464 paddy farmers across six Eastern and North-eastern states - Assam, Bihar, Chhattisgarh, Jharkhand, Odisha and Tripura to estimate the varietal replacement potential of NRRI varieties (n=1464). The NEMA dataset was accessed for the purpose of analysis. Pooja was found to be the most popular variety, adopted by 12.16% of the farmers in the sample, followed by Lalat (6.08%), Sahbhagidhan (3.55%), *Sarala* (3.14%), and Savitri (2.94%). *Pooja* had the highest share in varietal replacement (36.25%), followed by Lalat (18.13%), and *Sahbhagidhan* (10.59%). Farmers' field level yield was the highest for Gayatri (= 5.62 t ha^{-1}), followed by Panidhan (= 4.38 t ha^{-1}), and Swarna *sub1* (4.36 t ha^{-1}) in these states.

Problem analysis of farmers in rice farming

For assessing farmers' problems in rice farming, feedback was collected from 457 farmers selected randomly from Cuttack district of Odisha (n=457). Insect pests (65.4%), unavailability of irrigation (61.3%), disease infestation (53.4%), low price (33.0%), and inadequate availability of quality seeds (31.5%) were found to be the major five issues faced by farmers in rice cultivation in the district.

NRRI - Training Information Management System (TIMS)

The unified TIMS portal has been designed to keep records of training details conducted by the scientists of the Institute. This is a systematic approach of maintaining the database incorporating details of all training programmes organized by the institute for ready access (Fig. 5.1).

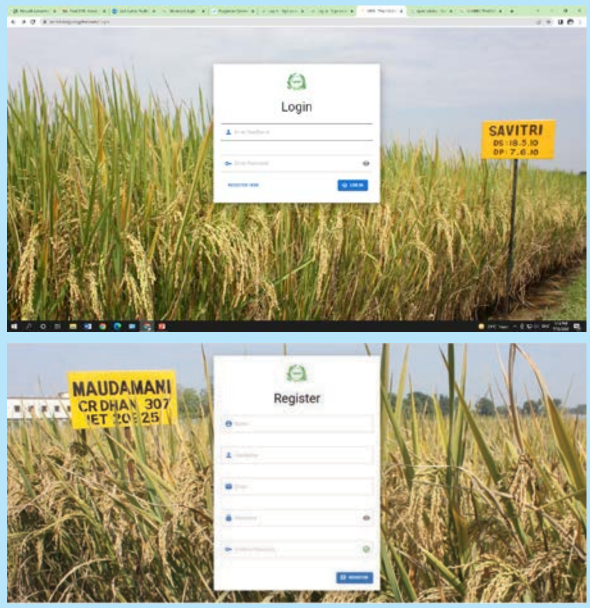


Fig. 5.1. NRRI-Training Information Management System (TIMS) Portal

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

Estimation of economic value of NRRI varieties

Economic analysis of resources used for agricultural research are essential, so, estimating social value of rice varieties in terms of aggregated economic benefits generated were attempted through measuring total economic value to the society using economic surplus approach. Economic surplus is incremental returns generated by technological change originated by research and comprises producer surplus as well as consumer surplus, which generally do not come in calculation in regular estimation procedure. For the first year, two varieties, namely Swarna *sub1* and Sahbhagidhan have been considered for estimation process and used the standard theoretical framework for calculation of producer surplus, consumer surplus as well as total surplus. Finally, net benefit calculated in terms of net-present value, internal rate of return (IRR) and benefit-cost ratio (BCR). The results indicated about 11.33 crores and 5.48 crores as net-present value (NPV) of the benefit and about 18 times and 13 times returns over investment. Total economic surplus generated from these two varieties were estimated to be of Rs.11.95 crores and Rs.5.90 crores, which are just enough to justify any amount of investment for developing such varieties (Table 5.3).

Estimation of economic value of specialty rice and premium seed varieties

Specialty rice and premium seed varieties hardly fetched any price dividends by the farmers though price differed at the market outlets. Further, there are no markets yet for high protein rice developed by the Institute. We attempted to measure people's willingness to pay (WTP) for specialty rice and premium seeds, which may rationalize the market price or better dividends to the farmers. The contingent valuation method have been employed and choice cards were used to elicit responses from different respondents' categories through field survey. Analysis of the collected data showed that people are willing to pay extra for specialty rice as well as premium seed and maximum increment

Table 5.3 Economic impact assessment of two paddy variety using Economic surplus model.

Sl. No.	Particulars	Variety	
		Swarna *sub1*	Sahbhagidhan
Cost-benefit analysis (Rs. crores)			
1	Net present value (NPV) (Rs. crores)	11.33	5.48
2	Net present cost (NPC) (Rs. crores)	0.67	0.45
3	Internal rate of return (IRR) (%)	204%	156%
4	Benefit-cost ratio (BCR)	17.85	13.01
Distribution of economic surplus (Rs. crores)			
5	Producer surplus (Rs. crores)	6.11	3.02
6	Consumer surplus (Rs. crores)	5.84	2.88
7	Total economic surplus (Rs. crores)	11.95	5.90

in WTP reached upto Rs.18.75, 15 and 40 for high protein rice, scented non-basmati rice and premium seed, respectively over and above the rate of similar category of products (Table 5.4).

Trend of rice consumption in India

A primary survey was conducted in four states *viz.,* Odisha, Chhattisgarh, Madhya Pradesh, and Maharashtra comprising a total of 137 respondents who were asked to rank few selected attributes (i.e. aroma, grain quality, price, polished/unpolished rice and cooking quality) in relation to rice consumption and observed that grain quality is the most deciding factor (Table 5.6).

Decade wise trend of rice area, yield and production estimated for two states

Decade wise compound annual growth rate (CAGR) of area, production and yield (APY) of rice calculated with respect to Uttar Pradesh & Bihar and the results indicated that area under rice increased in Uttar Pradesh but decreased in Bihar; yield growth and production growth was higher in Bihar than Uttar Pradesh (Table 5.6). Similarly, instability analysis indicated that production instability was higher than area and yield instability; Further, yield and production instability, both were higher in Bihar than Uttar Pradesh. Decomposition of production growth into area and yield effect revealed positive contribution of area and yield for Uttar Pradesh, whereas, positive contribution of yield and negative contribution of area in Bihar.

Impact of MSP on Rice Farmers' Socioeconomic Wellbeing

A survey was made to study the impact of minimum support price (MSP) for rice on socioeconomic wellbeing of farmers. A binary treatment indicator for access to MSP have been used, i.e. if accessed, 1; otherwise, 0. Analysis of data using propensity score matching (PSM) technique indicated that the farmers who have access to MSP realized Rs.545 extra for a quintal of paddy than the farmers who doesn't have access. The former group have 10% more marketed surplus and have more acreage under rice crop (by 2.25 acres) than their counterparts (Table 5.7). Their rice yields are also marginally higher, about 2 quintal a hectare.

Table 5.4. Measurement of Willingness to pay (WTP) for high protein rice, non-basmati scented rice and premium seeds.

Variables	Mean	Median	Mode	Maximum	Minimum	Std. Dev.
$WTP_{Protein}$	5.92	5.25	3.75	18.75	1.50	3.68
$WTP_{Scented}$	6.91	7.50	7.50	15.00	0.75	2.27
$WTP_{Prem.\ seed}$	11.45	7.75	7.50	40.00	1.00	8.26

Table 5.5. Ranking of consumption attributes pertains to rice.

Attribute	Garrett Score	Rank
Grain quality	11.93	I
Price	19.16	II
Cooking quality	24.34	III
Polished/ unpolished	28.36	IV
Aroma	41.06	V

Table 5.6. Growth and instability in area, yield and production of rice in Uttar Pradesh and Bihar.

Particulars	CAGR (%)	Instability index	Particulars	Decomposition of production growth (%)
Uttar Pradesh (1990-91 to 2019-20)				
Area	0.42	2.43	Area effect	14.21
Yield	0.95	4.85	Yield effect	80.07
Production	1.37	5.44	Interaction effect	5.72
Bihar (1990-91 to 2019-20)				
Area	-0.35	6.97	Area effect	-36.09
Yield	2.29	19.72	Yield effect	177.98
Production	1.93	23.43	Interaction effect	-41.89

Table 5.7. Impact of MSP on socioeconomic wellbeing of rice farmers' measured through selected parameters.

Impact Indicator	Estimation procedure	Observation (original number)	Treated observation (number)	Matched observation (number)	Impact estimate	t-value
Price (Rs. / q)	ATT	137	88	88	544.87	19.59***
Marketed surplus (%)	ATT	137	88	88	9.83	0.97
Marketed surplus (q)	ATT	137	88	88	17.71	19.14***
Acreage under rice crop (ha)	ATT	137	88	88	2.25	1.35*
Rice yield (q/ha)	ATT	137	88	88	2.01	0.47

ATT: Average treatment effect for the treated group; ***significant at 1% level; *significant at 10% level.

The programme visualizes quicker dissemination of NRRI varieties and technologies mostly through demonstration, awareness generation and capacity building. It further aims to guide policies for different groups of rice stakeholders. Apart from Government, the programme has oriented and empowered private institutions like NGOs, CSR Units and FPOs in profitable and sustainable rice based cropping system. Appraisal of economic value contributed by varieties and technologies developed by the institute; and economic value of specialty rice and premium seed varieties will guide future research pathways and take vital decisions relating to rice sector development. Analysis of trend of rice consumption; growth and instability in area, yield and production of rice, cost of paddy cultivation, and rice export will render important policy guidance in allocation of area under rice cultivation, increasing crop diversity, and sustainable rice production.

PROGRAMME-6

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

Rice productivity in rainfed areas has become increasingly threatened by both drought and flooding due to climate change. Identification of new germplasm resources with tolerance to multiple stresses is important for developing climate smart varieties. NRRI-Hazaribag is characterizing rice germplasm with climate resilience and identified many novel sources. During 2022, the station has released three varieties for rainfed drought-prone ecologies of Jharkhand. Simultaneously, production technologies have been assessed to improve and stabilize rice yield under rainfed conditions. Newer diagnostics for rice pathogens, false smut and tungro virus, using RPA techniques have been developed. Demonstrations of new varieties and production technologies have been undertaken along with organizing various workshops to improve the livelihood of farmers in rainfed drought-prone ecologies.

Rice is cultivated widely in Assam under rainfed lowland condition and productivity in the state is less than national average. Low temperature at seedling stage in *boro* season prolongs the crop harvest and recurrent pre-monsoon flood cause heavy crop loss to *boro* and early *ahu* paddy cultivated in lowlands of Assam. Developing thermo-insensitive *boro*, photo-insensitive *sali* and short duration *ahu* rice varieties, coupled with pest management tactics and dissemination of rice-based technologies can improve the production and productivity of rice in Assam.

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

Climate resilient varieties

Three rice varieties namely, CR Dhan 103, CR Dhan 107 and CR Dhan 415 (Table 6.1) were released by SVRC, Jharkhand and notified for cultivation in Jharkhand during the year (Fig. 6.1).

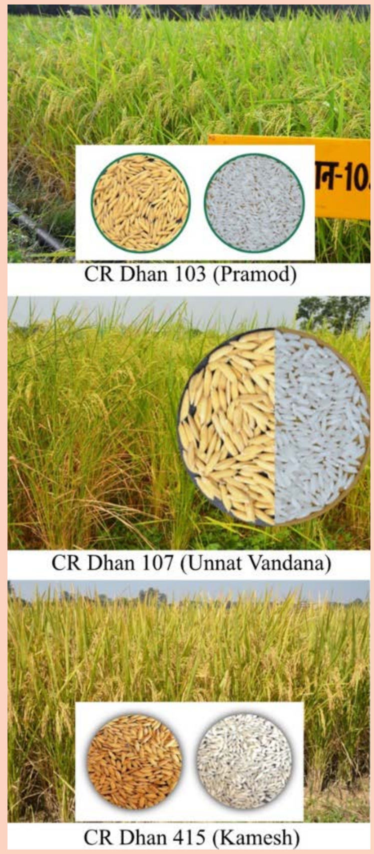


Fig. 6.1. New rice varieties released for Jharkhand.

Identification of multiple stress tolerant rice germplasm

Promising germplasm with tolerance to major abiotic stresses were identified based on multiple years experiments (Table 6.2). Marker-based survey of nine DTY QTLs and *SUB1* locus revealed that 17 accessions were potentially carrying one or more DTY QTLs, while most of the germplasm were positive for *SUB1A-1* allele, however their submergence survival rate varied widely (0.58-92.4%).

Genetic diversity of rice landraces collected from Nagaland

Seventy-eight rice landraces collected from Nagaland were characterized for 38 morpho-agronomic and grain quality traits along with SSR diversity. Factor analysis with all quantitative and qualitative traits

Table 6.1. Salient features of the varieties.

Variety	Ecology	Duration	Salient features
CR Dhan 103	Rainfed DSR (*Tanr*2 / *Don3*)	95-100 days	95-100 days; resistant to blast and brown spot and insect pests; excellent grain quality; yield 2.5 t ha^{-1} .
CR Dhan 107	Rainfed DSR (*Tanr*2 / *Don3*)	90-95 days	Developed through MAS ($qDTY_{2.3}$, $Q\ DTY_{3.2}$ and $DTY_{12.1}$) from Vandana; 90-95 days; yield 3.4 t ha^{-1}
CR Dhan 415	Rainfed(*Don2*)	120-125 days	120-125 days; yield 5-5.5 t ha^{-1}

Table 6.2. Multiple stress tolerant rice germplasm.

Stress	Promising genotypes
Grain yield under drought	Dular, N22, Chakra gora (IC 0640867), Brown gora (IC 0640869), Gora (IC 0640897), White gora (IC 0640859), Dani gora (IC 0640877), Gora (IC-0640871), Kalakeri (IC 0640883), Alsangagora (IC 0640866), Vandana, Gora (IC 0640864), Black gora (IC 0640880), Dani gora (IC 0640872), White gora (IC 0640889), Brown gora (IC 0640860)
Submergence (survival rate > 80%)	Kalakeri, Vandana, Dular, IC 0640897, IC 0640898, IC 0640880
Anaerobic germination(AG) index (> 0.70)	IC 0640882, IC 0640880, IC 0640868, IC 0640885, IC 0640865, IC 0640884, IC 0640881, IC 0640867, Kalakeri, IC 0640871, IC 0640862, Dular
Drought + Submergence + AG	Dular, Kalakeri, IC 0640880, IC 0640865, IC 0640862, IC 0640869, IC 0640896, Vandana

indicated phenotypic distinctness of terrace (TRC) and hill ecotypes. Similar trend was also observed in genetic diversity analysis using SSR markers. STRUCTURE analysis classified the accessions into *indica* and *japonica* group where TRC ecotypes were mostly *indicas* while hill landraces were *japonica* (Fig. 6.2). Sticky rice is preferred for varied specialty purposes. A survey of key polymorphisms in *Waxy* gene using functional markers revealed that Wx^b allele is frequent in landraces with low amylose content.

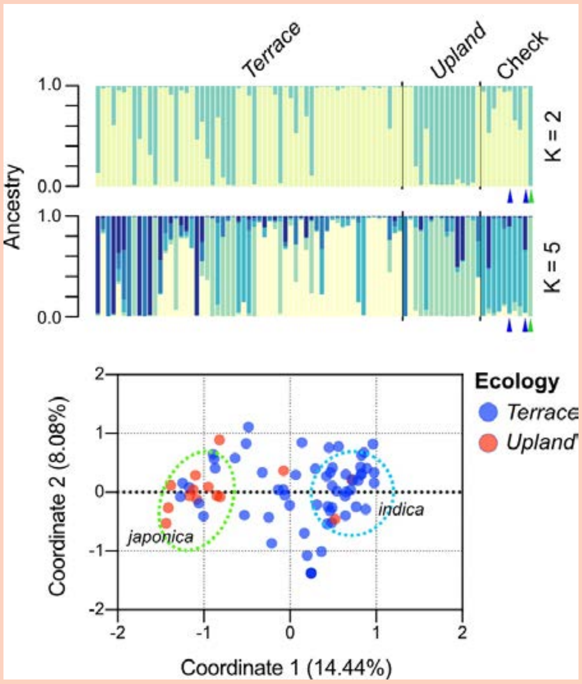


Fig. 6.2. Genetic structure and diversity of Nagaland landraces based on 30 SSR loci. STRUCTURE analysis plots with K value 2 and 5. The tropical japonica check is marked with green triangle, while indica checks are indicated with blue triangles below graph; Principal coordinate analysis with two rice field ecotypes colour coded, while indica and japonica groups outlined.

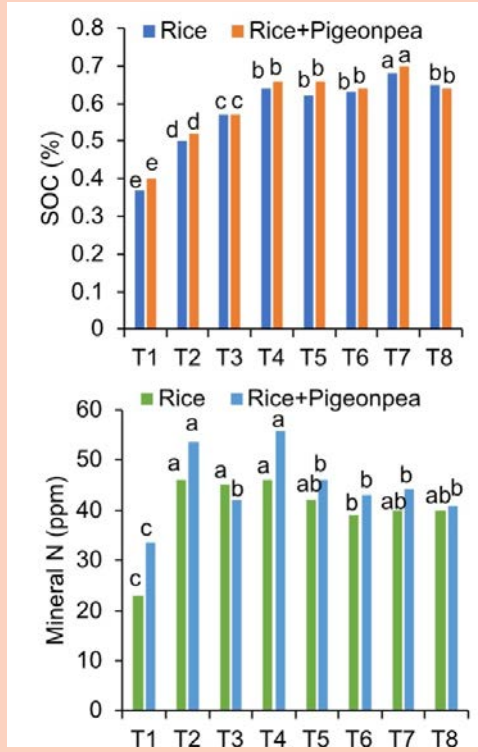


Fig. 6.3. SOC and mineral N content in rice sole and rice pigeon pea intercropping under different nutrient management options. T1 : Control; T2 :100% Recommended dose of fertilizers (RDF)*, T3 : 50% RDF + Farm Yard Manure (FYM) @ 5 t ha-1; T4 :50% RDF +FYM @ 5 t ha-1 + Arbuscular mycorrhiza (AM) 1.5 q ha-1 + Phosphorus Solubilizing Bacteria (PSB) 4 kg ha-1; T5 :50% RDF + Reside Incorporation (RI); T6 :100% FYM @ 10 t ha-1; T7 :100% FYM @ 10 t ha-1 + VAM 1.5 q ha-1 + PSB 4 kg ha-1; T8 :100% FYM @10 t ha-1 +RI.

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

INM for sustainable rice pigeon pea production under drought prone rainfed ecology

The soil samples from rice sole and rice pigeon pea intercropping was analysed for soil organic carbon (SOC) as well as mineral nitrogen contents. Highest SOC was recorded in INM treatment T_4 (50% RDF +FYM @ 5 t ha^{-1} and 50% RDF +FYM @ 5 t ha^{-1} + VAM 1.5 q ha^{-1}+ PSB 4 kg ha^{-1}) which was at par with other integrated options (Fig. 6.3). Overall, T_4 treatment was better to sustain both SOC and N content in soil compared to other nutrient managements. The three years pooled data on grain yield (rice and pigeon pea) also showed that highest REY was recorded in the 100% RDF (3.22 t ha^{-1}) followed by T_4 indicating that INM will be more suited to achieve the good yield as well as improve soil fertility status.

Brown manuring to enhance productivity

To evaluate the effect of brown manuring in rice-based cropping system (RBCS) under drought prone rainfed ecology, rice variety (Sahbhagidhan, CR 205 and CR Dhan 40) with three fertilizer management (no fertilizer, 50% RDF and 100% RDF) and two manure options in *kharif* and mustard and chick pea in *rabi* were evaluated. It was observed in the first-year trial that, main effect of brown manuring on rice grain yield was not significant but the significant effect was observed in *rabi* crops (mustard and chick pea). The interactive effect of brown manuring with fertilizer was significant in both the seasons (Table 6.3).

Biotic stress management strategies for rainfed drought-prone ecologies

Screening and identification of promising rice genotypes for biotic stress tolerance

Eighty-nine phenotypically resistant to moderately resistant rice landraces from north eastern India were screened for presence of eight major blast *R* genes (*Pi2, Pi9, Pi5, Pi54, Pita2, Pib, Pit and Pid2*). Except *Pib,* rest seven genes were detected with the genetic frequency ranging from 2.25% (*Pi9*) to 75.28% (*Pi5*). A list of resistant landraces with *R* gene information is given in Table 6.4 Four resistant accessions (Ngoba, Kisheghi, Neiju and Matikhrurie) devoid of any major blast *R* gene tested could be explored for novel *R* gene identification.

Development of advanced diagnostics for major rice pathogens

RPA-based diagnostics for rapid detection of false smut pathogen (*U. virens*) and rice tungro bacilliform virus (RTBV) has been developed and validated. For false smut, the primer pair Fsm-RPA F1/R1 designed from the GTP binding protein beta subunit (*UVGbeta-1*) gene (GenBank Acc. # GU014921) was able to amplify *U. virens* directly from crude extract prepared from infected rice spikelet at an isothermal condition (37°C) within 30 min (Fig. 6.4). In case of RTBV, the primer RTBV-RPA F3/R3 spanning the RT/RNase H domain of *ORFIII* (GenBank Acc.#FN377814) was able to detect RTBV at an isothermal condition

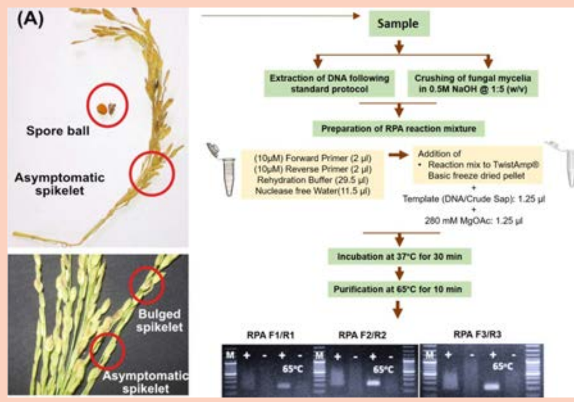


Fig. 6.4. RPA protocol for detection of U. virens from rice panicle.

Table 6.3. Interactive effect of manuring and fertilizer management on productivity of *rabi* crops.

	Chick Pea (q ha^{-1})			Mustard (q ha^{-1})		
Fertilizers	No Manure	Brown manuring	Mean	No Manure	Brown manuring	Mean
No fertilizer	3.20	4.60	3.90^{a}	1.84	2.34	2.09^{a}
50% RDF	5.69	7.96	6.82^{b}	4.62	5.20	4.91^{b}
100% RDF	7.40	9.31	8.36^{c}	4.78	6.90	5.84^{c}
Mean	5.43^{a}	7.29^{b}		3.74^{a}	4.81^{b}	

Table 6.4. Resistant landraces identified against blast disease.

Sl No.	Accessions No.	Cultivar	*R* gene
1	IC 0635838	Komal Dhan	*Pi2*
2	IC 0640925	Amusumicheghe	*Pi54*
3	IC 0635926	Chaha Pota	*Pi2+Pi5+Pi9+Pi54+Pita2+Pit+Pid2*
4	IC 0635825	Maguri Bao	*Pi2+Pi5+Pi54+Pita2+Pid2*
5	IC 0635842	Jol Bao	*Pi2+Pi5+Pi54+Pita2+Pid2*
6	IC 0635879	Ngoba	None detected
7	IC 0635909	Kisheghi	-do-
8	IC 0635915	Neijü	-do-
9	IC 0635921	Matikhrürie	-do-

(39°C) for 30 min from crude leaf extract. The developed assay was validated on Pan-India samples. In future, the developed RPA assay coupled with lateral flow-strip could be useful for early on-site detection of pathogens under field condition.

A total of 210.7 quintals of breeder seeds of 15 varieties (Anjali, Abhishek, CR Dhan 40, Hazaridhan, IR 64 *Drt1*, Sadabahar, Sahbhagidhan, Vandana, Virendra, etc.) were produced to fulfil the DAC indent and other requirements.

Rice production and productivity improvement in rainfed lowland ecosystem

CVRC notified five paddy varieties for release in Assam

The CVRC has notified these five paddy varieties namely, CR Dhan 307, CR Dhan 310, CR Dhan 311, CR Dhan 801 and CR Dhan 802 for release in Assam.

Seed Production

Produced 5445 kg breeder seeds and 2556 kg TL seeds at RRLRRS, Gerua during *boro* 2020-21. CR Dhan 307, CR Dhan 309, CR Dhan 310, CR Dhan 311, CR Dhan 801, CR Dhan 802, CR Dhan 500, CR Dhan 505, CR Dhan 506, CR Dhan 508, CR Dhan 909, BRRI 75 and Bina Dhan 17 were grown in 2.83 ha area during *kharif* 2022 for breeder seed production.

Efficacy of fungicide against Bakanae disease

To study the efficacy of fungicides against rice bakanae disease, root dip treatment of seedlings for two hours in carbendazim and propiconazol before transplanting and spray treatments of both the fungicides at 15 days after transplanting (DAT) were done during *boro* 2021-22. The study revealed that disease incidence was lowest for root dip treatment in propiconazol @ 2 g/ for 2 hours before transplanting followed by root dip treatment in carbendazim @ 2 ml litre^{-1} of water (Table 6.5). The disease incidence was high in foliar spray treatments of both the fungicides at 15 days after transplanting (DAT).

Management of rice stem borer and leaf folder

Application of cartap hydrochloride 4% G @ 20 kg ha^{-1} at 30 days after transplanting (DAT) recorded the lowest dead heart (2.53 and 1.91 %) and leaf folder folded leaves (0.97 and 0.73%) at 45 DAT and 60 DAT (Table 6.6). Cartap hydrochloride 4% G @ 20 kg ha^{-1} recorded the highest yield of 5.25 t ha^{-1} as compared to 3.72 t ha^{-1} in control.

Evaluation of the rice varieties suitable for the coastal saline ecosystems

Coastal ecosystems/ecologies are prone to a variety of climatic extremities like cyclones, floods, water logging conditions, salinity, and inundation of backwaters etc. During *kharif* 2021, four NRRI rice varieties (CR Dhan 307, CR Dhan 403, CR Dhan 409, CR Dhan 412), two NRRI rice genotypes (IET 27051 and IET 27865) were sown under rainfed lowland conditions along with CSR 36, MTU 1061 and MTU 7029 at RCRRS experimental farm to evaluate their performance in lowland coastal ecology. Among the varieties tested, high yield of 7.29 t ha^{-1} was achieved in CR Dhan 412 followed by IET 27865 (6.76 t ha^{-1}), MTU 7029 (6.44 t ha^{-1}), IET 27051(5.81 t ha^{-1}), CR Dhan 307 (5.6 t ha^{-1}), CSR 36 (5.35 t ha^{-1}), MTU 1061 (5.32 t ha^{-1}), CR Dhan 403 (4.75 t ha^{-1}) and CR DHAN 409 (4.57 t ha^{-1}).

Seasonal patterns and forecasting of rice pest in coastal ecosystem

Observations on seasonal incidence of rice insect

Table 6.5. Efficacy of fungicide against rice bakanae disease.

Treatment	Per cent disease incidence			Yield (t ha^{-1})
	15 DAT	30 DAT	40 DAT	
Root dip treatment of seedlings for two hours in propiconazol @ 2 ml/litre of water	2.87	1.57	0.37	4.2
Root dip treatment of seedlings for two hours in carbendazim@ 2 ml/litre of water	3.21	1.25	0.74	3.8
Spray treatments of propiconazol @ 2 ml/litre at 15 days after transplanting (DAT)	4.51	2.57	1.09	3.5
Spray treatments of carbendazim @ 2 ml/litre at 15 days after transplanting (DAT)	4.87	2.88	1.25	3.1
Control	5.61	4.1	3.7	2.9

Table 6.6. Management of rice stem borer and leaf folder.

Treatment	Per cent DH			Per cent LF			Yield (tha^{-1})
	Pre-treatment 30 DAT	45 DAT	60 DAT	Pre-treatment 30 DAT	45 DAT	60 DAT	
Cartap hydrochloride 4%G @ 20 kg ha^{-1}	5.37	2.53	1.91	1.37	0.97	0.73	5.25
Chlorpyrifos 50EC @ 2 ml litre^{-1}	4.97	2.99	1.95	1.40	1.26	0.89	5.23
Azadirachtin 0.03% Neem oil based EC @ 2 ml litre^{-1}	5.34	3.33	2.19	1.32	1.00	0.92	4.75
Pheromone trap @ 1 trap/25 sqm	4.81	2.88	2.09	1.05	1.22	1.58	4.73
Control	5.41	7.70	8.88	1.33	1.45	2.21	3.72
SEd	1.07	1.02	0.93	0.82	0.81	0.86	0.87
CD at p=0.05	NS	1.81	1.66	NS	1.45	1.53	1.54

pest in coastal lowland ecology during *kharif* 2022 was taken across ten locations *viz.,* Salihundam, Poosarlapadu, Amballavalasa, Buravilli-1, Buravilli-2, Naira-1, Naira-2, Byrivanipeta-1, Byrivanipeta-2 and RCRRS, farm in two varieties *viz.,* MTU1061 and BPT 5204. Observations showed that yellow stem borer (YSB) pheromone trap catches are below the economic threshold level (ETL) i.e., <25 moths/ week for the entire observation period (33-48 MSW). The % dead-hearts, % white-heads and folded leaves have crossed ETL i.e. 10% dead-hearts/hill, 10% white-heads/hill and 1 folded leaf/ hill, respectively in almost all the observed MSWs. During *rabi* 2021 seasonal incidence across five locations *viz.,* Aringipeta, Korni, Gara, Salihundam and Poosarlapadu in variety BPT 5204, revealed, YSB pheromone trap catches never crossed the ETL throughout the observation period (10-19 MSW). In the entire observed MSW, the % white-heads and folded leaves crossed the ETL. No false smut infection was found in varieties such as MTU 7029, CR Dhan 409, CR Dhan 409 and CSR 36. The infected varieties showed disease incidence ranging from 6-21% and bearing 10-39 smut balls per panicle.

Diversity of plant parasitic and beneficial nematodes in coastal rice ecosystems

Soil samples were collected from different locations (Gara, Arangipeta, Nakkapeta, Singuvalasa, Singupuram, etc.) in Srikakulam and Gara mandals of the Srikakulam district. Sampling was done at a depth of 20-30 cm from *rabi* sown crops like green gram, finger millet, sesamum, rice, vegetables where paddy was sown as *kharif* crop. In finger millet crop, nematode genera *Tylenchus, Tylenchorhynchus, Aphelenchus, Mononchus, Mylonchulus, Achromadora, Rhabditids, Dorylaimids* were observed. In Sesamum crop, *Meloidogyne, Tylenchus, Rhabditids, Dorylaimids* were observed. *Hirschmaniella* (rice root nematode) is the predominant nematode genus observed in *rabi* rice, which was sown under lowland conditions. Apart from rice root nematode *Dorylaimids*, bacterial feeders like *Cephalobus*, and *Diploscapter* were also observed (Fig. 6.5).

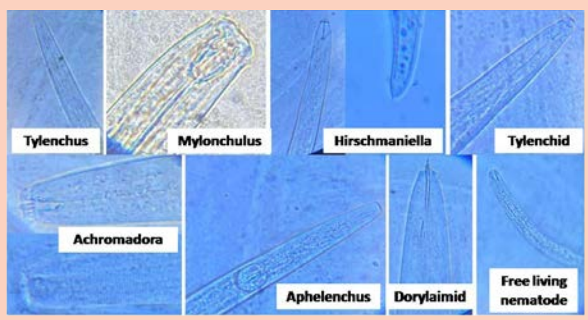
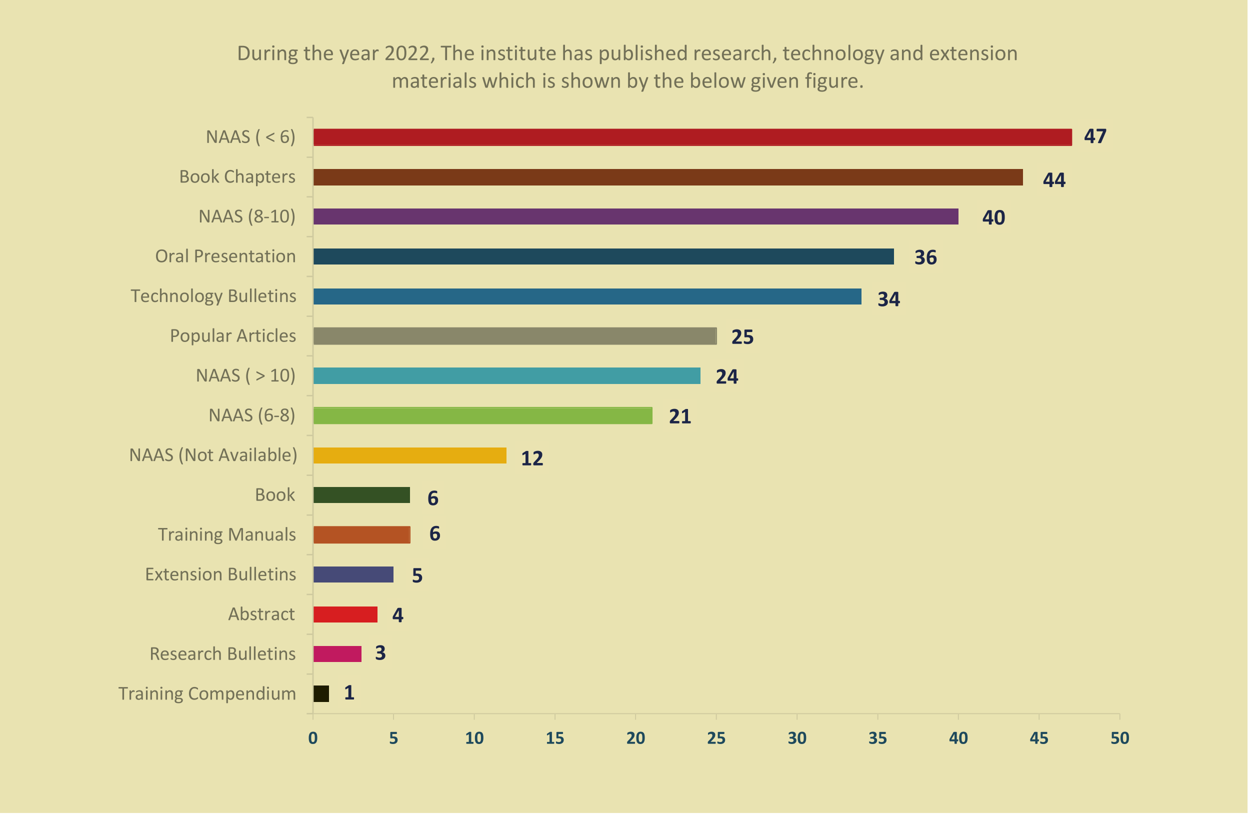


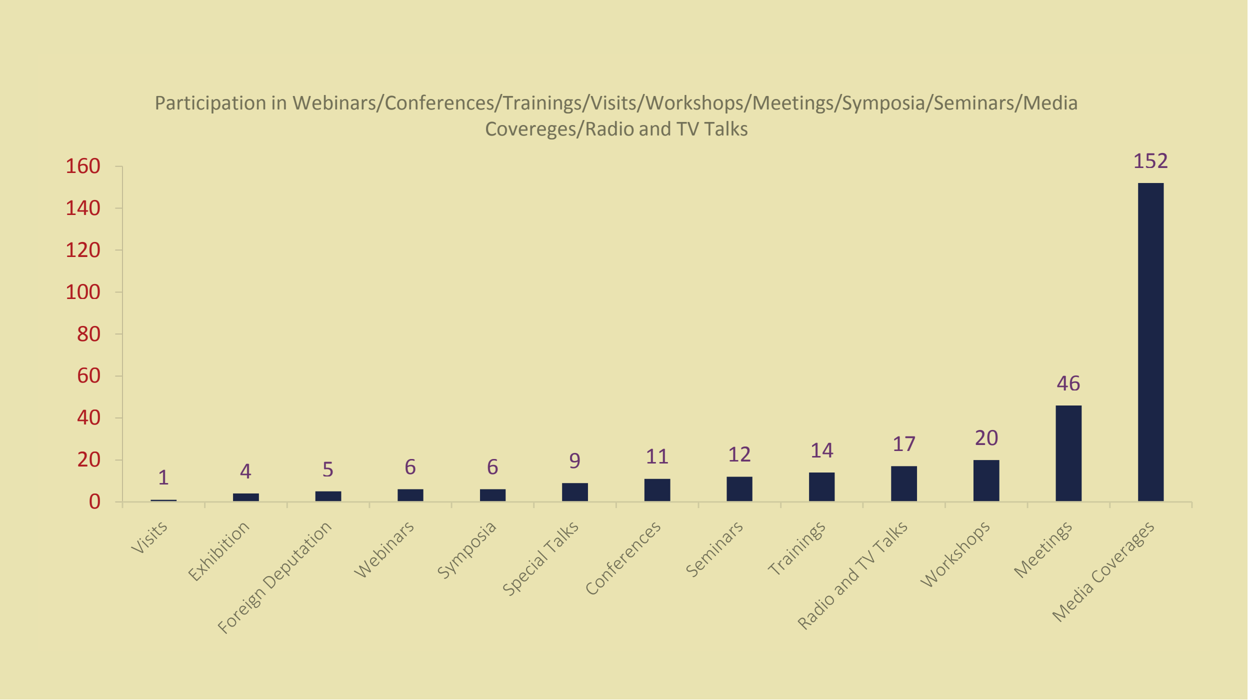
Fig. 6.5. Diversity of nematodes in coastal rice ecology.

Conclusion

NRRI Research Stations situated at Hazaribag, Gerua and Naira have developed and validated several rice varieties suitable to improve the climate resilience of rice production. CRURRS, Hazaribag has developed several rice varieties suitable for drought-prone rainfed ecologies along with crop production technologies to improve the climate resilience of rice production in rainfed drought-prone ecologies. RRLRRS, Gerua has produced breeder seeds of many HYV of rice suitable for the region and supplied to the seed chain of Assam state. Plant protection technologies evolved at the research station benefited the rice farmers in managing insect-pests and diseases of rice in rainfed ecologies. The research and extension activities undertaken through the Program has greatly supported this objective. The farming communities in the target ecologies along with the students have also been benefited through regular demonstrations, workshops and hands on training organized on various aspects of crop management.

Publications & Participation in Scientific Events





Activities and Events Undertaken

During the year 2022, ICAR-NRRI has organized several events and conducted diverse set of routine and extracurricular activity to comply with the council's vision and the Government of India programmes. The brief account of the undertaken events and activities are as follow-

A. Activities:

Activities	Distinguished participants
28th Research Advisory Committee (RAC) Meeting, 3-4 November 2022	Prof. SK Sopory (C), Dr. KK Jena (M), Dr. BC Viraktamath (M), Dr. AR Sharma (M), Dr. VV Sadamate (M), Dr. Chandish R Ballal (M), Shri PK Sahu (M), Shri A Mishra (M), Dr. BC Patra (M), Dr. RM Sundaram (SI), Dr. Sanghamitra Samantaray (MS)
35th Institute Management Committee (IMC) Meeting, 4 November 2022	Dr. BC Patra (C), Dr. SK Swain, Director, Research, OUAT, Bhubaneswar (M), Dr. RK Khatua, Director (A&FP), Dr. P.K. Mandal, PS, ICAR-NIPB, New Delhi, Shri S Ray, PS, NBSS & LUP Regional Centre, Kolkata, Dr. M. S. Madhav, PS, ICAR-IIRR, Hyderabad, Dr. N. Ravishankar, PS, ICAR-IIFSR, Modipuram, Shri J Biswal, FAO, ICAR-IIWM, Bhubaneswar, Dr. S Samantary (I), Dr. AK Nayak (I), Dr. PC Rath (I), Dr. MJ Baig (I), Dr. GAK Kumar (I), Shri A Mishra, (Non-Official) (M), Shri PK Sahu, (Non-Official) (M), Shri CP Murmu, AAO (I), Shri SK Sahu, AAO (I), Shri S.K. Behera, AAO (I), Shri NP Behura, Assistant (I), Shri DK Parida, Assistant (I) and Shri V Ganesh Kumar, Sr. AO, NRRI, (MS)
42nd Institute Research Council (IRC), 18 to 21 July 2022	Dr. Padmini Swain, (C), Dr. B Mondal (MS), Head of Divisions and Scientists of the Institute and KVKs
1st Institute Joint Staff Council (IJSC) Meeting, 28 May 2022	Dr. (Mrs.) Padmini Swain (C), Dr. MJ Baig, PS, Dr. R Tripathi, Sr. Scientist, Dr. B Gowda, Scientist, Shri V Ganesh Kumar, Sr. AO, Dr. SK Das, Sr. F& AO, Shri M Mohanty, Assistant, Shri NP Behura, Assistant, Shri SK Rout, TO, Shri PK Jena, TO, Shri B Pradhan, Sr. Technician (Secretary staff side), Shri D Naik, SSS, Shri B Naik, SSS, Shri B Naik, SSS and Shri SK Jena, AO (Secretary official side)
The 23rd Scientific Advisory Committee meeting of KVK, Cuttack, 19 May 2022	Dr. (Mrs.) Padmini Swain (C)
The Scientific Advisory Committee meeting of KVK, Koderma on 18 January 2023	Dr. NP Mandal (C)

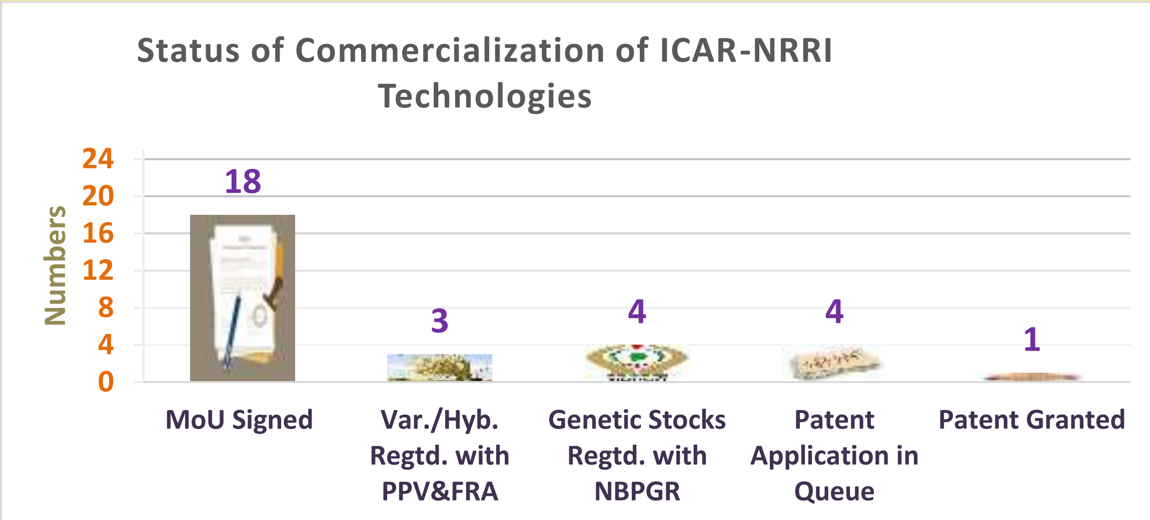
C: Chairman; M: Member; MS: Member Secretary; I: Invitee

B. Programmes and Events

Sl. No.	Events	Participants
1.	National Girl Child Day on 24 January 2022	50
2.	4th World Pulse Day on 10 February 2022 NRRI, Cuttack, KVK, Cuttack	150
3.	A seminar on "Agromet services playing a catalytic role in doubling farmers income" on 3 March 2022 KVK, Cuttack	100
4.	International Women's Day, 2021 on 8 March 2021, NRRI, Cuttack, KVK, Cuttack, KVK, Koderma	50
5.	A Hindi workshop on 30 March 2022	30
6.	Official language implementation committee (OLIC) of the institute for the quarter ending January-March, 2022 on 30 March 2022	30
7.	77th Foundation Day and Dhan Diwas on 23 April 2022	250
8.	Farmers' Fair "Bharatiya Prakritik Krishi Paddhati" on 26 April 2022 under Azadi Ka Amrit Mahotsav, KVK, Cuttack	200

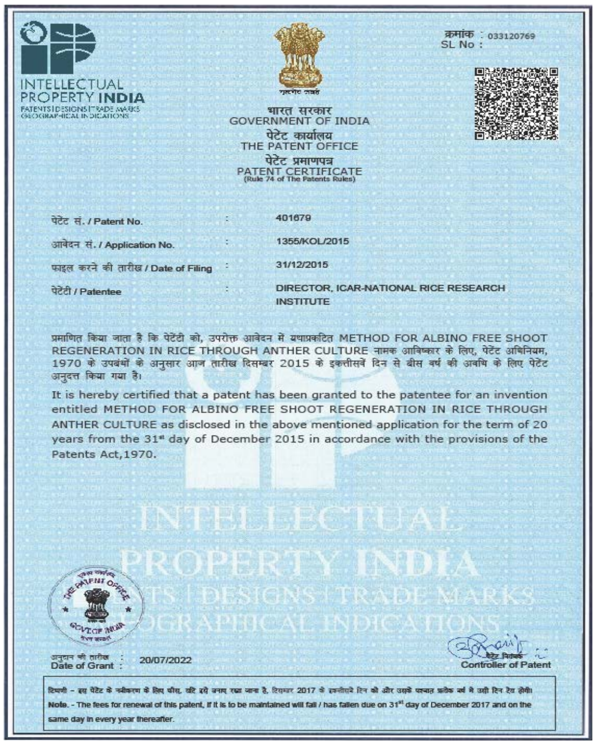
9.	Kisan Bhagidari, Prathmikta Hamari Campaign under *Azadi Ka Amrut Mahotsav* on 28 April 2022	290
10.	Pension Adalat on 5 May 2022	50
11.	Biocontrol laboratory and NRRI Rice Processing Unit inaugurated by Dr. Trilochan Mohapatra, Secretary DARE and DG, ICAR on 21 May 2022	100
12.	Invited talk on 'Waste to Wealth' delivered by Mrs. Ananya Das, IAS, Commissioner, Cuttack Municipal Corporation under Swachha Bharat Abhiyan on 25 May 2022	100
13.	Farmers' fair at KVK, Cuttack under the programme "Garib Kalyan Sammelan" on 30 May 2022	572
14.	Garib Kalyan Sammelan under *Azadi Ka Amrut Mahotsav* at Mahanga, Cuttack on 31 May 2022	2000
15.	An awareness programme World Milk Day by KVK, Cuttack on 1 June 2022	110
16.	Health camp on 4 June 2022	200
17.	Blood Donation Camp on 14 June 2022	102
18.	The 8th International yoga day (IYD) on 21 June 2022 NRRI, Cuttack, CRURRS, Hazaribag, KVK, Cuttack	100
19.	One-day Awareness Programme on Protection of Plant Varieties and Farmer's Rights (PPV&FR) Act 2001, Biological Diversity Act 2002 and Conservation and cultivation of Indigenous/Aromatic Rice Varieties on 16 June 2022	100
20.	A stakeholders meet on 'Value-Chain Nutrition' on 27 June 2022	50
21.	Launching a collaborative nutritional campaign on 'Inclusion of fish in daily diet for health promotion" on 29 June 2022	54
22.	*Parthenium* awareness week during 16-22 August 2022, CRURRS, Hazariabg	150
23.	A workshop on "Empowering women groups through entrepreneurship development" on 9 September 2022	300
24.	World Zoonosis Day Awareness Campaign-cum-Animal Health & Rabies Vaccination Camp 6 July 2022	50
25.	Hindi Diwas organized on 14 September 2022	60
26.	National campaign on Poshan Abhiyan and Tree Plantation on 17 September 2022	60
27.	World Rabies Day Awareness Campaign	3500
28.	PM Kisan Samman Sammeal on 17 October 2022	35
29.	XXVI Meeting of ICAR Regional Committee -II on 14 October 2022	200
30.	World Egg Day on 14 October 2022; KVK, Cuttack	252
31.	Mahila Kisan Diwas on 15 October 2022; KVK, Cuttack	52
32.	World Food Day on 16 October 2022; KVK, Cuttack	58
33.	PM Kisan Sammelan on 17 October 2022	35
	Hindi Fortnight-2022 was observed	75
34.	Vigilance Awareness Week was observed from 31st October to 6th November 2022	110
35.	Workshop on, "Promoting rice export from Odisha: strengths, opportunities and constraints on 21 November 2022	50
36.	ICAR-NRRI, Cuttack demonstrated Drone technology in more than 100 acres area from 28 October to 7 November 2022	1000
37.	World Soil Day on 5 December 2022; NRRI, Cuttack, KVK, Cuttack	110
38.	A launching workshop titled 4S4R Model for Production, Marketing and Export of Odisha Aromatic Rice (*arORIce*) on 7 December 2022	75
39.	Secretary (DARE) & Director General (ICAR) Dr. Himanshu Pathak visits ICAR-NRRI, Cuttack on 26 December 2022	150
40.	Swachhata Pakhwada- 2022 16-31 December, 2022	300

Commercialization of ICAR-NRRI Technologies



Patent Granted

Patent Granted for invention of Method for Albino Free Shoot Regeneration in Rice through Anther Culture on 20 July 2022 with patent No. 401679 – Sanghamitra Samantaray, Nupur Naik, Prachitara Rout, RL Verma, JL Katara, U Ngangkham, Soham Roy, Awadhesh Kumar and ON Singh.



INTELLECTUAL PROPERTY INDIA
PATENTS | DESIGNS | TRADE MARKS | GEOGRAPHICAL INDICATIONS

क्रमांक : 033120769
SL No :

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

पेटेंट सं. / Patent No.	:	401679
आवेदन सं. / Application No.	:	1355/KOL/2015
फाइल करने की तारीख / Date of Filing	:	31/12/2015
पेटेंटी / Patentee	:	DIRECTOR, ICAR-NATIONAL RICE RESEARCH INSTITUTE

प्रमाणित किया जाता है कि पेटेंटी को, उपरोक्त आवेदन में यथाप्रकटित METHOD FOR ALBINO FREE SHOOT REGENERATION IN RICE THROUGH ANTHER CULTURE नामक आविष्कार के लिए, पेटेंट अधिनियम, 1970 के उपबंधों के अनुसार आज तारीख दिसम्बर 2015 के इकत्तीसवें दिन से बीस वर्ष की अवधि के लिए पेटेंट अनुदत्त किया गया है।

It is hereby certified that a patent has been granted to the patentee for an invention entitled METHOD FOR ALBINO FREE SHOOT REGENERATION IN RICE THROUGH ANTHER CULTURE as disclosed in the above mentioned application for the term of 20 years from the 31st day of December 2015 in accordance with the provisions of the Patents Act,1970.

अनुदान की तारीख :
Date of Grant : 20/07/2022

पेटेंट नियंत्रक
Controller of Patent

Note. - The fees for renewal of this patent, if it is to be maintained will fall / has fallen due on 31st day of December 2017 and on the same day in every year thereafter.

Awards and Recognition

During the year 2022, ICAR-National Rice Research Institute and its staff members have bagged several prestigious awards. The details of the awards are given below.

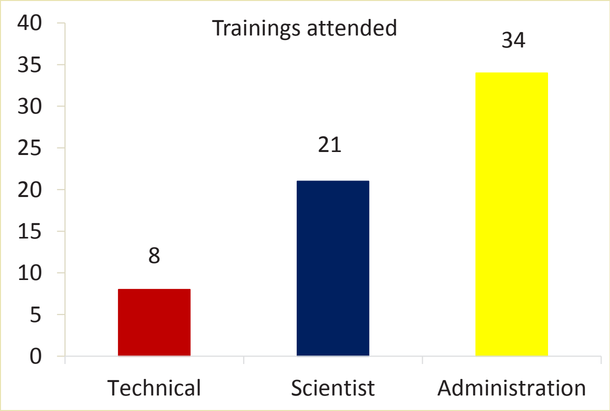
1.	Dr. A.K. Nayak, Director, ICAR-NRRI has been elected Fellow of The National Academy of Sciences, India (NASI) in the year 2022 for his pioneering work involving Crop natural resources management/carbon sequestration/ climate change : Adaptation and Mitigation.
2.	Dr. Koushik Chakraborty received the prestigious Lal Bahadur Shastri Outstanding Young Scientist Award – 2021 of ICAR in the category of Crop & Horticultural Sciences during the 94th Foundation Day and Award Ceremony of ICAR on 16 July 2022.
3.	Dr. Rahul Tripathi received the prestigious Lal Bahadur Shastri Outstanding Young Scientist Award – 2021 of ICAR in the category of Natural Resource Management & Agricultural Engineering during the 94th Foundation Day and Award Ceremony of ICAR on 16 July 2022.
4.	Dr. Dibyendu Chatterjee received prestigious membership of Indian National Young Academy of Sciences (INYAS) for a period of 5 years beginning February 2022 (https://inyas.in/).
5.	Dr. Rahul Tripathi received NAAS Associate 2022 from the National Academy of Agricultural Sciences, New Delhi from 1st January 2022.
6.	Dr. Somnath Roy received Dr. R.S. Paroda Young Scientist Award 2021 by Indian Society of Plant Genetic Resources, New Delhi.
7.	Dr. K.A. Molla received INSA Young Scientist Award at 88th Anniversary General Meeting at Visakhapatnam on 16 December 2022.
8.	Dr. P. Panneerselvam was awarded with "Fellow of Scholars Academic and Scientific Society (FSASS Membership ID: SAS/FSASS/527/2022).
9.	Dr. SD Mohapatra inducted as Fellow of the Society for Biocontrol Advancement Bengaluru, India, 2022
10.	Dr. Rahul Tripathi received the Outstanding Scientist award from "Outlook Agritech and Swaraj Awards 2022" on 14 September 2022 in NASC Complex, New Delhi.
11.	Dr. RK Mohanta received Dr. C.M. Singh Veterinary Science Excellence Award 2022 from Pashudhan Praharee on the occasion of World Veterinary Day 2022.
12.	Dr. Annie Poonam received Women Scientist Award 2022 at International conference on advances in agriculture technology and allied sciences (ICATAAS) organized by the Society of Agricultural Research and Social Development, MS Swaminathan School of Agriculture, Centurion University of Technology and Management (CUTM), Parlakhemundi, Odisha.
13.	Dr. P. Panneerselvam was invited as one of the Advisory panel experts by Tamil Nadu Agricultural University, Coimbatore for brain-storming workshop on researchable issues in Agricultural Microbiology on 16 September 2022.
14.	Dr Basana Gowda G was appointed as Review Editor in Frontiers in Physiology (Section: Invertebrate Physiology) and Academic editor, PlosOne.
15.	Dr. AK Mukherjee has been selected as Editor in Chief of the Journal of Plant Disease Sciences, ISSN: 0973-7456, (NAAS ID J435).
16.	Dr. Guru Pirasanna Pandi G has been appointed as Associate Editor of Indian Journal of Entomology and Oryza.

17.	Dr. Basana Gowda G, Scientist, received young Entomologist award at 3^{rd} National symposium on Entomology 2022: Innovation and Entrepreneurship at PJTSAU, Hyderabad, 8-10 December, 2022.
18.	Dr. K Chakraborty selected as 'Associate Editor' of the journal 'Plant Physiology Reports' published by Indian Society for Plant Physiology
19.	Dr. PS Hanjagi selected as 'Sectional Editor' of the journal Oryza published by Association of Rice Research Workers
20.	Dr. Basana Gowda G, Scientist, received SBA-Dr. T. M. Manjunath young Scientist award for significant contributions to Biological control research on 15^{th} December, 2022 from Society for Biocontrol Advancement, ICAR-NBAIR, Bengaluru
21.	Dr. MK Bag elected as executive council member and inducted as editorial board member of Indian Mycological Society, Kolkata
22.	Dr. Debarati Bhaduri received SERB-Power Grant from Department of Science & Technology (DST), Govt. of India
23.	Dr. U Kumar received AZRA Young Scientist Award-2022 in AZRA International Conference during 10-12 November 2022 at Hotel Suryansh, Bhubaneswar, Odisha
24.	Dr. Manish Debnath received Young Scientist Award in the 4^{th} International conference on Environment and Society during 23-24 December 2022 held at Gwalior, MP, India
25.	Dr. DR Sarangi was elected as a Councilor (East Zone) to the executive body of Association of Rice Research Workers for 2022-2023.
26.	Dr. RK Mohanta acted as a member of a committee for preparing the score card for the evaluation of K. Pradhan Young Scientist Award, ANSI Best M.V. Sc. Thesis Award and S.K. Ranjhan Award (for Ph.D Thesis) for Animal Nutrition Society of India.
27.	Dr. RK Mohanta has been inducted into the Publication Committee of Indian Journal of Animal Nutrition for the Biennium 2022-23.
28.	Dr. RK Mohanta was elected as a member of Executive Body of Animal Nutrition Association for the Biennium 2022-2023.

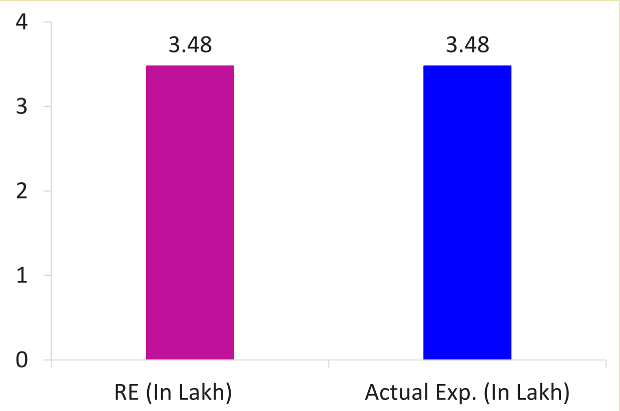
Human Resources Development and Capacity Building

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

Physical targets and achievements of HRD Cell

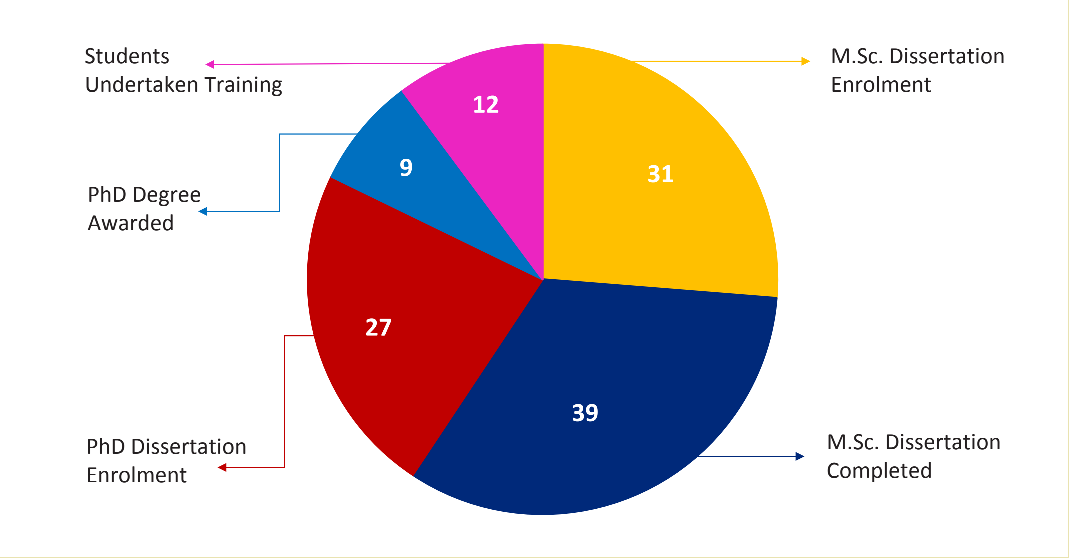


Financial targets and achievements of HRD Cell



During the year 2022, 39 M.Sc. Students completed their dissertations; 27 students have enrolled for PhD programme; 9 PhD students have completed dissertations.

Achievements of the HRD programmes for the students during 2022



Extension Activities

To impart knowledge and develop skill to various groups of stakeholders, ICAR-NRRI, Cuttack had undertaken several extension activities during 2022 as detailed below:

Field demonstrations

Several field demonstrations of newly released rice varieties and crop production as well as protection technologies in the farmers' field were conducted. About 20 promising rice varieties were demonstrated with 1576 farmers in about 11 states of the country which include Andhra Pradesh, Assam, Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Maharashtra, Odisha, Telangana and West Bengal. under '**IN**novative extension model for fast **SP**read of varieties **I**n**R**ice **E**cosystems' (INSPIRE 1.0) Model with the support of Krishi Vigyan Kendras (KVKs) and state agriculture department officials and INSPIRE 2.0 model initiated in collaboration with private institutions, like non-government organizations (NGOs), corporate social responsibility (CSR) units, and farmers' producers' organizations (FPOs). Further, demonstrations were also conducted to showcase the production and protection technologies, demonstrations under Farmer's FIRST Programme, SCSP and TSP programmes. The CRURRS, Hazaribag also conducted Front Line Demonstrations on drought tolerant rice variety IR 64 *Drt1* under ICAR-IRRI Collaborative project.

Exhibitions

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

Visitor's advisory services

Physical visits by different categories of visitors improved little bit as compared to earlier two years due to relaxation of COVID restrictions. A total of 3253 visitors comprising of farmers & farm-women, students and agriculture officers from the states of Jharkhand, Karnataka, Odisha, Tamil Nadu, Telangana and West Bengal visited experimental sites and demonstration plots, net houses, agricultural implement workshop and *Oryza* museum of the institute during the year.

Fortnightly agro-advisory services

Overall 24 agro-advisories on rice were issued on fortnightly basis in English as well as Odia language during the year 2022. The advisories were sent by e-mail to the officials of agriculture and related departments of the state as well as uploaded in Institute website for public awareness and reference. In addition, block wise weather forecast based agro-met advisory bulletins of Cuttack district were issued 4-5 times per month. Advisories were also issued through 'NRRI Video *Barta*' every fortnight and circulated through social media for wider reach.

Training programmes for farmers and extension professionals

A total of 1376 participants including farmers, extension officials, administrative personnel and others were trained through 24 programmes of different durations (2-8 days) conducted physically or through virtual mode on various aspects of rice production and protection technologies.

Mera Gaon Mera Gaurav (MGMG) Programme

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

Tribal Sub-Plan (TSP) Programme

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

Scheduled Caste Sub-Plan (SCSP) Programme

During the year 2022, under SCSP programme four more villages were selected in addition to earlier adopted six villages. During *kharif* 2022, 101.15 quintal paddy seeds of improved varieties were distributed to 953 farmers and bio-control agents (1000 tricho-cards) were provided for control of pest. Total 15 User Groups (UGs) were created (all farmers are member of one or other group) through Gramsabha meeting at each selected villages and 84 large machines were distributed for creation of custom-hiring centre. A total of 1104 number of medium equipment/ machinery like sprayer, power thresher, pump sets, etc. were distributed to the 555 beneficiaries as per the need assessed. Small tools like cono-weeders, spade, wrench, hammer, crowbar, sickle and household items like thermosflask, grain storage container, tarpaulin etc. (4894 number of items to 904 beneficiaries). Seven exposure visits were organized and about 520 farmers visited the Institute to see the research and demonstration farms and had interaction with the scientists. During the year total 16 training and capacity building programme were organised to upgrade the skill of 901 farmers, artisans and SHG women.

NEH Programme

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

Personnel (January-December 2022)

Dr. Amaresh Kumar Nayak, Director

CROP IMPROVEMNENT DIVISION

Scientist								
S Saman-taray (I/C Head)	ON Singh	BC Patra	MK Kar	SK Pradhan*	LK Bose	K Chatto-padhyay	L Behera	SK Dash
H Subudhi	A Anandan*	M Cha-karaborti	J Meher	RL Verma	S Sarkar	Md Azhar-ud-heen TP	RP Sah	BC Marndi
P Sang-ha-mitra	JL Katara	K Ali Molla	Parames-waran C	Devanna	Anil Kumar C	Reshmi Raj K.R.		
Technical Staff								
B Nayak	JS Anand	PL Dehury	LK Singh	M Soren	N Barik	KC Mallik	B Mondal	B Mishra
D Nayak	D Samal	B Behera	A Parida	D Majhi	B Hembram	B Ray	M Patra	S Sarkar
R Rana	KC Munda							
Administrative Staff								
M Swain								
Skilled Support Staff								
B Bhoi	G Dei	J Biswal	P Dei					

CROP PRODUCTION DIVISION

Scientist								
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S Munda	A Kumar	D Chatter-jee	D Bhaduri	U Kumar	PC Jena	BN Totaram	PK Guru	S Chaterjee
M Debanath	R Khanam	M Siva-sha-nkari	BR Goud	S Priyadar-sani	K Kumari			
Technical Staff								
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BC Behera	KC Palaur	PK Jena	R Jamunda	S Panda	PK Parida	SC Sahoo	SP Lenka	P Samantaray
EV Ramaiah	S Baskey	G Mandi	A Pal	PK Ojha	D Parida	D Baral	D Behera	G Bihari
S Mohanty	CK Ojha	S Pradhan	R Beshra	JK Sahu	S Kumar	KK Meena	SP Sahoo	TK Behera
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CROP PROTECTION DIVISION

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Kiran Gandhi B	B Gayatri							
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KVK, Santhpur

Technical Staff								
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Nil								

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Skilled Support Staff								
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Administrative Section

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SK Sahu	RK Behera	RC Das	R Kido	N Mahavoi	D Khuntia	N Jena	MB Swain	S Sahoo
NP Behura	SK Sahoo	M Mohanty	SK Nayak	DK Parida	MK Sethi	KC Behera	PC Das	
AK Pradhan	RC Pradhan	V Kumar	SK Lenka	SK Sahoo	M Das	RC Nayak	S Pradhan	A Sethi
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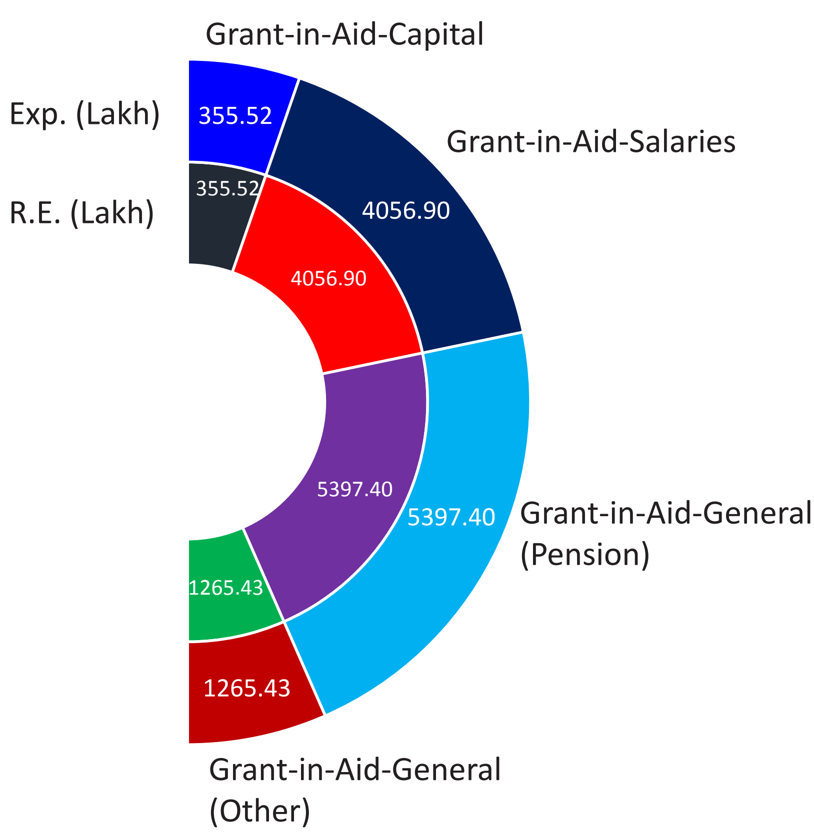
Canteen Staff

A Jena	R Naik	B Naik	P Naik	B Naik	B Das			

Financial Statement (January-December 2022)



Institute Research Programmes for the Year 2022-23

Code No.	Title of the Projects	Programme Leader (PL), Principal Investigator (PI) and Co PIs
Programme 1: Genetic improvement of rice for enhancing yield, quality, and climate resilience		
1.1	Managing Rice genetic resources for sustainable utilization	BC Patra, BC Marndi, P Sanghamitra, S Samantaray, M Chakraborty, JL Katara, Md Azharudheen TP, Anilkumar C, Devanna, Parameswaran C, NN Jambhulkar, Somnath Roy
1.2	Maintenance Breeding and Genetic dissection of seed Quality Traits.	BC Marndi, RP Sah, Md Azharudheen TP, Anilkumar C, AK Mukherjee, Awadhesh Kumar, NKB Patil, Raghu S, Annamalai M, Gourav Kumar, BC Patra, GAK Kumar
1.3	Pre-breeding for broadening the genetic base of rice by utilizing wild species of Oryza	MK Kar, LK Bose, M Chakraborti, S Samantaray, Md Azharudheen TP, BC Patra, SK Dash, KA Molla, P Sanghamitra, JL Katara, Parameshwaran C, Devanna, PC Rath, S Lenka, AK Mukherjee, Guru Pirasanna Pandi G, S Sarkar Associates: P Swain, K Chakraborty, NP Mandal, Awadhesh Kumar, N Basak, Gaurav Kumar, BC Marndi
1.4	Developing genetic solutions for enhancing input use efficiency in rice for rainfed and irrigated ecologies	A Anandan/J Meher, J Meher, RP Sah, Parameswaran C, SK Dash, LK Bose, Reshmi Raj KR, P Swain, P Panneerselvam
1.5	Breeding for Aroma and Grain Quality in Rice	S Sarkar, MK Kar, K Chattopadhay, SK Dash, HN Subudhi, B Mondal, J Meher, M Chakraborti, S Roy, A Banerjee, TB Bagchi, P Sanghamitra, N Basak, Basana Gowda G, Sivashankari M, Reshmi Raj KR
1.6	Gene mapping and precision breeding for enhancing climate resilience in lowland varieties	SK Pradhan/SK Dash, RP Sah, Md Azharudheen TP, P Sanghamitra, Reshma Raj KR, M Annamalai, Sushma M Awaji, L Behera Associates: AK Mukherjee, MK Bag, P Hanjagi, Guru Pirasanna Pandi G, K Chakraborti, J Meher, Devenna, S Lenka, LK Bose
1.7	Genetic Enhancement for Multiple Stress Tolerance in Rice for Coastal Ecosystem	K Chattopadhyay, BC Marndi, K Chakraborty, LK Bose, KR Rao, A Poonam, KA Molla Associates: Devanna, AK Nayak, SD Mohapatra, AK Mukherjee
1.8	Hybrid rice for enhancing yield, quality and sustainability	RL Verma, JL Katara, Reshmi Raj KR, S Sarkar, S Samantaray, Parameswaram C, BC Patra, SK Dash, Devanna, Priyamedha Associates: SD Mohapatra, AK Mukherjee, N Mondal, BC Marndi
1.9	Development of New Generation Rice for enhancing yield potential in favourable ecology	SK Dash, MK Kar, J Meher, HN Subudhi, S Sarkar, L Behera, JL Katara, Parameswaran C, Devanna, Anilkumar C, RL Verma, LK Bose, S Roy, SD Mohapatra, P Swain, A Banerjee
1.10	Utilization of genome editing, transgenics and doubled haploid technologies for rice improvement	S Samantaray, Devanna, Parameswaran C, JL Katara, KA Molla, RL Verma, Anilkumar C, Reshmi Raj KR, Awadhesh Kumar, Sushma M Awaji, Jeevan B Associates: SK Lenka, Raghu S, Basana Gowda G
1.11	Development of Novel Genomic Resources for Rice Improvement	L Behera, Devanna, Parameswaran C, RP Sah, Md Azharudheen TP, M Chakraborti, J Meher, Guru Pirasanna Pandi G, Raghu S, P Hanjagi, Awadhesh Kumar, SK Dash, SK Pradhan, MK Kar
Programme 2: Enhancing the productivity, sustainability and resilience of the rice-based system		
2.1	Enhancing nutrient use efficiency in rice through advance agronomy using smart sensors, models and nano fertilizers	S Mohanty, AK Nayak, Rahul Tripathi, D Bhaduri, D Chatterjee, Anjani Kumar, Md Shahid, U Kumar, R Khanam, BC Verma, B Raghavendra Goud
2.2	National level zonation of rice ecologies, site specific planning and development of cropping and farming system models	A Poonam, Rahul Tripathi, BS Satapathy, D Chatterjee, B Raghvendra Goud, Kavita Kumari, NN Jambhulkar Associates: S Saha, M Nedunchezhian, SC Giri, GC Acharya, SK Lenka, Basanna Gowda G, U Kumar, SM Prasad
2.3	Vulnerability analysis and assessment of climate smart agricultural technologies for enhancing resilience in stress prone rice ecologies	M Shahid, AK Nayak, R Khanam, D Chatterjee, S Mohanty, D Bhaduri, S Munda, Rahul Tripathi, P Bhattacharyya, BB Panda and B Mondal
2.4	Developing agronomy for new generation rice and rice-based cropping systems	BB Panda, BS Satapathy, Anjani Kumar, S Munda, SK Dash, B Raghavendra Goud
2.5	Ecosystem services quantification and analysing the nexus of climate change-land use change-food security in rice production systems	Rahul Tripathi, AK Nayak, Md Shahid, P Bhattacharyya, S Mohanty, D Bhaduri, D Chatterjee, BB Panda, S Priyadarsani, B Mondal, JP Bisen, B Raghvendra Goud
2.6	Environment friendly management of rice straw and value addition for income generation to rice-farmers.	P Bhattacharyya, AK Nayak, D Bhaduri, P Panneerselvam, S Munda, B Satapathy, NT Borkar, S Priyadarsani, Sivashankari M, Kavita Kumari, BC Verma

2.7	Harnessing microbiome for enhancing rice productivity and improving soil health.	P Panneerselvam, U Kumar, Guru Pirasanna Pandi G, Parameshwaran C, Anjani Kumar, AK Nayak
2.8	Development of weed management strategies and assessing the risk of herbicide resistance in rice weeds	S Saha, S Munda, BS Satapathy, B Mondal, Kavita Kumari, B Raghavendra Goud
2.9	Development and Refinement of Farm implements, Post-harvest and Value addition Technologies for small farm mechanization	Sivashankari M, NT Borkar, S Priyadarsani, TB Bagchi, Awadhesh Kumar Associates: P Panneerselvam, S Sarkar
2.10	Enhancing water use efficiency in rice-based cropping system	Anjani Kumar, AK Nayak, Rahul Tripathi, BB Panda, Kavita Kumari, D Chatterjee, R Khanam, PS Hanjagi, BC Verma, B Raghavendra Goud, D Jena Associates: D Bhaduri, S Munda, S Mohanty, P Panneerselvam
Programm 3: Biotic Stress Management in Rice		
3.1	Identification and characterization of donors against biotic stresses	MK Bag, PC Rath, AK Mukherjee, SD Mohapatra, S Mandal, S Lenka, Guru Pirasanna Pandi G, NKB Patil, Basana Gowda G, A Banerjee, Annamalai M, Raghu S, SR Prabhukartikeyan, MS Baite, Keerthana U, Prasanthi G, Rupak Jena, Jeevan B Associate: MK Kar
3.2	Ecology, diversity and interaction of plant, pests & natural enemies in rice	KR Rao, SD Mohapatra, Guru Pirasanna Pandi G, Annamalai M, Gourav Kumar, M K Bag, A K Mukherjee, U Keerthana, Prasanthi G, Prabhukarthikeyan SR, G Gayatri, Kiran Gandhi B Associates: T Adak, Basana Gowda G
3.3	Use of Precision Tools and Techniques in Rice Insect Pest and Disease Management	SD Mohapatra, Rahul Tripathi, Raghu S, MS Baite, NN Jambhulkar
3.4	Search for novel mediators in plant defense response to pathogenic infections in rice through molecular techniques	AK Mukherjee, S Mandal, Raghu S, Guru Pirasanna Pandi G, Prabhukarthikeyan SR, KA Molla, MS Baite, P Golive, TB Bagchi, Devanna,
3.5	Plant protection molecules: efficacy, distribution, toxicity and remediation	T Adak, PC Rath, MK Bag, S Lenka, Prabhukarthikeyan SR, Annamalai M, MS Baite, Raghu S, Basana Gowda G, NKB Patil, Guru Pirasanna Pandi G, U Kumar, Rupak Jena, Jeevan B Associates: AK Mukherjee, P Bhattacharyyaa
3.6	Dissemination of integrated pest management strategies for insect pest, diseases and nematodes in rice	Guru Pirasanna Pandi G, PC Rath, AK Mukherjee, SK Lenka, SD Mohapatra, T Adak, NKB Patil, Basana Gowda G, Annamalai M, Raghu S, MK Bag, Prabhukarthikeyan SR, MS Baite, GAK Kumar, A Banerjee, Rupak Jena, Jeevan B
Programm 4: Photosynthetic Enhancement, Abiotic Stress Tolerance and Grain Nutritional Quality in Rice		
4.1	Photosynthesis and productivity of rice under changing climate	MJ Baig, P Swain, K Chakraborty, KA Molla, PS Hanjagi, N Basak, Gaurav Kumar, Susma M Awaji
4.2	Evaluation of rice genotypes for new sources of multiple abiotic stress tolerance and understanding the underlying mechanism	K Chakraborty, P Swain, MJ Baig, PS Hanjagi, Susma M Awaji, M Chakraborti, KA Molla, Anilkumar C
4.3	Characterization of rice genotypes for improved Physico-chemical and Nutritional properties	Awadhesh Kumar, TB Bagchi, N Basak, Gaurav Kumar, Sivashankari M, RP Sah
Programm 5: Research to enhance socio-economic wellbeing of rice stakeholders		
5.1	Reaching stakeholders to Enhance their socio-economic CAPacities (RECAP) through rice technologies	SK Mishra/ S Paul, GAK Kumar, B Mondal, NN Jambhulkar, JP Bisen, AK Pradhan, S Paul, BS Satapathy, S Priyadarsani, S Saha, SK Pradhan, AK Mukherjee, KR Rao, S Lenka, SM Prasad, K Saikia, Anjani Kumar, Sivashankari M
5.2	Working to Increase farm Net Gain through Socioeconomic research (WINGS)	B Mondal, GAK Kumar, SK Mishra, NN Jambhulkar, JP Bisen, AK Pradhan, S Paul, SM Prasad, K Saikia Associates: SK Pradhan, MK Kar, S Saha, K Chattopadhyaya, SK Dash, S Sarkar, MK Bag, S Roy, BS Satapathy, RP Sah, KR Rao, Basana Gowda G
Programme 6: Development of climate resilient technologies for rainfed upland, rainfed lowland and coastal rice ecology		
6.1	Development of resilient production technologies for rice under rainfed drought-prone agro ecosystems	S Roy, NP Mandal, SM Prasad, S Bhagat, BC Verma, A Banerjee, Priyamedha, Soumya Saha, P Swain, L Behera, S Saha, K Chakraborty, D Bhaduri, N Basak
6.2	Rice production and productivity improvement in rainfed lowland ecosystem	R Bhagawati, K Saikia
6.3	Development of Resilient technologies for coastal rice ecologies	Kiran Gandhi B, B Gayatri Associates: KR Rao, K Chattopadhyay, BC Marndi, MK Kar, SK Pradhan, Rahul Tripathi, Md Shahid, MS Baite

Externally Aided Projects (EAPS)

Sl. No.	Project No.	Title of the Project	Source of Funding
1.	EAP-27	Revolving fund scheme for seed production of upland rice varieties at CRURRS, Hazaribagh – N P Mandal, Priyamedha	AP Cess
2.	EAP-49	Revolving fund scheme for breeder seed production - B C Marndi, R P Sah, Md. Azharudheen, Anil kumar	NSP/Mega seed
3.	EAP-60	Front line Demonstration under Macro-Management scheme of Ministry of Agriculture – New High Yielding Varieties – B C Verma	DAC
4.	EAP-130	All India Network Project on Soil Biodiversity – Biofertilizers - B C Verma	ICAR
5.	EAP-139	AICRP on energy in agriculture and agro-based industries – N T Borkar, P K Guru	AICRP (DRET-SET/ DRET-BCT)
6.	EAP- 140	Intellectual Property Management and Transfer/ commercialization of agricultural technology under National Agricultural Innovation Fund (NAIF) – B C Patra, G A K Kumar	ICAR
7.	EAP- 141	DUS Testing of Rice under Centrally sponsored scheme of PPV&FRA under "Sub-Mission on Seeds and Planting Material" – B C Patra, Anilkumar C	PPV&FRA
8.	EAP- 178	National Initiative on Climate Resilient Agriculture - Sudhanshu Shekhar	NICRA (ICAR)
9.	EAP- 189	Front Line Demonstrations under NFSM - Asit Kumar Pradhan, SK Mishra, B Mondal	DAC –IIRR (NFSM)
10.	EAP- 197	Consortia research platform (CRP) on bifortification - K Chattopadhyay, S Samantaray, TB Bagchi, M Chakraborty, A Kumar, N Basak, L K Bose, A Poonam, S Sarkar, B C Marndi, D Bhaduri	ICAR Plan-CRP
11.	EAP-198A	Incentivizing Coordinating Unit - M J Baig	ICAR
12.	EAP-198B	Incentivizing Research in Agriculture: Study of rice yield under low light intensity using genomic approaches - L Behera, M J Baig, A Kumar, SK Pradhan, S Samantaray, N Umakant	ICAR Plan
13.	EAP-199	Incentivizing Research in Agriculture: Towards understanding the C_3-C_4 intermediate pathway in *Poaceae* and functionality of C4 genes in rice – M J Baig, P Swain, L Behera, Gaurav Kumar, A Kumar, K Ali Molla	ICAR Plan
14.	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
15.	EAP-201	Incentivizing Research in Agriculture: Molecular genetic analysis of resistance/ tolerance to different stresses in rice, wheat, chickpea and mustard including sheath blight complex genomics - M K Kar, L Behera, A Mukherjee, Mathew Baite, N P Mandal, S Samantaray, Devanna, K A Molla, M Chakraborti, L K Bose	ICAR Plan
16.	EAP-204	CRP on Agro-biodiversity: PGR Management and Use of Rice (Component I) - B C Patra, BC Marndi	ICAR-NBPGR
17.	EAP-207	Conservation agriculture for enhancing the productivity of rice based cropping system in Eastern India - AK Nayak, R Tripathi, BB Panda, M Shahid, S Munda, S Saha, SD Mohapatra, P Guru, R Khanam, B R Goud	CAP - ICAR
18.	EAP-209	CRP on hybrid technology - R L Verma, J L Katara	CRP - ICAR
19.	EAP-211	CRP on molecular breeding - M K Kar, L Behera, G P Pandi, A Mukherjee, M Chakraborti, P C Rath, L K Bose	CRP - ICAR
20.	EAP-215	Agri-Business Incubation Centre - G A K Kumar, B C Patra, N C Rath, S Saha, R K Sahu, B B Panda, B Mondal, A K Mukherjee, P K Guru, J P Bisen, G P Pandi, N N Jambhulkar	NAIF, IP&TM – ICAR

21.	EAP-227	Creation of seed hub for increasing indigenous production of pulses in India - S Sethi, D R Sarangi, T R Sahoo, M Chourasia, R K Mohanta	DAC &FW
22.	EAP-228	Increasing productivity and sustaining the rice-based production system through Farmer FIRST approach - SK Mishra, B Mondal, S K Pradhan, S Saha, S Lenka, S D Mohapatra, B S Satapathy, R Tripathi, J P Bisen, N T Borkar, Supriya Priyadarsani, Lipi Das, G C Acharya, SC Giri, S Paul	ICAR-Farmer FIRST
23.	EAP-245	Strategic research component of National Innovation in climate resilient agriculture (NICRA) - P Swain, A K Nayak, P Bhattacharyya, K Chattopadhya, A Anandan, S Mohanty, D Chatterjee, K Chakraborty, H Pathak	ICAR Net work
24.	EAP-252	Development and demonstration of Rice based integrated farming system for livelihood security of small and marginal farmers in coastal Odisha - A Poonam, A K Nayak, S Saha, B S Satpathy, G A K Kumar, P K Sahu, K Chattapadhyay, S K Lenka, L K Bose, P K Guru	RKVY, Odisha
25.	EAP-260	Development of climate smart practices for climate resilient varieties - Anjani Kumar, H Pathak, A K Nayak, S Saha, B R Goud	IRRI
26.	EAP-271	Harvest Plus Programme : Biofortification of rice - K Chattopadhyay, Awadhesh Kumar, P Sanghamitra, G Kumar, L K Bose	IFPRI & CIAT
27.	EAP-272	Strengthening entrepreneurs in marketing and export of value added agricultural products by establishing a state of art quality assessment laboratory in Odisha - Sutapa Sarkar, N Basak, P Sanghamitra, T Adak, B Mondal, M Chakraborty, M J Baig, G Kumar, S Priyadarsani, Sivashankari M, T B Bagchi	RKVY-Odisha
28.	EAP-274	Bio-Bank: Production and promotion of biocontrol agents and entrepreneurship development in aspirational districts of Odisha - Basana Gowda G, N K B Patil, G P Pandi, Totan Adak, Prasanthi G, Annamalai M, Raghu S, Prabhukartikheyan S R, P C Rath, A K Mukherjee	RKVY-Odisha
29.	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, A K Nayak, S K Mishra	RKVY-Odisha
30.	EAP-277	New high yielding rice varieties for irrigated and rainfed ecosystem through TRB - S K Dash, R L Verma, J L Katara, S Sakar, Rameswar Sah, J Meher	IRRI
31.	EAP-282	Application of Next-Generation breeding, Genotyping and digitalization approaches for improving the genetic gain in Indian staple crops – S K Dash, L Behera, M Chakraborti	ICAR-BMGF
32.	EAP-283	Building climate resilience of Indian small holders through sustainable intensification and agro-ecological farming systems to strengthen food and nutritional security (RESILIENCE) - A K Nayak, B B Panda, S D Mohapatra, R Tripathi, MD Shahid, S Mohanty, S Priyadarshini, S Saha, H Pathak DR Sarangi	Norwegian Institute of Bioeconomy Research (NIBIO), Norway
33.	EAP-284	RKVY-RAFTAAR-Agribusinees incubation - G A K Kumar, B C Patra, R.K Sahu, A K Mukherjee, Sanjoy Saha, B B Panda, Narayan Borkar, M Sivashankari, B Mondal, Rameswar Saha, Sutapa Sarkar, G Prasanthi	RKVY
34.	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 - S D Mohapatra, R Tripathi, U Keerthana (On study leave)	SAC-ISRO
35.	EAP-290	Advance breeding technologies to speed up genetic gain, create durable resistance to biotic stresses and increase indian farmers and consumers food and nutritional security – S K Pradhan	IRRI-India
36.	EAP-291	Attracting and Retaining Youth in Agriculture (ARYA) - S Sethy, D R Sarangi, T R Sahoo, R K Mohanta	ICAR
37.	EAP-295	Greenhouse gas emission, mitigation & adaptation: strategies for better inventory and management of such gases in rice ecosystems of two agro-climatic zones of Assam - P Bhattacharya, H Pathak, S Chatterjee	DBT
38.	EAP-296	Development of multiple stress tolerant versions of rice varieties Gomati and Tripura Chikan Dhan through molecular breeding – S K Dash, M Chakraborti, A K Mukherjee	DBT
39.	EAP-297	Exploration and utilization of endophyte diversity in wild rice for health management of rice crops - Rupalin Jena, (A K Mukherjee)	DST Inspire

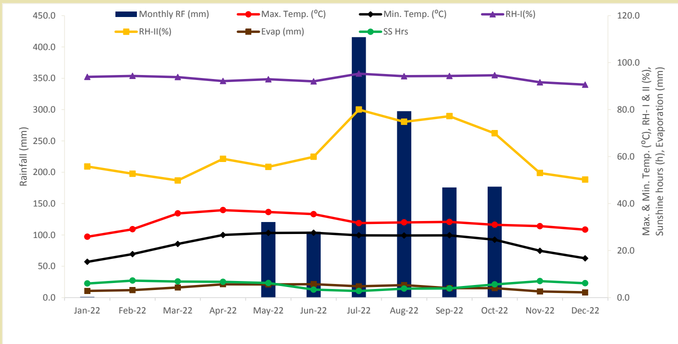
40.	EAP-298	Amelioration of soil borne diseases in rice using endophytic community of wild rice of Odisha for benefit of rice farmers - Soma Samanta, (A K Mukherjee)	DST- Women Scientist (B)
41.	EAP-299	Leveraging institutional innovations for inclusive and market led agricultural growth in Eastern India - B Mondal, B S Satapathy, Asit Kumar Pradhan, SK Rout, S R Dalal	ICAR
42.	EAP-302	Establishment of Biotech KISAN Hub at Central Rainfed Upland Rice Research Station (CRURRS), ICAR-NRRI, Hazaribag, Jharkhand - D Maiti, SM Prasad, BC Verma, S Roy, A Banerjee	DBT
43.	EAP-303	Insect Pest and disease forecasting and decision support system (ICAR-IRRI Collaborative Project, SD Mohapatra, G Prasanthi	ICAR-IRRI
44.	EAP-304	CRISPR / Cas based editing of susceptibility gene promoters to develop bacterial blight and sheath blight resistant rice plants avoiding pleiotropic effects - Subhasis Karmakar	DBT-RA
45.	EAP-306	Develop and validate crop establishment practices for drought-tolerant/ new varieties in a rainfed upland environment of Jharkhand. (Under programme: Climate smart management practices) – B C Verma	IRRI
46.	EAP-307	Climate Smart Management Practices under DSRC - Sanjay Saha, B S Satpathy, Virendra Kumar-IRRI, Sudhanshu Singh-IRRI, Pradip Sagwal-IRRI	IRRI
47.	EAP-308	IRRI-ICAR collaborative Project- "Accelerating impact and equity" – Sivashankari M	IRRI
48.	EAP-309	Establishment of Biotech KISAN Hub at Regional Rainfed Lowland Rice Research Station (RRLRRS), ICAR-NRRI, Gerua, Hajo, Kamrup, Assam - R Bhagawati	DBT
49.	EAP-310	Development of superior haplotype based near isogenic lines (Haplo- NILs) - L Behera, Devanna, Koushik Chakraborty, G P Pandi, N Basak	DBT
50.	EAP-311	Paddy straw residues management through in-situ microbial decomposition with mechanical interventions – P Paneerselvam, U Kumar, A Kumar, M Shahid	NASF
51.	EAP-312	Mainstreaming rice landraces diversity in varietal development through genome wide association studies: A model for large scale utilization of gene bank collections of rice - L Behera, J L Katara, B C Marndi, Devanna, Amrita Banerjee, Somnath Ray, Kaushik Chakraborti, MK Bag, Prasant K S Hanjagi, Gourav Kumar, Aravindan S, Annamalai M, AK Mukherjee	DBT
52.	EAP-313	Integration of in-vitro based Doubled Haploid, Marker Assisted Selection, Transgenic and CRISPR- *Cas 9* technology in rice improvement (Training Project) - S Samantaray, J L Katara, Parameswaran, Devanna, R L Verma	DBT
53.	EAP-315	ICAR-IRRI collaborative Project on climate smart management practices- Development of appropriate machinery systems for rice mechanization - Narayan Borkar, S Priyadarshi	IRRI
54.	EAP-316	Double haploid breeding in development of rice variety for enhancing resilience against biotic and abiotic stresses - S Samantaray, A Anandan, J L Katara, Parameswaran C, Devanna, R L Verma	BIRAC, India
55.	EAP-318	Exploring insecticide induced hormesis to develop superior strain of egg parasitoid, Trichogramma japonicum and its molecular characterization - Basana Gowda G, Totan Adak, N K B Patil	Science and Technology Deptt., Odisha
56.	EAP-319	Evaluation of zinc oxide suspension concentrate (39.5% Zn) on rice against Zn SO4 through soil application with urea - M Shahid, A K Nayak	Yara Fertilizer India Pvt. Ltd.
57.	EAP-321	Promotion of pheromone traps for managing fall army worm and related insect pests in various crops – K Rajasekhara Rao, M Annamalai, T Adak, P K Nayak, Gaurav Kumar, Bapatla Kiran Gandhi, Sunil Kumar Das	RKVY
58.	EAP-322	Global challenges research fund (GCRF) South Asian Nitrogen Hub (GCRF-SANH Project) - D Chatterjee, S Mohanty, J Meher, B Mondal, A K Nayak, Parameswaran C	GCRF
59.	EAP-323	Value chain and nutritional research output: Fish for nutritional and health of women and children - G A K Kumar, Sujata Sethy, R Mahanta, J Pani, P K Sahoo	CGIAR (WorldFish-ICAR W3)
60.	EAP-324	Study on impacts of primary and secondary pollutants on soil and crops around Vedanta Limited factory, Jharsuguda - M Shahid, A K Nayak, U Kumar, R Khanam	Vedanta Ltd

61.	EAP-326	Accelerated genetic gain in rice (AGGRI- Alliance)- Irrigated rainfed (Drought, salinity & submergence) and DSR ecologies - S K Dash, N P Mandal, K Chattopadhyay, S Roy, R P Sah, L K Bose	IRRI
62.	EAP-328	Creation of seed infrastructure facility - R L Verma	Government of India, Ministry of Agriculture & Farmers Welfare
63.	EAP-330	Formation and promotion of FPOs in Balasore - G A K Kumar, B C Patra, S K Das, B Mondal, R P Sah, Basana Gowda, A K Mukherjee, A K Pradhan, S R Dalal, S Paul	NCDC
64.	EAP-331	Study on chemical constituents of rice root modulating herbivory by the rice root knot nematode: a chemical ecology perspective - Totan Adak, Rupak Jena	DST
65.	EAP-332	Bio-efficacy of PIX 10172 64%WG against rice blast and sheath blight - S Lenka, Raghu S, Prabhukarthikeyan S R, G P Pandi, P C Rath	PI Industries Pvt. Ltd
66.	EAP-334	DST Inspire Fellow - Sonali Panda, (M J Baig)	DST Inspire
67.	EAP-335	Exploring AUS rice for drought, submergence and phosphorus starvation tolerance: Mining superior alleles and deciphering mechanism of tolerance - S Roy, N P Mandal, A Banerjee, B C Verma, Koushik Chakraborty, Padmini Swain, P S Hanjagi, D Bhaduri	NASF
68.	EAP-337	Formation and promotion of FPOs in Odisha - GAK Kumar, B C Patra, S K Das, R P Sah, B Gowda, A K Mukherjee, A Pradhan, S R Dalal, Ankit Anand, S Sethi, S K Rout, B K Jha, S M Prasad, S Paul	Govt. of India (SFAC)
69.	EAP-339	Ph.D Dissertation work - Priya Das, (M J Baig)	DBT JRF
70.	EAP-340	Targeting serotonin and senescence pathways for enhancing brown plant hopper resistance and yield in rice - Bijayalaxmi Sahoo (Parameswaran C)	DST Inspire fellowship
71.	EAP-341	Evaluation of bio-efficacy and phytotoxicity of IIF-1516 against diseases of paddy - Prabhukarthikeyan S R, Raghu S, Mathew S Baite, N K B Patil, P C Rath	Indofil Industries Ltd.
72.	EAP-342	To evaluate the bio-efficacy and phytotoxicity of IFC067 against major rice diseases (bacterial blight, false smut and blast) - Raghu S, Mathew S Baite, Prabhukarthikeyan S R, Basana Gowda, P C Rath	Indofil Industries Ltd.
73.	EAP-343 (Merger of EAP-36 and EAP-100)	AICRIP on Seed (Crops) - B C Marandi, Anil Kumar, A K Mukherjee, N K B Patil, R P Sah, Md. Azharudheen, Raghu S, Annamalai M	ICAR
74.	EAP-344	Development of Steel slag based cost-effective eco-friendly fertilizers for sustainable agriculutre and inclusive growth - M Shahid, A K Nayak, Rubina Khanum	Ministry of Steel
75.	EAP-345	Evaluation of bio efficacy of MCI 9197 10% WG against sucking insect pest of rice - Dr. Guru Pirasanna Pandi G, Totan Adak, P C Rath	PI industries ltd
76.	EAP-346	Bio-Efficacy and phytotoxicity of pesticides applied through drone technology in rice - Dr. Basana Gowda G, Totan Adak, P C Rath, R P Sah	M/s Mahindra and Mahindra Mumbai
77.	EAP-347	Droplet deposition and phyto-toxicity studies of Tetraniliprole 200 g/l SC (Vayego) and Tebuconazole 50% + Trifloxystrobin 25% WG Native in rice crop using an unmanned aerial vehicle (UAV) - Dr. Basana Gowda G, Totan Adak, R P Sah	M/S Bayer Crop Science Limited, Mumbai
78.	EAP 348	Evaluating performance of *Nano*- urea with respect to yield and nitrogen use efficiency of rice - S Mohanty, A K Nayak	Indian Farmers Fertiliser Cooperative Limited (IFFCO)
79.	EAP-349	Evaluation of bioefficacy of BAS 764 00 F against major rice diseases (Blast, sheath rot, false smut & Sheath blight) in rice - Raghu S, Mathew S Baite, Prabhukarthikeyan SR, G P Pandi, P C Rath	BASF India Ltd.
80.	EAP-350	Biological Nitrification Inhibition (BNI) in Rice: A novel approach to enhance Nitrogen use efficiency *vis a vis* reducing denitrification N-loss - U Kumar	ICAR (Lal Bahadur Shastri Award)

81.	EAP-351	Identification of rice cultivars with low As concentration in grain through As specific study and developing management practices to mitigate As contamination - M Shahid	ICAR (Lal Bahadur Shastri Award)
82.	EAP-352	Decrypting the chemical interaction of rice and its specialist herbivore, *Scirpophaga incertulas* - Totan Adak, B Gowda	SERB, DST
83.	EAP-353	Network programme on precision agriculture (NePPA) - R Tripathi, A K Nayak, S Mohanty, S D Mohapatra, Raghu S, B R Goud	ICAR
84.	EAP-354	Development of azadirachtin based zinc-oxide nano-formulation for sustainable management of brown plant hopper and other key pest of rice in Odisha - G P Pandi G, T Adak, Raghu S	DST, Odisha
85.	EAP-355	Improvement of aromatic indica rice cultivars for bacterial blight disease resistance through marker assisted doubled haploid breeding - (Prakash Singh), S Samantaray	SERB-Tare, DST
86.	EAP-356	Understanding the effect of aerobic adaptation loci on yield of drought tolerant rainfed shallow lowland cultivar rice using genome editing tool – Parameswaran, Devanna	SERB
87.	EAP-357	Identification of genomic region(s) for 21 days submergence tolerance in rice using sequence based trait mapping approach - J L Katara, S Samantaray, Parameswaran	SERB
88.	EAP-358	Evaluation of Bayer rice hybrids under DSR condition at NRRI - RL Verma, B C Patra, SD Mohapatra, A K Mukherjee	Bayer seeds Pvt. Ltd (Contract research)
89.	EAP-359	Enhancing resilience of smallholders to climate change through sustainable intensification and digital driven knowledge dissemination (E- CHASI) - A K Nayak, S Mohanty, R Tripathi, S D Mohapatra, B S Satpathy, B Mondal, D Maiti, U Kumar, Anjani Kumar, Raghu S, PC Jena, PP Panneerselvam	OIIPCRA, Deptt. Of Water Govt. of Odisha
90	EAP-360	Biodegradable nanofibre encapsulated bio-fertilizer to enhance phosphorus and other micronutrient uptake in rice - P Panneerselvam	DBT
91.	EAP-361	National mission mode program on nutritional improvement of digestible protein content and quality in rice - K Chattopadhyay, S Sarkar, TB Bagchi	DBT
92.	EAP- 362	Identification and characterization of low starch digestibility rice based on types of resistant starch and cooking quality - Awadhesh Kumar	SERB, DST
93.	EAP-363	Evaluation of rice lines and hybrids for yield traits - R P Sah, Md Azharudheen TP, Raghu S, B Gowda G, B C Patra, Anilkumar C, Reshmi Raj	PAN Seed Pvt. Ltd.
94.	EAP-364	Improving vegetative stage drought tolerance by integrating Genomic selection, GWAS and QTL mapping in rice - J L Katara	SERB, DST
95.	EAP-365	Nanoherbicide: A controlled release formulation to improve rice production - Totan Adak, S Munda	DST
96.	EAP-366	Transformative strategy for controlling rice disease in developing countries – Devanna, M Chakraborti (PI in absence of Dr. Devanna), K A Molla, A K Mukherjee	BMGF (collaborative project with Heinrich Heine University, Germany)
97.	EAP-367	Development of bacterial blight and sheath blight resistant rice plants through CRISPR/ Cas mediated genome editing of host susceptibility gene - S Karmakar, M J Baig	NPDF, DST
98.	EAP-368	Comparative Assessment of Aldor as an Alternative to Urea on Rice growth, Yield, Nitrogen use efficiency and Soil Health - Mohammad Shahid, A K Nayak	Sirius Minerals India Pvt Ltd (SMIPL)
99.	EAP-369	Popularization of BPH resistant rice variety for uplifting the Odisha rice farmers' income - Guru-Pirasanna-Pandi G, P C Rath, B Gowda, T Adak, G A K Kumar, Annamalai M, Raghu S, M K Kar, N K B Patil, Parameshwaran, S K Mishra, R Sah, L K Bose	RKVY, Govt. of Odisha
100.	EAP-370	Biotech- Krishi Innovation Science Application Network (Biotech-KISAN) Hub at Sikkim University - P Panneerselvam	DBT
101.	EAP-371	AICRIP (Rainfed) – B C Patra, K Chattopadhyay, S K Dash, M. Chakraborti, A Kumar, S Saha, A K Mukherjee, G P Padhi, Md. Shahid, K Chakraborty, N N Jambhulkar, A Pradhan, N Basak	ICAR

102.	EAP-372	Development of haploid inducer rice lines using CRISPR/ *Cas9* gene editing system for high induction frequency - S Samantaray, Devanna, Parameswaran, J L Katara	DBT
103.	EAP-373	Sub Mission on agricultural mechanization for implementation of its component No.1 under drone technology demonstration - Asit Kumar Pradhan, Basana Gowda	DAC
104.	EAP-374	Allele mining for the epigenetic regulator NGR5 and other yield associated gene (GRF4) and their modulation using multiple genomic and molecular approaches to enhance rice yield under low nitrogen conditions - Kutubuddun Molla, M J Baig	NASF
105.	EAP-375	To evaluate the bio efficacy and phytotoxicity of Tebuconazole 430 G/ L SC against rice leaf and neck blast diseases - Raghu S, Mathew S Baite, Prabhukarthikeyan S R, Basana Gowda G, P C Rath	Bayer Crop Sciences Ltd.
106.	EAP-376	To evaluate the bio efficacy and phytotoxicity of Fluopyram 400 g /L SC (Velum Prime) against major nematode pests of rice - Rupak Jena, Raghu S, Basana Gowda G, P C Rath	Bayer Crop Sciences Ltd.
107.	EAP-377	Quantitative assessment of soil quality, yield sustainability and grain quality of rice in Eastern India: A unified triangular approach - Debarati Bhaduri	DST-SERB
108.	EAP-378	Evaluation of Bio-efficacy and phytotoxicity of IIF-222 against diseases of Paddy - S R Prabhukarthikeyan, Raghu S, Mathew S Baite, P C Rath	Indofil Industries Ltd.
109.	EAP-379	Deciphering and deploying low phosphorus tolerance and nitrogen use efficiency in rice - J Meher, Parameswaran, D Chatterjee	NASF
110.	EAP-380	Blue carbon sequestration and climate change mitigation by managing mangrove-soil-algae system in coastal wetland - Sujit Kumar Nayak, P Bhattacharya	DST-Inspire
111.	EAP-381	CRISPR Crop Network: Targeted improvement of stress tolerance, nutritional quality and yield of crops by using genome editing - Parameswaran C, S Samantaray, Awadesh Kumar, Kutubuddin Ali Molla, Prabhukarthikeyan SR	NASF
112.	EAP- 382	Identification and characterization of fungal effectors and host factors in rice-false smut pathosystem – Devanna, S Samantaray, (PI in absence of Devanna), M K Bag	NASF
113.	EAP-383	Improvement of stress adaptive traits in crops using endophytes under different agroecology - Prashant Kumar Hanjagi	NICRA
114.	EAP-384	Studying the Effect of Adopting Regenerative Agriculture Practices on Smallholder Farmer Livelihoods – A K Nayak, Rahul Tripathi	J-PAL
115.	EAP-385	Evaluation of Dammu: Propargite 50% + Bifenthrin 5% SE for bio-efficacy (against Lepidopteran, Hemipteran and Mite pests), phytotoxic effect and impact on natural enemies in coastal rice ecosystem - Kiran Gandhi B	Indofil Industries
116.	EAP-386	Evaluation of bio-efficiency and phytotoxicity of Chlorantraniliprole 0.6% + Thiomethoxam 1.25% + Fipronil 1.25% GR (TAS0211) against major insect pests of paddy - Naveen B Patil, B Gowda, T Adak, P Golive	Tropical Agrosystem (India) Pvt. Ltd. Chennai
117.	EAP-387	Computer vision for plant phonemics and smart agriculture - Rahul Tripathi, S K Dash, Prashant Kumar Hanjagi, P Swain	IIT, Jodhpur
118.	EAP-388	Phyto-toxicity evaluation of Dinetofuran 15% + Pymetrozine 45% WG and Iprobenfos 48% EC on rice crop - Guru-Pirasanna-Pandi G, B Gowda, T Adak, P C Rath	PI Industries Pvt. Ltd.
119.	EAP-389	Establishment of hybrid rice seed system and state of art for genetic purity testing in Odisha – R L Verma, J L Katara, S Samantaray, B C Patra, G A K Kumar, A K Mukherjee, U Kumar	RKVY
120.	EAP-390	Outscaling of Natural Farming through KVKs - Dillip Ranjan Sarangi, Sujata Sethy, TR Sahoo, R K Mohanta	ICAR
121	EAP-391	4S4R Model for production, marketing and export of Odisha aromatic rice – GAK Kumar, B C Patra, B Mondol, T Adak, S Sarkar, M Chakraborti, S Priyadarshini, S K Dash, S Sethy, J P Bisen, Asit Kumar Pradhan	RKVY
122.	EAP-392	Improving rice genetics and its ecosystem through genome engineering and bioagents to reduce dependency on chemical N_2 fertilizer – KA Molla, M J Baig, AK Mukherjee, T Adak, J Meher	Ignite Life Science Foundation
123.	EAP-393	Scaling of Natural Farming through KVKs (Koderma) - SM Prasad	ICAR

Weather



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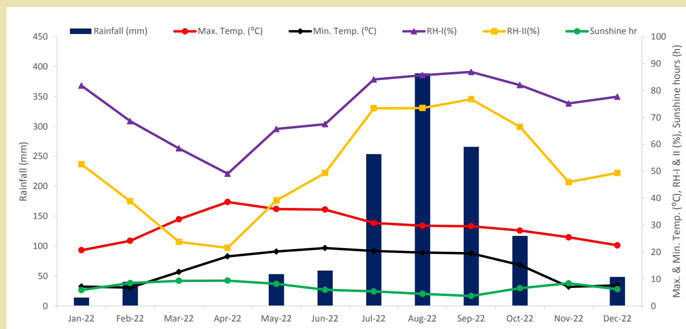

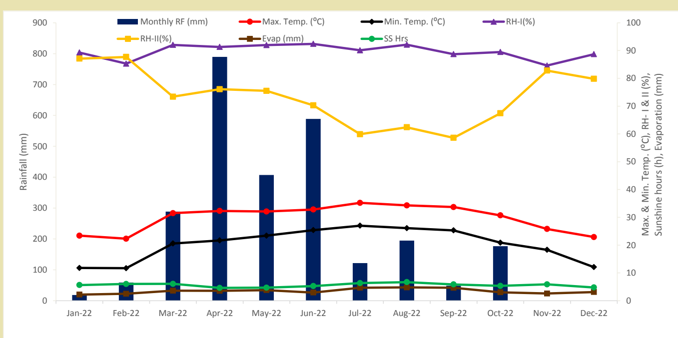

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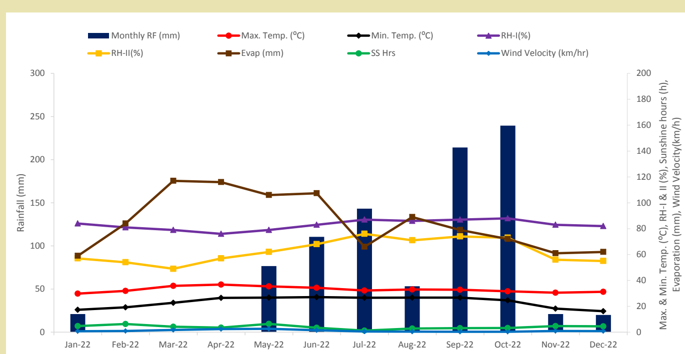

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