NRRI
वार्षिक प्रतिवेदन
ANNUAL REPORT 2016-17

भाकृअनुप-राष्ट्रीय चावल अनुसंधान संस्थान
(भारतीय कृषि अनुसंधान परिषद)
ICAR-National Rice Research Institute
(Formerly Central Rice Research Institute)
An ISO 9001:2008 Certified Institute
(Indian Council of Agricultural Research)

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भाकृअनुप - राष्ट्रीय चावल अनुसंधान संस्थान
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C O N T E N T S


NRRI

PREFACE

Rice is the staple food for nearly half of the world's population and 3/4th of the Indian population. It is grown in all the continents of the world, except Antarctica, and is a part of cultural heritage to several countries. Out of about 141 million hectare (Mha) of net cultivated area in India, rice occupies the maximum i.e., about 44 Mha. About 45% of rice area is rainfed and about 70% of this lies in the eastern India. Rice farming in the rainfed regions of the country faces multiple pressures from intense competition for land and water, a more difficult growing environment because of climate change, higher price for energy and fertilizers, labour shortage, increasing cost of cultivation, declining profit margin and greater demand for reduced environmental footprint. The socio-economic dynamics and food habits are also changing adding another dimension to an already complex problem. The rice production systems, particularly in the rainfed ecologies, therefore, have to be revitalized for increasing productivity, ensuring food and nutritional security, increasing farmers' income and achieving Sustainable Development Goals (SDGs).

The ICAR-NRRI, established in 1946, is country's premier Institute for rice research. It has contributed immensely in country's Green Revolution and food security. The Institute so far has developed 124 popular high-yielding varieties for various rice ecosystems, collected and conserved around 35,000 germplasm and developed production and protection technologies for cost-effective, environment-friendly and climate-smart rice production. The country has harvested the record production of rice of about 109 Mt last year. Almost all the states of the country are now self-sufficient in rice. Rice has now become foreign exchange earner and the country exports about 10 Mt of rice annually.

Now, rice farmers and rice researchers are facing new challenges. So far we have been concentrating on productivity gain but now we need to increase the income and also the nutritional quality of rice. This challenge has to be realized under the constraints such as climate change, poor soil health, low nutrient use efficiency and increased emergence of insects and diseases. Another major challenge is to reduce the yield gap, which varies from 40 to 70%. To double the income of Indian farmers by 2022, rice farming needs special attention with innovative technologies and policy support.

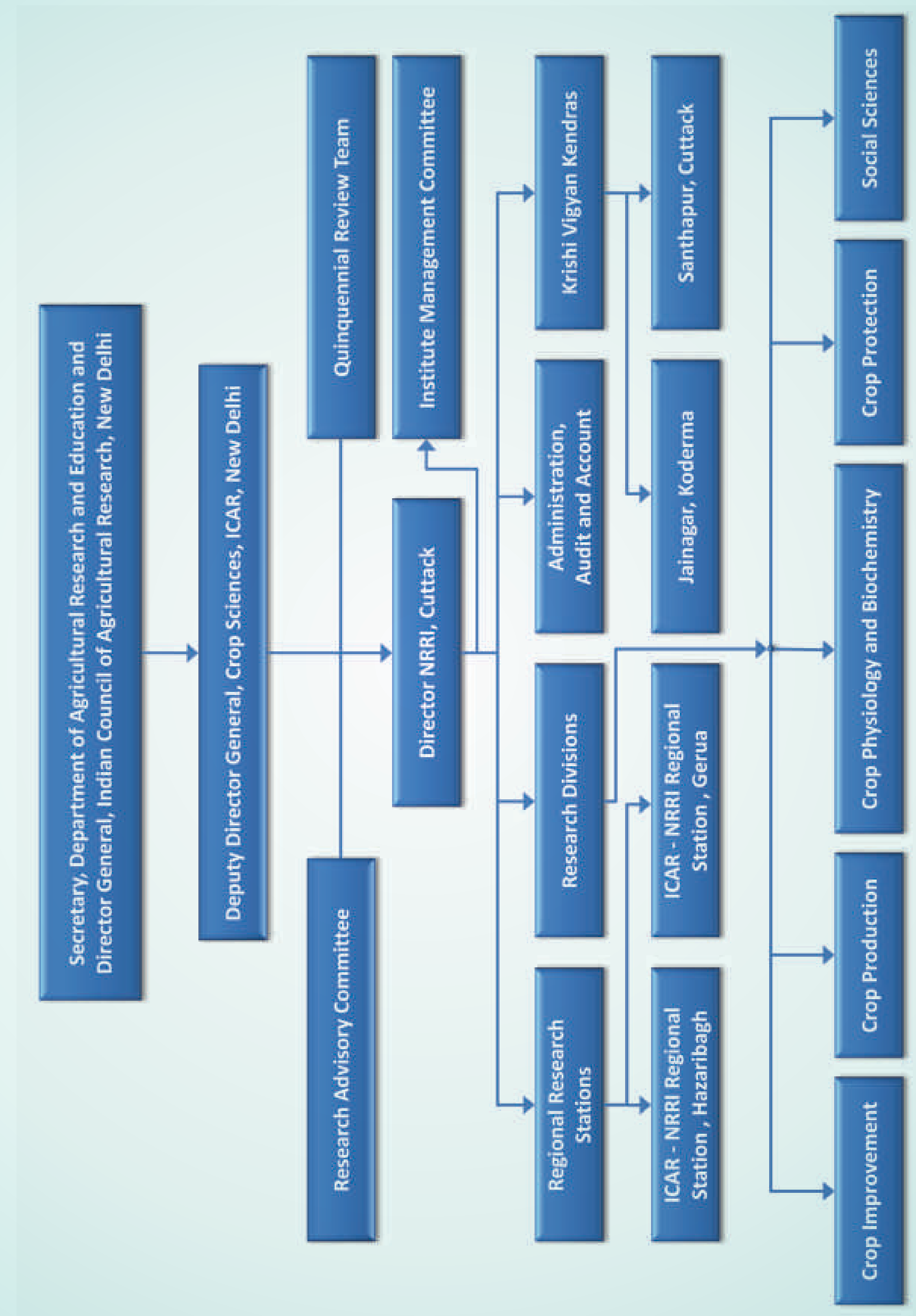
During the year 2016-17, the Institute has released nine varieties of rice suitable for different ecologies including high protein varieties such as CR Dhan 310 and CR Dhan 311; developed a rapid method to differentiate between low and high protein rice; evaluated and identified genotypes for tolerance to abiotic and biotic stresses and developed environment-friendly and climate-smart nutrient water management technologies. The NRRI varieties are currently grown in large areas across 14 states of India. The Institute is the nodal agency for Bringing Green Revolution to Eastern India.

The Institute sincerely acknowledges the guidance and encouragements received from Dr. Trilochan Mohapatra, Director General, ICAR and Secretary, DARE. The valuable guidance and support received from Dr. VL Chopra, Chairman, Research Advisory Committee (RAC); Dr. JS Sandhu, DDG (Crop Sciences), ICAR; esteemed members of RAC and Institute Research Council (IRC). Sincere thanks and gratitude are due to Dr. IS Solanki, ADG (FFC), ICAR and other officials of the Council for their constant support and guidance. I sincerely thank the Heads of the Divisions, Officer In-Charges of Regional Stations, and Administration and Finance sections of the Institute for their whole-hearted efforts and involvement in carrying out the activities of the Institute. My thanks are due to the Publication Committee and Publication Unit for compiling and editing the Annual Report. I heartily appreciate the efforts and commitment of all the staff to serve the rice farmers of the country and taking the Institute to new heights.

I sincerely hope that the Report will be useful for the researchers, policy makers, development functionaries, farmers, farmwomen and students and help in promoting rice research and development.

(Himanshu Pathak)
Director

ORGANOGRAM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Crop Production
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Executive Summary

Crop Improvement Division is mainly focusing on rice germplasm collection, conservation, evaluation and development of suitable genotypes for almost all the rice ecologies in India. With the help of modern science, basic, strategic and applied research in rice are being carried out, which contribute significantly towards achieving goal of food and nutritional security in India.

The Institute released nine varieties through central and state variety release committee in 2016-2017. CR Dhan 508 was released and notified by CVRC for deep water ecology in the state of Odisha, West Bengal and Assam. Seven rice varieties for the state, Odisha were released by the Odisha State Sub-committee for Agricultural Crops during the meeting held on 8th November 2016. Among them, CR Dhan 207 (Srimati) and CR Dhan 209 (Priya) for aerobic condition, CR Dhan 407 (Pradhandhan) for shallow rainfed lowland and CR Dhan 507 (Prasant) for waterlogged situation were released. Bacterial blight resistant variety, CR Dhan 800 (Swarna- MAS) was also released by SVRC, Odisha. This variety was developed through marker assisted selection by pyramiding of three bacterial blight resistance genes (*xa5*, *xa13* and *Xa21*) into popular variety Swarna. SVRC, Odisha also released nutrient rich rice variety, Mukul (CR Dhan 311) having high (10.1%) grain protein and moderate level (20 ppm) of Zn content. This high yielding variety (4.4 t/ha in 120 days) was developed through backcrossing in the background of popular variety, Naveen. Another short grain aromatic rice variety CR Sugandh Dhan 910 was released by the SVRC, Odisha. Another culture, CRR 363-36 (IET 19251) with long slender aromatic grain was released in the name of 'Gangavati Emergency' for irrigated ecology in Karnataka. Apart from that with the aim of expansion of area of hybrid rice cultivation, a medium duration hybrid, Rajalaxmi which was released earlier for Odisha, was released now by SVRC, West Bengal.

Significant progress in breeding programme was realized from the higher rate of promotion (around 25%) of the nominated entries (224) in ecology specific and across the ecology AICRIP trials. Apart from that success of the inter-specific hybridization (Lalat /*O. nivara* (AC 100476)//Lalat) was found through the development of genotypes with high grain yield of 6.33 t/ha or more. In addition, as a mark of significant progress in the doubled haploid breeding, sixteen promising doubled haploid lines were selected from the rice hybrid, 27P63. To generate the rice genomic information, two donors and two elite cultivars, Salkathi, PDK Shriram, TN 1 and Heera were re-sequenced using NGS technology. Considering the Institute mandate, two exploration programmes were conducted for collection of traditional, medicinal and wild rice germplasm from Kerala and Uttar Pradesh. Finally, as par the DAC indent, breeder seeds of 872.90 q were produced from 48 varieties and nine parental lines for various rice growing states of India.

Long term fertilizer experiment revealed that the SOC concentration and stocks have increased significantly with the input of chemical fertilizer and manure as compared to control in surface soil (0-15 cm). Experiment on crop and varietal diversification revealed that rice yield did not differ significantly with the systems like, rice-groundnut-cowpea and rice-maize-cowpea. System productions (REY) were at par with higher net returns of Rs. 81,988/- in rice-maize-cowpea.

In the study to enhance the NUE and reduction of GHGs emissions in lowland rice, finding suggested that the basal application of briquettes by three row basal applicator along with manual placement of two consecutive split doses of N minimized N_2O emission with sustainable yield. Cumulative CO_2-C emission was increased with increasing rate of biochar application; however, the mineralization rates (dc/dt) were similar with and without biochar added soil.

Physiological responses of contrasting rice cultivars (Shabhagidhan, IR 64 and IR 64 *drt*) to the VAM and phosphorus application revealed that with imposition of drought stress, maximum decrease (213.9%) in grain yield was observed in IR64 as compared to IR64 drt (36.6%) and Sahbhagidhan (42.2%) over well-watered conditions. System productivity in terms of rice equivalent yield of zero tillage system was at par with that of conventional tillage in rice -maize cropping system. PAR interception in Naveen was higher when planted in the month of July as compared to June planting. On an average, Pooja, intercepted more PAR as compared to Naveen.

The modified single row dry land power weeder was tested with width of blades of 14 cm in Naveen variety of rice sown with row spacing of 20 cm, 25 cm, and 30 cm. A four row power operated rice transplanter was also developed to transplant mat type seedling at row to row spacing of 24 cm and hill to hill spacing of 15 cm.

Weed management under zero tillage transplanted rice was done under different herbicide treatments. It was noted that sequential application of bispyribac and fenoxaprop-p-ethyl recorded highest yield (4.28 t ha^{-1}) and cyhalofop butyl recorded the lowest yield (3.38 t ha^{-1}) among the herbicide treatments. Efficient ligno-cellulolytic microbial consortium for rice straw decomposition was identified.

Genotypes AC 36797, 35799, 36370, 36362, 35720, 36357, 36253, 35734, 36369, 35719, 35740, 36283, 35714 and 36294 consistently showed resistance against most virulent bacterial blight isolate of NRRI. Ranjit and Luna Suvarna, were free from false smut infection whereas CR Dhan 907, CR Dhan 303, Nua Kalajeera, Ketakijoha, Nua Dhusara, Nua Chinikamini have exhibited moderate level of infection under field condition. Among 1314 germplasm accessions evaluated for leaf blast resistance at Hazaribagh, 19 accessions (IC 245865, 246277, 246403, 246274, 454167, 121865, 199562, 218270, 245927, 246012, 246228, 246273 and 246659) were highly resistant (SES scores 0, 1, 2). Out of 80 NRRI-released varieties, 19 were resistant against leaf blast. Significant incidence of Bakanae disease was observed in Cuttack and Jajpur district of Odisha in popular rice varieties like Pooja, Naveen, Abhishek, Pratiksha, Swarna, Swarna *sub-1* and hybrid Rajalakshmi. Tricyclazole 20% + tebuconazole 16%SC @ 2.25 ml $litre^{-1}$ was best for the management of sheath blight disease. *Trichoderma* isolates were promoting growth of the seedlings and exhibited higher defense enzyme expression.

Three wild–derivative accessions from IRRI, Philippines, namely, IR 73382-80-9-3-13-2-2-1-3-B (IR 64 x *O. rufipogon*), IR 75870-8-1-2-B-6-1-1-B (IR 64 x *O. glaberrima*) and IR77390-6-2-18-2-B (IR69502-6-SRN-3-UBN-1-B x *O. glaberrima*) were found highly resistant against NRRI-BPH population. The gall midge known-gene differentials having resistant genes 1, 2, 3, 4, 5, 6, 7, 9, 10 and 11 showed susceptible reaction to NRRI gall midge population (Biotype 2) indicating a population change. Four rice accessions, i.e., AC 34222, AC 34264, AC 38468 and AC 42425 were again confirmed as resistant against WBPH. There was a significant positive corelation of minimum and maximum temparature with YSB emergence during *rabi* (Correlation coefficient : 0.890 and 0.795, respectively) whereas rainfall has negative corelation during *kharif* season (-0.456). In semi deep water rice ecology, spiders (8.2/ sweep) outnumbered the other predatory groups. Imidacloprid application had transient negative effects on soil microbes. Dissipation half life of chlorantraniliprole was 115.5-138.6 days. Higher organic carbon and pH in presence of moisture play a significant role in degradation behavior of chlorantraniliprole. Eucalyptus oil @ 5% has shown highest repellency against *Tribolium castaneum.* Monitoring through Pheromone trap for YSB and application of neem oil for leaf folder and BPH reduced pesticide application significantly in on-farm IPM trial.

Preventive sprays with Hexaconazole at booting and flowering stage, was most effective in minimizing false smut infection and increasing rice yield in rainfed transplanted condition. Seed treatment with *Trichoderma*, had significantly enhanced seed germination, seedling vigour and minimized leaf blast incidence. Rice swarming caterpillars (*Spodoptera mauritia*) population rapidly built up during 2nd and 3rd weeks of September in Assam and infested 56,768 ha of winter rice crop. Balimah Putih, IR 20, Pankhari 203, PTB 8, PTB 18, PTB 21, Shuli 2, Utrirajapan and Utri Merah showed resistant reaction against Gerua isolate of *tungro* disease.

The brown rice of Bindli, which had the lowest PA (0.82%) showed highest Zn bioavailability (12.51 ppm), while PB267, which had the highest amount of PA (2.62%) showed low bioavailability of Zn (8.94 ppm) and Fe (4.04 ppm). Lower level expression of *ipkI* transcripts was detected at the initial and final stages of grain development in all the three cultivars (Bindli, Heera and PB267). There was several fold increase (13.67X in Bindli, 16.52X in Heera and 32.82 times in PB 267) in the expression level of *ipkI* in the middle stage in the three genotypes. In another study, the Glycemic index (GI) was estimated in rice cultivars grown in different ecologies where large variation in the value of GI (60.07-70.36) was observed. Among the genotypes studied, Mahsuri (irrigated rice) showed lowest GI (60.07), while the highest value for GI (70.36) was found in Abhishek (upland rice). In a study fifty pigmented rice genotypes were evaluated for anthocyanin and gamma-oryzanol content. The effect of processing of rice on anthocyanin and gamma-oryzanol content was also studied in Chakhao, Mamihunger and Mornodoiga. Highest reduction in anthocyanin and gamma-oryzanol content (97 and 88%, respectively) was observed after parboiling and open-pan cooking of the parboiled rice, whereas only 2-3% reduction in anthocyanins and 70% reduction in gamma-oryzanol content was observed in popped and puffed rice.

Promising rice genotypes, IC 145357, IC 459362, IC 451469, IC 450292, IC 449848, IC 580261, AC 43409, AC 43365, AC 43391, AC 43351 and FR13A are identified for multiple abiotic stress (complete submergence with saline water). On assessing chlorophyll fluorescence imaging techniques using contrasting genotypes, Rashpanjar was found to be a tolerant cultivar.

Out of the two hundred ninety selected genotypes screened for vegetative stage drought tolerance, 135 genotypes were observed to be highly tolerant with SES score “0” and “1”, 51 were tolerant (SES '3'), 39 were moderately tolerant (SES '5'), 45 were susceptible (SES '7') and 18 were found to be highly susceptible. Out of the one hundred and ninety drought tolerant lines, 20 best genotypes observed to have higher values for more than one root trait.

In another study a total of 350, F8 RILs derived from IR 20 (susceptible parent) and Mahulata (tolerant parent) were evaluated for drought tolerance at vegetative stage along with parental lines. Polymorphic survey for gene identification was performed between two parents (IR 20 and Mahulata) using molecular markers. A total of 1010 STMS (sequence tagged microsatellite site) markers were used for polymorphic survey. Out of these 108 (10.7%) markers were found polymorphic. Study under the project “Improvement of Photosynthetic efficiency of rice”, maximum photosynthesis was recorded in Pantdhan-102 and GAR-13 followed by Rajendradhan-102 and Himalaya-L under normal light and the same trend was observed under reduced light environment. Data obtained from the RT-Result for *Sorghum bicolour* (Sb), *Zea mays* (Zm) and *Setaria italica*(Si) were normalized using Actin as reference gene and the data for *Oryza sativa* (Os) was normalized using β-tubulin gene as reference. Highest expression level of PPDK and ME was found in *Seitaria italica* plant. Based on the expression analysis results, the ME gene showed highest expression in *Seitaria italica* plant.

Under Rice-based Model Village programme, seven rice varieties were demonstrated *viz.*, Reeta, Sahabhagidhan, Chakka Aakhi, CR Dhan-202, Naveen, CR Dhan-300 and CR Dhan-701 in total area of 2 ha covering 18 farmers. Interventions in livestock production and management were taken up like earlier years through animal health camps, distribution of fodder kits and demonstration of health management in goats. As part of the Swachhta Pakhwada, a 'Village Awareness-cum-Cleaning Drive' was organized on 25th October 2016 at Gurujanga village of Tangi-Chowdhar block of Cuttack district.

Under sub-project gender sensitive approaches in rice farming, the input-output analysis from rice cultivation indicates 42% yield increase and 76% increase in net return over pre-project year (2011-12). Segregation of source-wise household income indicated that crop cultivation including horticultural crops and vegetables contributed about 59% of the household income followed by livestock (15%), non-farm sources (14%) and labour wages (12%). Majority of the respondents had positive perceptions with regards to comparative advantage of recommended/ demonstrated rice varieties over earlier grown varieties in terms of yield, marketability, cooking qualities, storage quality and resistance to weed/insect pest/diseases.

Among the demonstrated rice varieties during dry season 2016-17 at NRRI farm, the rice hybrid Rajalaxmi gave the highest yield of 7.3 t ha^{-1}, while Satyabhama gave the lowest yield of 4.1 t ha^{-1}. Similarly, during *kharif* 2016, Rajalaxmi gave the highest yield of 7.1 t ha^{-1}, while Luna Barial and CR Dhan 203 gave the lowest yield of 7.1 t ha^{-1} each.

The findings of feedback analysis indicated that 'non-availability of sufficient quantity of quality seeds in time, at farmers doorstep was perceived as the most important problem. Among different government schemes in operation, the schemes namely, ATMA, BGREI and NFSM have been well appreciated by the beneficiary farmer stakeholders.

A business plan on paddy seed production through FPO was prepared. The total cost of the project was estimated at Rs.30.5 lakhs. As per profitability projections for the first year, it was estimated that the project incurred a loss to the extent of Rs.87,668, however, from second year onwards Break-even Point was achieved.

Analysis of seed distribution and other related data collected from seven states *viz.,* Assam, Haryana, Karnataka, Kerala, Puducherry, Punjab and Tamil Nadu revealed that NRRI varieties were found to be grown in four states. Four varieties *viz.,* Abhisek, Naveen, Chandrama and Sahabhagi were grown to the extent of 68,131 ha in Assam state, while CR-1009 was found to be grown to the extent of 115,238 ha in Tamil Nadu. The variety CR-1009 was grown to lesser extent in Kerala and Puducherry. Compilation of data of all the states revealed that thirty NRRI varieties are grown to the extent of 2.83 million ha in 14 states of India.

Analysis of cost of cultivation data for 34 years (1980-2013) revealed that on an average, at all India level the fertilizer use in rice crop is computed to be 142 kg ha^{-1} during 2009-13 period and the rate of use has increased over years. The highest fertilizer use was observed in the state of Karnataka (274 kg ha^{-1}) and lowest in the state of Assam (16 kg ha^{-1}). The average all India manure use has decreased from 28 quintals/ha during early 1980s to 13 quintals per ha during the period 2009-2013. The expenditure on pesticide use was Rs. 863 at all India level at constant 2013-14 price with highest use in the state of Punjab (Rs. 3340 ha^{-1}) and lowest use in Jharkhand. The land rent has also increased over years at all India level from Rs. 8293 per ha in early 1980s to Rs. 13896 per ha during the period 2009-13.

Twenty five ARIMA models were fitted to the rice production data (53 years) of Uttar Pradesh and ARIMA (1, 1, 1) was found to be the best fitted model.

कार्यकारी सारांश

फसल उन्नयन प्रभाग भारत में धान के सभी पारिस्थितिकियों के लिए धान जननद्रव्य संग्रहण, संरक्षण तथा उपयुक्त जीवप्ररूपों के मूल्यांकन एवं विकास पर मुख्य रूप से ध्यान केंद्रित करता है। आधुनिक विज्ञान की सहायता से धान पर मौलिक, रणनीतिक एवं प्रायोगिक अनुसंधान कार्य किया जा रहा है जिससे भारत में खाद्य तथा पौषणिक सुरक्षा की लक्ष्य की प्राप्ति के लिए महत्वपूर्ण रूप से योगदान हो रहा है।

संस्थान ने वर्ष २०१६-२०१७ में केंद्रीय एवं राज्य किस्म विमोचन समिति के माध्यम से नौ धान की किस्में विमोचित की हैं। केंद्रीय किस्म विमोचन समिति ने ओडिशा, पश्चिम बंगाल एवं असम के गहराजल पारिस्थितिकी के लिए सीआर धान ५०८ किस्म को विमोचित एवं अधिसूचित किया। ओडिशा राज्य कृषि फसल उप-समिति ने ८ नवंबर २०१६ को आयोजित बैठक में ओडिशा राज्य में खेती के लिए सात धान की किस्में विमोचित कीं। इनमें से सीआर धान २०७ (श्रीमती) तथा सीआर धान २०९ (प्रिया) ऐराबिक परिस्थिति के लिए, सीआर धान ४०७ (प्रधानधान) उथली निचलीभूमि परिस्थिति के लिए तथा सीआर धान ५०९ (प्रशांत) जलांक्रात परिस्थिति के लिए विमोचित की गई। राज्य किस्म विमोचन समिति द्वारा जीवाणुज अंगमारी प्रतिरोधी किस्म सीआर धान ८०० (स्वर्णा-एमएएस) किस्म विमोचित किया गया है। लोकप्रिय किस्म स्वर्णा में जीवाणुज अंगमारी प्रतिरोधी के तीन जीनों (एक्सए ५, एक्सए १३ एवं एक्सए २१) को चिन्हक सहायतित चयन द्वारा पिरामिडिंग करके इस किस्म का विकास किया गया है। राज्य किस्म विमोचन समिति ने पौषणिक समृद्ध धान किस्म मुकुल (सीआर धान ३११) का विमोचन किया है जिसमें १०.१ प्रतिशत उच्च प्रोटीन की मात्रा तथा मध्यम मात्रा (२० पीपीएम) में जस्ता है। इस अधिक उपज (१२० दिनों में ४.४ टन प्रति हेक्टेयर) देने वाली चावल किस्म का विकास नवीन किस्म की पृष्ठभूमि में बैकक्रॉसिंग के माध्यम से किया गया है। राज्य किस्म विमोचन समिति ने लघु सुगंधित दाना किस्म सीआर सुगंध धान ९१० का विमोचन किया। लंबा एवं पतला सुगंधित दाना किस्म सीआरआर ३६३-३६ (आईईटी १९२५१) को कर्नाटक के सिंचित परिस्थिति में खेती के लिए 'गंगावती इमरजेंसी' के नाम से विमोचित किया गया। इसके अतिरिक्त, संकर चावल के क्षेत्रों के विस्तार की लक्ष्य से, मध्यम अवधि वाली संकर किस्म राजलक्ष्मी जिसे ओडिशा में खेती के लिए पहले से विमोचित किया जा चुका है, राज्य किस्म विमोचन समिति ने वर्तमान पश्चिम बंगाल में इसे विमोचित किया।

एआईसीआरआईपी के परिक्षणों तथा विशिष्ट पारिस्थितिकियों में चयनित प्रविष्टियों (२२४) के उच्चतर प्रचार (लगभग २५ प्रतिशत) से प्रजनन कार्यक्रम में महत्वपूर्ण प्रगति हुई। अंतराविशिष्ट संकरीकरण की सफलता के अतिरिक्त, ललाट/ओ.निवारा (प्रविष्टि १००४७६/ललाट) से ६.३३ टन प्रति हेक्टेयर की अधिक उपज वाली जीनप्ररूपों विकसित की गई। इसके अतिरिक्त, डबल हैप्लायड प्रजनन में हुई महत्वपूर्ण प्रगति से, सोलह आशाजनक डबल हैप्लायड वंशों को संकर चावल २७पी६३ से चयन किया गया। चावल जीनोमिक सूचना के उत्पन्न हेतु, दो दाताओं एवं दो श्रेष्ठ संवर्धनों, सालकाथी, पीडीके श्रीराम, टीएन१ एवं हीरा को एनजीएस तकनीकी द्वारा दुबारा सीक्वेंसिंग किया गया। संस्थान के अधिदेश को ध्यान में रखते हुए, केरल एवं उत्तर प्रदेश से पारंपरिक, औषधीय एवं जंगली धान जननद्रव्य के संग्रह हेतु दो खोज कार्यक्रम आयोजित की गईं। कृषि एवं सहकारिता विभाग की मांग के अनुसार, भारत में चावल की खेती करने वाले विभिन्न राज्यों में ४८ चावल किस्मों एवं नौ जनक वंशों से ८७२.९० क्विंटल प्रजनक बीजों का उत्पादन किया गया।

दीर्घकालिक उर्वरक परीक्षण से पता चला है कि रासायनिक उर्वरक एवं खाद के प्रयोग से एसओसी सांद्रण एवं स्टॉक में महत्पूवर्ण वृद्धि हुई। किस्म विविधकरण से पता चला कि धान-मूंगफली-लोबिया तथा धान-मक्का-लोबिया की खेती से धान की उपज में कोई विशेष अंतर उपज में नहीं हुआ। धान-मक्का-लोबिया की खेती से ८१९८८ रुपये की अधिक आय हुई।

निचलीभूमि धान में पोषकतत्व प्रयोग कार्यक्षमता की वृद्धि तथा ग्रीनहाउस गैस के उत्सर्जन की कमी करने के लिए किए गए एक अध्ययन से पता लगा कि ब्रिकेट का आधारी प्रयोग तथा नत्रजन के लगातर दो भागों में प्रयोग से नाइट्राजनऑक्साइड की कमी हुई तथा उपज भी स्थिर रही। सूखा दबाव के तहत आईआर ६४ में अनाज उपज कम रही। नवीन की रोपाई जूप की अपेक्षा जुलाई में करने पर पीएआर की वृद्धि हुई।

संशोधित एकल कतार वाला शुष्कभूमि शक्तिचालित वीडर का परीक्षण किया गया। इसमें १४ सेंटीमीटर आकार के १४ ब्लेड लगे थे और २० सेंटीमीटर, २५ सेंटीमीटर तथा ३० सेंटीमीटर की कतार दूरी पर नवीन किस्म में धान की बुआई की गई। चटाइदार बिचड़ों की कतार से कतार २४ सेंटीमीटर की दूरी में तथा १५ सेंटीमीटर पूंजा से पूंजा रोपाई हेतु एक चार कतारवाला शक्तिचालित धान प्ररोपक का विकास किया गया है।

जीरो टीलेज प्रतिरोपित धान के तहत खरपतवार प्रबंधन हेतु विभिन्न शाकनाशियों का प्रयोग किया गया। यह देखा गया कि शाकनाशियों के उपाचारो में बाइस्पिरिबैकंडफेनोक्साप्रोप-पी-इथाइल के प्रयोग से सर्वाधिक उपज मिली तथा साइहालोब्यूटील के प्रयोग से सर्वनिम्न उपज मिली।

एनआरआरआई के सबसे अधिक विषैले जीवाणुज अंगमारी वियुक्त के विरुद्ध जीनप्ररूप प्रविष्टियों जैसे ३६७९७, ३५७९९, ३६३६२, ३५७२०, ३६३५७, ३६२५३, ३५७३४, ३६३६९, ३५७१९, ३५७४०, ३६२८३, ३५७१४ तथा ३६२९४ में लगातार प्रतिरोधिता पाई गईं। रणजीत तथा लुणा सुवर्णा में फल्स स्मट संक्रमण नहीं हुआ जबकि सीआर धान ९०७, सीआर धान ३०३ पुआ कालाजीरा, केतेकीजोहा, नुआ धूसरा, नुआ चिनिकामिनी जैसे किस्मों में फल्स स्मट संक्रमण का मध्यम प्रकोप देखने को मिला। हजारीबाग में पता प्रध्वंस प्रतिरोधिता के लिए मूल्यांकन किए गए १३१४ जननद्रव्य प्रविष्टियों में से १९ प्रविष्टियां (आईसी २५४८६५, २४६२७७, २४६४०३, २४६२७४, ४५४१६७, १२१८६५, १९९५६२, २१८२७०, २४५९२७, २४६०१२, २४६२२८, २४६२७३ तथा २४६६५९) अत्यधिक प्रतिरोधी (एसईएस स्कोर में ०, १,२) पाई गईं। एनआरआरआई द्वारा विमोचित ८० किस्मों में से १९ किस्में पत्ता प्रध्वंस प्रतिरोधी पाए गए। ओडिशा के जाजपुर एवं कटक जिले में लोकप्रिय चावल किस्में जैसे पूजा, नवीन, अभिषेक, प्रतिक्षा, स्वर्णा, स्वर्णा सब-१ तथा संकर राजलक्ष्मी में गंभीर रूप से बकाने रोग दिखाई दिया। आच्छद अंगमारी रोग के नियंत्रण के लिए ट्राइसाइक्लाजोल २० प्रतिशत तथा टेबुकोनाजोल १६ प्रतिशत एससी २.२५ मिलीलीटर प्रतिलीटर दर पर का प्रयोग सबसे श्रेष्ठ उपाय था। ट्राइकोडर्मा वियुक्त पौद की वृद्धि में सहायक सिद्ध होने के साथ-साथ एनजाइम प्रकटीकरण में उच्चतर प्रतिरोधिता देखने को मिला। आईआरआरआई, फिलीपाइन्स से प्राप्त तीन जंगली उत्परिवर्ती प्रविष्टियां जैसे आईआर ७३३८२-८०--९-३-१३-२-२-२-३-बी (आईआर ६४ X ओ.रुफिपोगन), आईआर ७५८७०-८--१-२-बी-६-१-१-बी (आईआर ६४ X ओ.ग्लाबेरिमा) तथा आईआर ७७३९०-६-२-१८-२-बी (आईआर ६९५०२-६एसआरएन-३-यूबीएन-१-बी X ओ.ग्लाबेरिमा) को एनआरआरआई की भूरा पौध माहू कीटों के विरुद्ध अत्यधिक प्रतिरोधी पाई गई। गाल मिज प्रतिरोधी जीन १, २, ३, ४, ५, ६, ७, ९, १० एवं ११ में एनआरआरआई की गालमिल कीटों (जैवप्रकार २) के विरुद्ध ग्राह्यशील प्रतिक्रिया देखने को मिला जिससे कीटों की संख्या में हुई परिवर्तन का पता चलता है। चार चावल प्रविष्टियां जैसे प्रविष्टि ३४२२२, प्रविष्टि ३४२६४, प्रविष्टि ३८४६८ तथा प्रविष्टि ४२४२५ को सफेदपीठ वाला पौध माहू के विरुद्ध पुनः प्रतिरोधी पाया गया। रबी फसल में पीला तना छेदक के साथ न्यूनतम एवं अधिकतम तापमान का सकारात्मक सहसंबंध (सहसंबंध गुणांक क्रमशः :०.८९० तथा ०.७९५) की पुष्टि की गई जबकि खरीफ मौसम में वर्षा का नकारात्मक संहसबंध (-०.४५६) देखा गया। अर्द्धगहरा जल चावल पारिस्थितिकी में मकड़ियों की संख्या (८.२ प्रति मार) अन्य नाशकजीव समूहों से अधिक थी। इमिडाक्लोप्रिड के प्रयोग से मृदा रोगाणुओं पर अस्थायी प्रभाव पड़ा। क्लोराट्रानिलिप्रोल के अर्धजीवन का लोप ११५.५-१३८.६ दिन था। अधिक जैविक कार्बन तथा नमी में पीच की मात्रा के कारण महत्वपूर्ण रूप से क्लोराट्रानिलिप्रोल का न्यूनीकरण हुआ। ट्राइबोलियम कास्टानियम के विरुद्ध यूकालिप्टस का तेल सबसे श्रेष्ठ विकर्षक साबित हुआ। प्रक्षेत्र में हुए समन्वित नाशककीट प्रबंधन परीक्षण में

पीला तना छेदक की निगरानी के लिए फीरोमोन जाल तथा पत्ता मोड़क एवं भूरा पौध माहू के विरुद्ध नीम का तेल का प्रयोग से कीटनाशी के प्रयोग में बहुत कमी हुई।

वर्षाश्रित प्रतिरोपित परिस्थति में बूटिंग एवं फूल लगने की अवस्था में फल्स स्मट संक्रमण को कम करने में हेक्साकोनाजोल का छिड़काव असरदार पाया गया। ट्राइकोडर्मा से बीज उपचार करने पर बीजांकुरण एवं बीज ओज बेहतर हुआ तथा पत्ता प्रध्वंस में कमी हुई। असम में सितंबर के द्वितीय एवं तृतीय सप्ताहों में चावल की फसल में इल्लियों (स्पोडोप्टेरा मौरिशिया) की संख्या में भारी वृद्धि देखने को मिला ५६,७६८ हेक्टर की शीतकालीन चावल फसल बुरी तरह से प्रभावित हुई। बालिमाह पुटीह, आईआर २०, पंखारी २०३, पीटीबी ८, पीटीबी १८, पीटीबी २१, शुलि २, उत्रिरजापन तथा उत्रिमेराह में टुंगों रोग के गेरुआ वियुक्त के विरुद्ध प्रतिरोधिता देखने को मिला।

फाइटिक एसिड मात्रा के लिए बहत्तर चावल किस्मों में से, छह किस्मों को भूरा चावल एवं कुटाई की गई चावल से लौह एवं जस्ता जैवउपलब्धता के लिए मूल्यांकन किया गया तथा यह देखा गया कि विभिन्न किस्मों में फाइटिक एसिड की मात्रा तथा लौह एवं जस्ता की जैवउपलब्धता में विपरित संबंध है। बिंदली का भूरा चावल जिसमें फाइटिक एसिड की मात्रा सबसे कम (०.८२ प्रतिशत) है, में जस्ता जैवउपलब्धता सबसे अधिक है जबकि पीबी२६७ में जिसकी फाइटिक एसिड की मात्रा सर्वाधिक है, जस्ता एवं लौह की जैवउपलब्धता सबसे कम पाया गया। बिंदली, हीरा एवं पीबी२६७ के दाना विकास के आरंभिक एंव अंतिम समय में आईपीकेएल ट्रांसस्क्रिप्टस का कम स्तर दिखाई दिया जिससे यह पता लगा कि दाना भरण

के मध्य अवस्था में फाइटिक एसिड का जमाव होता है। इनमें से, पीबी२६७ में दाना भरण के मध्य अवस्था के दौरान सर्वाधिक आईपीकेएल प्रकटीकरण हुआ जिससे फाइटिक मात्रा का संबंध के बारे में पता चला। एक और अध्ययन में, विभिन्न पारिस्थितिकियों में खेती की गई चावल संवर्धनों की ग्लाइसेमिक सूचक में काफी विभिन्नता पाया गया। महसूरी में सबसे कम ग्लाइसेमिक सूचक जबकि अभिषेक किस्म में ग्लाइसेमिक सूचक सर्वाधिक पाया गया। आंथोसाइनिन एवं गामा-ओराइजानोल मात्रा के लिए पचास पिगमेंटेट धान जीनप्ररूपों का मूल्यांकन किया गया। कालोबात में सर्वाधिक आंथोसाइनिन मिला, दूसरा स्थान मामीहंगर, तीसरा स्थान मकिणपुरीब्लैक एवं कालाबायोरिन को मिला जबकि मामीहंगर, चखाओ एवं कालोबात में गामा-ओराइजानोल मात्रा भी अधिक मिला। चखाओ, मामीहंगर एवं मोरनोडोएगा चावल की कुटाई के समय आंथोसाइनिन एवं गामा-ओराइजानोल के प्रभाव पर अध्ययन किए गए। उसना चावल को खुले पात्र में उबालने से आंथोसाइनिन एवं गामा-ओराइजानोल मात्रा की बहुत कमी देखने को मिली जबकि मुरमुरा में इसकी मात्रा में कम नहीं के बराबर हुई। इससे पता चला कि खाना पकाते समय या उसनाने के समय आंथोसाइनिन की एक बड़ी मात्रा नष्ट हो जाती है।

लवणीय जल में संपूर्ण निमग्नता के प्रति बहु-अजैविक दबाव के लिए आईसी-१४५३५७, आईसी-४५९३६२, आईसी-४५१४६९, आईसी-४५०४९२, आईसी-४४९८४८, आईसी-५८०२६१, एसी-४३४०९, एसी-४३३६५, एसी-४३३९१, एसी-४३३५१ तथा एफआर१३ए जैसे आशाजनक धान जीनप्ररूपों की पहचान हुई।

वृद्धि अवस्था में सूखा सहिष्णुता के लिए दो सौ नबे चयनित जीनप्ररूपों में से, १३५ जीनप्ररूप सर्वाधिक सहिष्णु पाए गए। एक सौ नबे सूखा सहिष्णु वंशों में से २० श्रेष्ठ जीनप्ररूपों में अधिक मूल्य देखने को मिला। एक और अध्ययन में, आईआर-२० तथा महुलता को सुखा सहिष्णुता के लिए वृद्धि अवस्था के दौरान जनक वंशों के साथ मूल्यांकन किया गया। जीन पहचान हेतु आण्विक चिन्हकों का प्रयोग करते हुए दो जनकों आईआर-२० तथा महुलता के बीच पोलिमोरफिक सर्वेक्षण किया गया। पोलिमोरफिक सर्वेक्षण के लिए कुल १०१० माइक्रोसेटेलाइट चिन्हकों का प्रयोग किया गया। ताप सहिष्णु किस्म एन-२२ की बालियों में कुल शर्करा का जमाव अधिक देखा गया जबकि ग्राह्यशील किस्म नवीन में कम था। धान के पर्णहरित कार्यक्षमता में सुधार नामक कार्यक्रम के तहत सामान्य प्रकाश में प्रधान-१०२ तथा जीएआर-१३ में पर्णहरित कार्यक्षम सबसे अधिक हुआ जबकि राजेंद्रधान-१०२ एवं हिमालय-एल में कम हुआ। विश्लेषण के परिणामों के आधार पर, मैलिक एनजाइम जीन में सर्वाधिक पीपीडीके देखने को मिला।

चावल आधारित नमूना गांव कार्यक्रम के तहत, सात चावल की किस्मों रीता, सहभागीधान, चकाआखी, सीआर धान-२०२ तथा सीआधान-७०१ को १८ किसानों के २ हेक्टेयर भूमि में प्रदर्शित किया गया। पिछले वर्ष की तरह, इस वर्ष भी पशु स्वास्थ्य शिविर, चारा किटों का वितरण एवं बकरियों में स्वास्थ्य प्रबंधन, पशुधन एवं उनका प्रबंधन पर परामर्श दिए गए। स्वच्छता पखवाड़ा के तहत कटक जिले के टांगी-चौद्वार प्रखंड के गुरुजंग गावं में २५ अक्टूबर २०१६ को एक गांव-जागरूक एवं सफाई अभियान कार्यक्रम आयोजित किया गया।

चावल की खेती में लैंगिक संवेदनशील उपागम परियोजना के तहत निवेश-लागत किए गए विश्लेषण से पता चला कि २०११-१२ में की गई खेती और उससे प्राप्त कुल आय की अपेक्षा ४२ प्रतिशत अधिक उपज एवं ७६ प्रतिशत अधिक आय मिली है। बागवानी फसल एवं सब्जियों से आय में ५९ प्रतिशत, पशुधन से १५ प्रतिशत मिली। अधिकांश किसानों ने स्वीकार किया कि संस्तुत की गई एवं प्रदर्शित की गई चावल किस्मों को अपनाने पर उपज, विपणन, खाना पकाने के गुण, भंडारण गुण, रोग/कीट/खरपतवार प्रतिरोधिता स्तार पर लाभान्वित हुए हैं।

एनआरआरआई प्रक्षेत्र में २०१६-१७ के दौरान, संकर चावल राजलक्ष्मी से ७.३ टन प्रति हेक्टेयर की सर्वाधिक उपज मिली जबकि सत्यभामा से ४.१ टन प्रति हेक्टेयर की सर्वनिम्न उपज मिली। २०१ के खरीफ के दौरान, राजलक्ष्मी से ७.१ टन प्रति हेक्टेयर की सर्वाधिक उपज मिली जबकि लुणा बरियल एवं सीआर धान २०३ से सर्वनिम्न उपज मिली।

गुणवत्ता बीजों की पर्याप्त मात्रा में उचित समय पर अनुपलब्धता किसानों के लिए प्रमुख समस्या है। आत्मा, बीजीआरईआई एवं एनएफएसएम की योजनाओं को हितधारकों ने सराहा।

एफपीओ के माध्यम से धान बीज उत्पादन पर एक व्यवसाय योजना तैयार किया गया। इस परियोजना का कुल खर्च लगभग ३०.५ लाख रुपये है। इस परियोजना के प्रथम वर्ष में मिलने वाला लाभ के संबंध में यह आकलन किया गया कि इसमें ८७,६६८ रुपये का नुकसान हुआ है लेकिन द्वितीय वर्ष से लाभ मिलना आरंभ हुआ।

असम, कर्नाटक, हरियाणा, केरल, पुडुचेरी, पंजाब एवं तमिल नाडु से संग्रह किए गए बीज वितरण विश्लेषण तथा अन्य संबंधित आंकड़ों से पता चला कि एनआरआरआई की किस्में चार राज्यों मं खेती की जा रही हैं। अभिषेक, नवीन, चंद्रमा तथा सहभागी किस्मों की खेती असम में ६८१३१ हेक्टेयर में जबकि तमिल नाडु में सीआर-१००९ किस्म की खेती ११५२३८ हेक्टेयर में की जा रही है। केरल और पुडुचेरी में सीआर-१००९ किस्म की खेती कम क्षेत्र में की जा रही है। सभी राज्यों से संबंधित आंकड़ों के संकलन से पता चला कि एनआरआरआई की ३० चावल की किस्में भारत के १४ राज्यों के २.८३ मिलियन हेक्टेयर में की जा रही है।

पिछले ३४ वर्षों की खेती की लागत के विश्लेषण से पता चला कि अखिल भारतीय स्तर पर धान की फसल में उर्वरक का प्रयोग औसतन २००९-१३ के दौरान १४२ किलोग्राम प्रति हेक्टेयर है तथा प्रयोग का दर भी इस वर्षों में बढ़ा है। कर्नाटक में उर्वरक का सर्वाधिक (२७४ किलोग्राम प्रति हेक्टेयर) प्रयोग देखने को मिला जबकि असम में उर्वरक का सर्वानिम्न (१६ किलोग्राम प्रति हेक्टेयर) प्रयोग हुआ है। अखिल भारतीय स्तर पर धान की फसल में खाद का प्रयोग १९८० के दशकों में २८ क्विंटल प्रति हेक्टेयर से घटकर २००९-१३ के दौरान १३ क्विंटल प्रति हेक्टेयर हो गया है। अखिल भारतीय स्तर पर कीटनाशक का प्रयोग ८.६३ रुपये रहा जो २०१३-१४ का मूल्य है। पंजाब में कीटनाशक का प्रयोग सर्वाधिक (३३४० रुपये प्रति हेक्टेयर) रहा जबकि झारखंड में यह सबसे कम रहा। अखिल भारतीय स्तर पर पिछले वर्षों के दौरान भूमि का मूल्य १९८० में ८३९३ रुपये से बढ़कर २००९-१३ में १३८९६ रुपये हो गया है।

उत्तर प्रदेश के पच्चीस एआरआईएमए नमूनों को धान उत्पादन आकड़ों (५३ वर्ष) से जोड़ा गया है तथा एआरआईएमए नमूने (१,१,१) को सबसे अधिक उपयुक्त पाया गया।

Introduction

National Rice Research Institute (NRRI), formerly known as Central Rice Research Institute (CRRI), was established by the Government of India in 1946 at Cuttack, as an aftermath of the great Bengal famine in 1943, for a consolidated approach to rice research in India. The administrative control of the Institute was subsequently transferred to the Indian Council of Agricultural Research (ICAR) in 1966. The institute has two research stations, on at Hazaribagh, in Jharkhand, and other at Gerua, in Assam. The NRRI regional substation, Hazaribagh was established to tackle the problems of rainfed uplands, and the NRRI regional substation, Gerua for problems in rainfed lowlands and flood-prone ecologies. Two Krishi Vigyan Kendras (KVKs) also function under the NRRI, one at Santhpur in Cuttack district of Odisha and the other 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 stastistics for the country as a whole in relation to their potential productivity and profitability.

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

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

Thrust Areas

Exploration of rice germplasm from unexplored areas and their characterization; trait-specific germplasm evaluation and their utilization for gene discovery, allele mining and genetic improvement.

Designing, developing and testing of new plant types, next generation rice and hybrid rice with enhanced yield potential.

Identification and deployment of genes for input use efficiency, tolerance to multiple abiotic/biotic stresses and productivity traits.

Intensification of research on molecular host parasite/pathogen interaction and understanding the pest genomes for biotype evolution, off-season survival and ontogeny for devising suitable control strategy.

Developing nutritionally enhanced rice varieties with increased content of pro-vitamin A, vitamin E, iron, zinc and protein.

Development of climate resilient production technologies for different rice ecologies; designing and commercialization of efficient farm machineries suitable for small farms.

Development of cost effective and environmentally sustainable rice-based integrated cropping/farming systems for raising farm productivity and farmer' income.

Research Achievements

The institute has released 114 rice varieties including three hybrids suitable for cultivation in upland, irrigated, rainfed lowland, medium-deepwater logged, deepwater and costal saline ecologies. Besides, three high yielding varieties and the varieties suitable for aerobic germination, low glycemic index, high protein content, super rice etc. were identified.

The institute maintains more than 30,000 accessions of rice germplasm including nearly 6,000 accessions of Assam Rice collection (ARC) and 5,000 accessions from Odisha. Complied database on passport information for more than 30,000 germplasm accessions.

Marker-assisted selection was used for pyramiding BLB and blast resistance genes and for developing BLB and blast resistance rice cultivars.

Used marker-assisted breeding for introgression of resistance to drought, submergence and abiotic stresses.

Developed a rice-based farming system including rice-fish farming system integrating multiple enterprise initiatives with a rationale for ensuring food and nutritional security, stable income and employment generation for rural farm family.

Knowledge-based and leaf colour chart (LCC) N management strategy for increasing N-use efficiency for rainfed lowlands including use of integrated N management involving use of both organic and inorganic sources of N-fertilizer. Developed several agricultural implements such as manual seed drill, pre-germinated drum seeder, multicrop bullock and tractor drawn seed drill, flat disc harrow, finger weeder, conostar weeder, rice husk stove, mini par boiler an power thrasher with the sole aim of reducing both drudgery and cost of rice cultivation.

Different bio-agents for management of rice pests and growth promotion of rice have been developed with suitable formulation for field application. Plant products and pesticides have been tested for successful management of field pest of rice.

Identified biochemical and biophysical parameters for submergence and other abiotic stress tolerance in rice.

Developed crop modeling of G x E interaction studies that showed that simulation of crop growth under various environments could be realistic under both irrigated and favourable lowlands situations and climates resilient rice varieties.

Developed suitable rice production technologies for rainfed uplands, lowlands amd irrigated ecology including production technologies for hybrid rice and scented rice that were field tested and transferred to farmers.

Addressing rice production constrains in eastern India through BGREI programme.

Evaluated and popularized varieties through frontline demonstrations (FLD) in farmers' fields.

Commercialized three hybrids, LCC and IPM for rice-based cropping system. Submitted one patent and developed agri-entrepreneurship.

Provided farmers' advisory services through regular radio talks and TV telecasts on rice production technologies. Developed 15 training modules for farmers and extension workers.

Imparted short-term and long-term training for personnel from the State Departments of Agriculture, State Agricultural Universities (SAU) and other educational institutions.

Imparted advance training and research leading to Masters (M.Sc.) and Doctoral degrees (Ph.D.).

Linkages

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

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 $85^0$55′48" E to $85^0$56′48" longitudes and $20^0$26′35" N to $20^0$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).

Hansa Dubraj 2013/1507
Falodhan 2015/690
Hardi Gakhi 2013/1509
Krushna Bhog 2011/1250
Nataki 2014/2147
IC-517000 Kh-07
Ban Kena 2014/1667
Phool Mecha 2013/1556
Kava Kor 2013/1546
Godavari 2013/1552
Bokita 2015/168

PROGRAMME : 1

Genetic Improvement of Rice

Under the Crop Improvement programme, basic, strategic and applied researches are conducted with specific target of achieving genetic improvement of rice for national food security. Research on rice genetic resources, conventional and molecular marker assisted breeding, transgenic and seed aspects are conducted.

Two exploration programmes were conducted for collection of trait specific rice germplasm (traditional rice, medicinal rice and wild rice) from Kerala and Uttar Pradesh. During the year, 5482 accessions of rice germplasm were supplied to various researchers of the country. One variety, CR Dhan 508 was released and notified by CVRC for deep water ecology of Odisha, West Bengal and Assam. Another seven varieties were released by Odisha State for different ecologies. Among these, two varieties CR Dhan 207 (Srimati) and CR Dhan 209 (Priya) were released for aerobic condition. CR Dhan 407 (Pradhandhan) and CR Dhan 507 (Prasant) have been released for rainfed shallow lowland and waterlogged situations, respectively. Apart from this, CR Sugandh Dhan 910, a short grain aromatic rice variety was released by the SVRC, Odisha. An improved culture of popular variety Swarna where three bacterial blight resistance genes (*xa5, xa13* and *Xa21*) have been incorporated through marker assisted selection was released as CR Dhan 800. A nutrient rich rice variety, Mukul (CR Dhan 311) with high (10.1%) grain protein and moderate (20 ppm) Zn contents was also released. A long slender aromatic variety (Gangavati Emergency) was released for irrigated ecology of Karnataka.

The advancement of the entries under AICRIP was also very encouraging. Nearly 25% of the 224 entries were promoted to different stages of advanced varietal trial of AICRIP under different ecologies. Doubled hapolidy through anther culture technique is now routinely used for rapid development of homozygous genotypes. Besides this, four cultivars namely Salkathi, PDK Shriram, TN 1 and Heera were re-sequenced through Next Generation Sequencing for designing genome wide SNPs. To make the seeds of improved varieties available to the stakeholders, the institute produced 872.90 q of breeder seed. Besides development of new varieties and technologies, a total of 36 research papers were published by the scientists of the Division in various journals in last one year out of which 23 were published in journals with NAAS rating of more than 6.0.

Exploration, Characterization and Conservation of Rice Genetic Resources

Exploration and collection of rice germplasm

Two exploration programmes were conducted during the period in different parts of the country for collection of trait specific rice germplasm. They are listed below.

The first exploration and collection programme of traditional rice, medicinal rice and wild rice (*Oryza nivara*) germplasm was conducted from northern parts of Kerala during 22-30 October, 2016 and a total of 33 accessions were collected from 10 districts. The patented Geographical Indicator (GI) registered medicinal rice; *njavara* rice is cultivated in Palakkad district because of its commercial potential in ayurvedic treatments and also Govt. subsidy. However, the occurrence of wild rice *O. nivara* was observed in some patches but *O. rufipogon* was rare.

Another programme was conducted in collaboration with ICAR-National Bureau of Plant Genetic Resources (NBPGR), Base Center, Cuttack for collection of wild rice and landraces of cultivated rice germplasm from Jaunpur, Azamgarh, Mau and Deoria districts of Uttar Pradesh during 20-27 November, 2016. A total of 50 accessions, *viz.,* wild rice *O. nivara* (21) and *O. rufipogon* (6); weedy rice i.e. *O. sativa* var. *spontanea* (10) and cultivated rice *O. sativa* (12) were collected. Wide range of inter specific variability was recorded among collected rice landraces for various morpho-agronomic traits.

Collection of Kalanamak, aromatic short grain rice and Interaction with farmers of U.P.

Rejuvenation of the conserved germplasm and the new collections

A set of 1478 accessions of rice germplasm conserved in Medium Term Storage (MTS) in different years of *kharif* harvest (2000, 2001, 2003, 2005, 2006, 2007, 2008, 2009 and 2012) were randomly picked up from the gene bank and evaluated for seed viability. Out of which 222 accessions were found viable (>85% germination) and 59 accessions were found with < 85% germination. Interestingly, 58 accessions of *kharif*-2000 and 87 accessions of *kharif*-2001 were found to possess >90% viability even after 16 years of storage which envisaged high viability potential of these accessions in a full proof system of *ex situ* conservation.

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

Agro-morphological characterization

A total of 5800 germplasm including wild and weedy rice were grown for characterization on agro-morphological traits of 30 DUS characters as per the descriptors. This included the set of 5000 accessions of rice germplasm which were received from NBPGR under CRP Agro biodiversity project and 580 newly acquired accessions. All the 30 morphological observation data on 19 qualitative characters and 11 quantitative characters were recorded as per the descriptors at appropriate stages of plant growth and maturity. These materials were harvested, processed, packed and sent to National Gene Bank for long term storage (LTS).

Molecular characterization of land races of rice (*Oryza sativa* L.) collected from North-Eastern India

A total of 17 landraces from North Eastern India along with five popular rice varieties were characterized using STMS markers. A pre-screening of 60 STMS markers was done out of which only 16 STMS markers showed best amplification and reproducibility; these were selected for further analysis. Sixteen STMS markers produced a total of 53 bands out of which 47 bands (88.67%) were found polymorphic. The maximum number of total alleles (5) was amplified with RM10655, RM580, RM1 and RM3412 while RM10619 produced the lowest number (1) of total alleles. The amplicons were observed in the range of 30 to 450 bp. The maximum PIC value (0.495) was observed with the marker RM23805 followed by 0.375 in RM10890, while RM10619 and RM13129 showed the minimum value of 0.086 and 0.138, respectively. The unique bands were observed in some of the markers (RM318, RM10655, RM580, RM 1, and RM13129) used for this study.

For the genetic similarities analysis, 16 STMS markers data were used to construct a dendrogram by using UPGMA method to the segregation of the 17 landraces and five popular rice varieties into two distinct groups. Clustering results showed a clear distinction into major and minor groups with 17 landraces and five popular rice varieties (Fig 1.1).

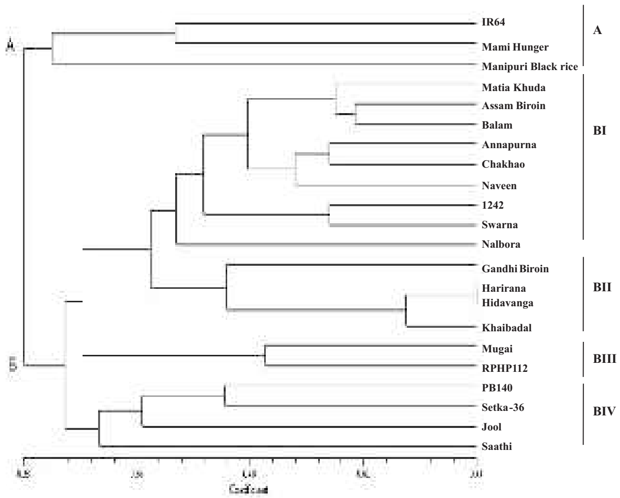


Fig.1.1. Dendrogram derived from UPGMA cluster analysis using Jaccard's similarity coefficient based on 16 STMS markers showing the associations among the land races collected from North-Eastern India.

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

With the aim of creating database, 14000 rice germplasm accessions characterized earlier were documented. The data revealed that majority of the accessions were with green basal leaf sheath, green leaf blade, well exserted panicle, panicle intermediate type, long fully awned, intermediate threshing, white kernel colour, some aromatic, erect flag leaf angle and fast leaf senescence type (Fig. 1.2).

Wide range of variation among the accessions for the traits was observed for grain yield/plant, number of effective tillers and 100 grain weight. The lowest range of variation among the accessions for the traits was observed for panicle length, seedling height and days to maturity. Earliest flowering germplasm was identified as AC 13622 (63 days), while flowering in IC-1947 took 167 days. Number of effective tillers ranged from 1.0-23.6 (IC7165- AC 14080). Plant height ranged from 39.0-240.0 cm (AC 12735 – AC 12305), grain yield ranged from 8.4-60.6 g/plant (IC 5020-AC 11555) and grain l/b ratio ranged from 1.35-5.85 (AC 12379- IC 7343) (Table 1.1).

Phenotypic similarity of these accessions having all the qualitative and quantitative characters were evaluated by UPGMA (Unweighted pair group method of average) based on Euclidean distances. Cluster analysis based on UPGMA distributed 8949 accessions into six groups based on quantitative characters (Fig. 1.3). Higher number of accessions were in cluster 1 (6915), followed by cluster 2 (1994) and minimum number of accessions in cluster 5 (1) followed by cluster 3 (4). Inter cluster variability was the highest between cluster 4 and 6 followed by cluster 5 and 6. Intra cluster variability was high in cluster 2 and low in cluster 3.

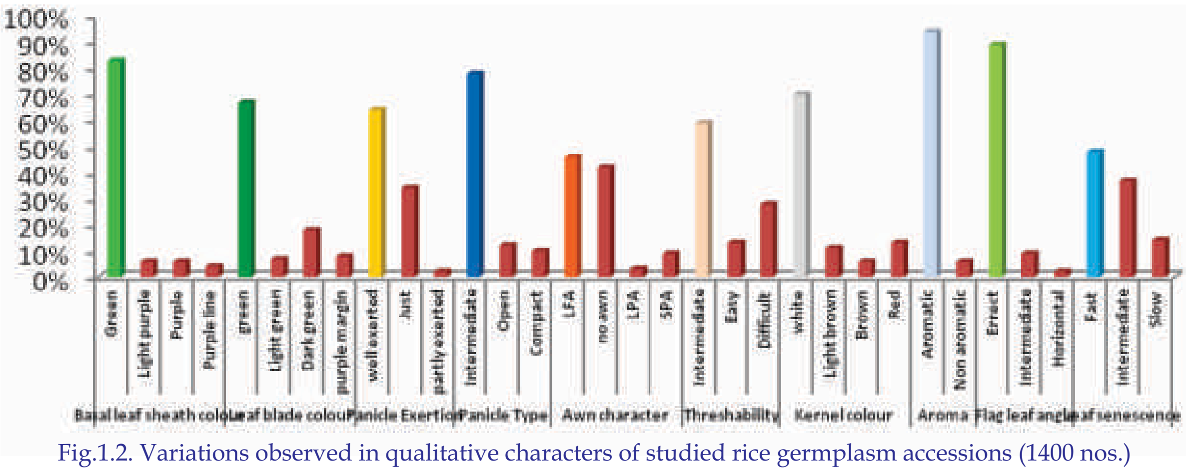


Fig.1.2. Variations observed in qualitative characters of studied rice germplasm accessions (1400 nos.)

Table 1.1. Variability observed for quantitative traits

Sl No.	Characteristics	Mean+S.E	Range	C.V.(%)
1	Seedling height (cm)	19.30+0.04	8.4-30.6 (EC1230 – IC1920)	12.00
2	Leaf length (cm)	57.5+0.12	18.0 – 96.90 (AC13482 - IC7545)	19.25
3	Leaf width (cm)	1.10+0.002	0.35-22.4 (AC13622- AC13290)	16.20
4	Days to 50% flowering	124.6+0.12	63.0 -167.0 (AC13622- IC1947)	15.04
5	No. of Effective tillers	5.84+0.02	1.0-23.6 (IC7165- AC14080)	28.02

6	Plant height (cm)	158.6±0.23	39.0-240.0 (AC12735 - AC12305)	17.58
7	Panicle length (cm)	26.43±0.03	12.0-38.0 (AC13247- AC13160)	11.30
8	Days to maturity	156.02±0.20	93.0-199.0 (AC 13069- EC 1198)	12.05
9	l/b ratio	3.11±0.006	1.35-5.85 (AC 12379- IC 7343)	18.56
10	100 grain weight (g)	2.36±0.005	0.70-5.10 (AC 13447- IC 4439)	21.42
11	Grain yield (g/plant)	12.7±0.05	8.4-60.6 (IC 5020- AC 11555)	37.97

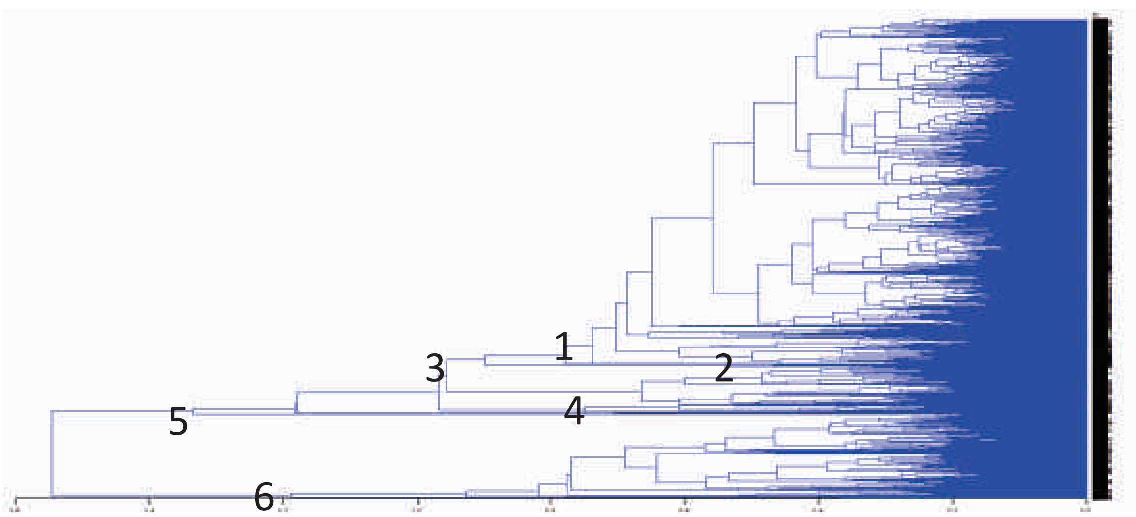


Fig.1.3. Dendogram derived from UPGMA cluster analysis based on Euclidean distances

Germplasm conservation

Five thousand and eight hundred accessions of rice germplasm were characterized and rejuvenated for conservation. These materials were conserved in three layered aluminum foil pouches at NRRI in Medium Term Storage (MTS) facility.

Supply of germplasm seeds

Five thousand three hundred and eighty eight accessions of rice germplasm/elite lines/ donors/ released and notified varieties were supplied to different researchers all over the country and also to the Institute scientists for screening, evaluation and utilization. Out of 5388 accessions, 188 were shared with different institutes/organizations through proper signing of Material Transfer Agreement (MTA).

Maintenance Breeding and Seed Quality Enhancement

Nucleus and breeder seed

Panicle progeny rows of 42 varieties were grown for maintenance breeding from which a total of 1352 kg nucleus seed was produced. This nucleus seed will be used for the production of Breeder seed in the coming year. As per the indent received from the Dept. of Agriculture and Cooperation, Govt. of India, a total of 872.90 qtls of breeder seed of 48 varieties and nine parental lines were produced. (Table 1.2).

Participatory Seed Production

Under National Seed Project, Farmer's Participatory Seed Production was taken up in two villages in agreement with Mahanga Krushak Vikash Manch and Mahatma Gandhi Farmer's Club, respectively. The programme was taken up in the farmer's field with the involvement of the farmers and under the supervision of NRRI scientists. Looking at the demand of the farmers, four popular varieties namely, Pooja, Sarala, Gayatri and Swarna *sub 1* were taken up for seed production. About 1156.88 quintals of seeds which qualified as TL seed standard were procured back and processed for selling to the farmers as TL Seed.

Table 1.2. Breeder seed production during the year 2016-17

Sl. No.	Variety name	Production during *rabi* 2015 - 16 (q)	Production during *kharif* 2016 (q)	Total Production (q)
1.	Annada	10.2	-	10.2
2.	CR Dhan 70	-	0.9	0.90
3.	CR 1014	-	6.9	6.90
4.	CR 1017 (Dharitri)	-	11.4	11.4
5.	CR 1018 (Gayatri)	-	7.8	7.80
6.	CR 1030	-	0.9	0.9
7.	CR Borodhan – 2	21.0	-	21.0
8.	CR Dhan 10	21.0	-	21.0
9.	CR Dhan 300	-	1.5	1.5
10.	CR Dhan 310	0.3	1.5	1.8
11.	CR Dhan 401	-	2.4	2.4
12.	CR Dhan 405	0.5	-	0.5
13.	CR Dhan 500	-	36.0	36.0
14.	CR Dhan 505	-	1.8	1.8
15.	CR Dhan 601	21.5	-	21.5
16.	CR Sugandha dhan 3	-	1.2	1.2
17.	CR Sugandha dhan 907	-	18.3	18.3
18.	Geetanjali	5.0	11.1	16.1
19.	Improved Lalat	-	0.9	0.9
20.	Jaldidhan 6	0.6	-	0.6

21.	Ketekijoha	-	2.4	2.4
22.	Khitish	15.5	1.8	17.3
23.	Luna Sampad	-	0.6	0.6
24.	Luna Suvarna	-	1.5	1.5
25.	Lunishree	-	0.9	0.9
26.	Moti	-	1.5	1.5
27.	Naveen	114.0	-	114.0
28.	Nua Kalajeera	-	1.8	1.8
29.	Nua Chinikamini	-	2.1	2.1
30.	Padmini	-	2.1	2.1
31.	Pooja	-	47.4	47.4
32.	Ranjeet	-	4.2	4.2
33.	Ratna	0.3	-	0.3
34.	Sahbhagidhan	2.0	-	2.0
35.	Sarala	-	10.5	10.5
36.	Savitri	-	0.6	0.6
37.	Shatabdi	47.5	-	47.5
38.	Swarna *sub1*	-	400.0	400.0
39.	Varshadhan	-	29.4	29.4
40.	Ajay (A line)	0.8	-	0.8
41.	Ajay (B line)	0.25	-	0.25
42.	Ajay (R line)	0.25	-	0.25
43.	Rajalaxmi (A line)	0.8	-	0.8
44.	Rajalaxmi (B line)	0.25	-	0.25
45.	Rajalaxmi (R line)	0.25	-	0.25
46.	CR Dhan 701 (A line)	1.0	-	1.0
47.	CR Dhan 701 (B line)	0.25	-	0.25
48.	CR Dhan 701 (R line)	0.25	-	0.25
	Total	**263.5**	**609.4**	**872.9**

Evaluation of NRRI released varieties for seed dormancy

Ninety four NRRI released varieties were screened for days to dormancy after 35 DAH (days after heading). The seeds were tested for germination percentage immediately after harvest and in subsequent days in petri-plates. Days taken by a variety to achieve 80% germination were considered as duration of seed dormancy. The varieties Jayanti, Jayantidhan, Nua Chinikamini and Lunishree were observed with ⩾15 days dormancy harvested at 35 DAH. The days to dormancy of each variety is presented in the Table 1.3.

Evaluation of NRRI released varieties for seed viability potential

A set of 43 NRRI released varieties were evaluated for their seed viability potential. These varieties immediately after harvest were stored under normal room temperature and relative humidity condition. At every month, the germination percentage was recorded till the germination fell below 80%. Among the 43 varieties tested, Satyabhama, Kalinga II, Anjali and Sneha were observed with poor viability (showing 80 % viability up to 120 days after harvest), whereas, Satyakrishna, CR Dhan 305, CR Dhan 601, Neela, Saket 4, Shaktiman and Vanaprabha were observed with higher viability even after 300 days of harvest (Fig. 1.4).

Table 1.3. Duration of Dormancy (days) of 95 NRRI released varieties tested at 35 days after heading

Sl. No.	Varieties	Days	Sl. No.	Varieties	Days	Sl. No.	Varieties	Days
1	Abhishek	0	33	CR Borodhan 2		65	CR Dhan 201	8
2	Ajay	0	34	CR Dhan 601	0	66	CR Dhan 202	0
3	CR Dhan 10	0	35	Annada	0	67	CR Dhan 203	9
4	CR Dhan 300	10	36	CR Dhan 101	0	68	CR Dhan 204	0
5	CR Dhan 301	0	37	CRDhan 40	13	69	CR Dhan 205	2
6	CR Dhan 303	0	38	Dhalaheera	12	70	CR Dhan 206	8
7	CR Dhan 304	0	39	Heera	0	71	CR Dhan 404	0
8	CR Dhan 305	0	40	Neela	9	72	CR Dhan 407	0
9	CR Dhan 306	0	41	Phalguni	0	73	CR Dhan 408	4
10	CR Dhan 307	4	42	Sadabahar	4	74	CRHR 32	0
11	CR Dhan 310	0	43	Sattari	0	75	Dharitri	0
12	CR Dhan 907	6	44	CR Dhan 100	0	76	Ketekijoha	0
13	Geetanjali	0	45	Sneha	0	77	Moti	9
14	Indira	0	46	Tara	0	78	Nua Chinikamini	20
15	Imp Lalat	0	47	Vandana	8	79	Nua Kalajeera	12
16	Imp Tapaswini	0	48	Vanaprabha	10	80	CR Sugandha dhan 3	9

17	Jayanti	15	49	Virendra	7	81	Padmini	0
18	Khitish	11	50	Sahbhagidhan	0	82	Pooja	0
19	Kshira	0	51	CR Dhan 70	0	83	CR Dhan 902	0
20	Narendra-1	13	52	CR Dhan 500	0	84	CR Dhan 401	0
21	Naveen	0	53	CR Dhan 501	6	85	Samalei	0
22	Radhi	6	54	CR Dhan 505	7	86	Savitri	9
23	Rajalaxmi	0	55	Jaladidhan 6	11	87	Swarna *sub-1*	9
24	Ratna	0	56	CR Dhan 503	14	88	Swarna	11
25	Shatabdi	0	57	Jayantidhan	20	89	CR Dhan 406	12
26	Saket-4	0	58	Kalashree	0	90	Luna Sampad	8
27	Shaktiman	0	59	Panidhan	0	91	CR Dhan 405	11
28	Sarasa	0	60	Sarala	14	92	Lunishree	18
29	Supriya	0	61	Tulasi	0	93	Luna Suvarna	7
30	Tapaswini	0	62	Utkalprava	8	94	Sonamani	9
31	Udaya	6	63	Varshadhan	11			
32	Chandrama	0	64	CR Dhan 200 (Pyari)	0			

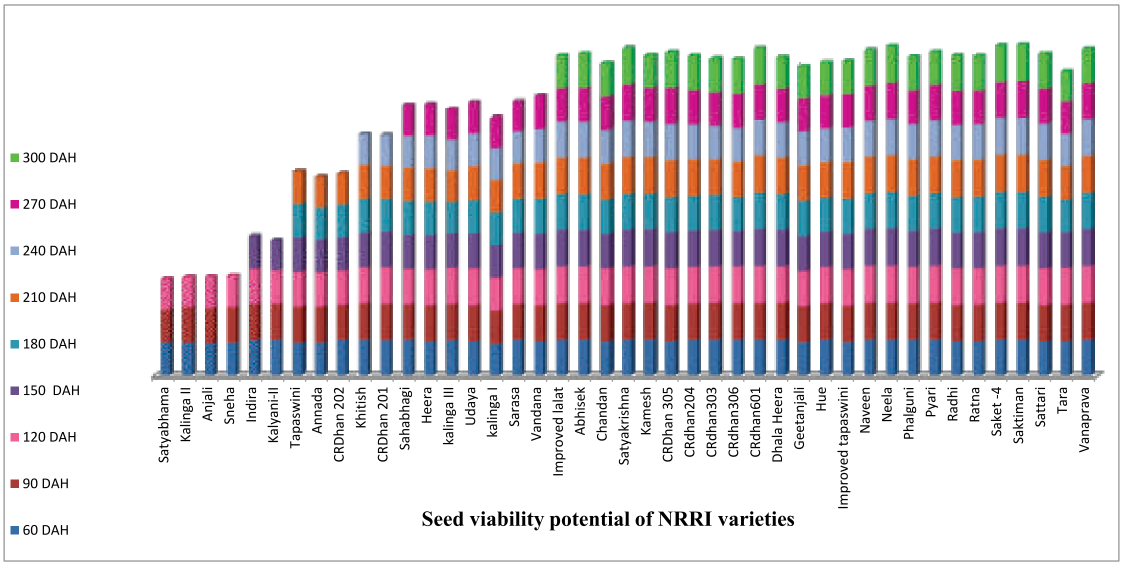


Fig. 1.4. Seed viability potential of NRRI released rice varieties

Impact of False Smut Disease on Seed Health

In diseased panicle, percent filled grain decreased lead to increased chaffy grain. It was increased while 1000-grain weight was decreased and this change was significantly different from healthy panicle. Seedling vigour index (SVI) was lesser in diseased grain both in terms of root-shoot length (SVI-I) and dry weight of seedling (SVI-II) (Table 1.4).

Evaluation of Some Varieties against False Smut Disease

Twenty three varieties from the Breeder seed chain were evaluated against false smut disease. The varieties Ranjeet and Luna Suvarna were found to be highly resistant to false smut disease while CR Dhan 70, Pooja, Sarala, CR 1014, Varshadhan and Tapaswini were found to be susceptible (Table 1.5).

Utilization of new alleles from primary and secondary gene pools of rice

Development of pre-breeding lines for biotic stress resistance/tolerance

Sheath blight resistance

Twelve accessions of wild rice *Oryza rufipogon* (AC 100014, 100015, 100102, 100165, 100166, 100173, 100263, 100373, 100380, 100444, 100492 and 100495) were grown for this study. They were artificially inoculated with the virulent isolate (ShbSL 4) of sheath blight pathogen, *Rhizoctonia solani* Kuhn by inserting sclerotial bodies with bits of mycelia inside the leaf sheaths. Tapaswini was taken as susceptible and CR 1014 as resistant check. The susceptible check Tapaswini showed maximum disease with SES score of 7.4 (highly susceptible reaction), whereas the resistant check, CR 1014 showed minimum of score 2.7. Sheath blight incidence with least SES score of 2.9 (moderately resistance reaction) was found in AC 100015, whereas, three accessions AC 100444, 100263, 100380 were found to be tolerant showing disease scores of 3.2, 4.2, 4.6, respectively. Maximum disease score of 6.7 was observed in AC 100014 and AC 100173 (Table 1.6). The identified accessions will be re-evaluated for sheath blight resistance.

Table 1.4. Impact of False Smut Disease on Seedling Vigour Index

Sl. No.	Variety	Seedling vigour index - I		% decrease of SVI-I over healthy grain
		Healthy	Diseased	
1.	Tapaswini	1729.8	1287.9	25.5
2.	Pooja	1547.5	1300	16
3.	Gayatri	2118.9	1734	18.2
4.	CR 1014	1974.4	1725.8	12.6
5.	Utkalprava	2677.7	2228.3	16.8
6.	Padmini	1946.9	1510.9	22.4
7.	CR Dhan 401	1750.9	1496	14.6
8.	Dharitri	1806.9	1269	29.8
9.	Sarala	1694.9	1233.8	27.2
10.	Ranjeet	2238	2120.9	5.2
11.	CR Dhan 500	1532.5	1341.7	12.3

Table 1.5. Evaluation of Varieties against False Smut disease

Sl. No.	Variety	SD	SDS	DI%	DIS	CEI	CEIS	DR
1.	Geetanjali	2.8	3	11.9	5	4.2	5	MS
2.	CR Dhan 907	1.0	1	2.4	1	1	3	MR
3.	CR Dhan 303	1.8	3	8.8	3	3	3	MR
4.	Nua Kalajeera	1.0	1	3.8	3	2.2	3	MR
5.	Phalguni	3.3	3	17.5	5	4.2	5	MS
6.	Lunishree	2.1	3	19.0	5	4.2	5	MS
7.	Luna Sampad	2.0	3	10.1	5	4.2	5	MS
8.	CR Dhan 70	4.0	3	31.0	7	5.4	7	S
9.	Ketekijoha	1.5	3	8.1	3	3	3	MR
10.	CR Sugandh Dhan 3	1.0	1	3.6	3	2.2	3	MR
11.	Nua Chinikamini	2.0	3	8.6	3	3	3	MR
12.	Padmini	3.3	3	10.9	5	4.2	5	MS
13.	Improved Lalat	1.0	1	16.7	5	3.4	5	MS
14.	Utkalprabha	4.5	3	13.3	5	4.2	5	MS
15.	Pooja	3.4	3	39.0	7	5.4	7	S
16.	Sarala	3.5	3	30.2	7	5.4	7	S
17.	Ranjeet	0.0	0	0.0	0	0	0	HR
18.	Dharitri	2.3	3	21.1	5	4.2	5	MS
19.	CR 1014	2.4	3	32.7	7	5.4	7	S
20.	CR 1018	3.0	3	10.1	5	4.2	5	MS
21.	Varshadhan	1.5	3	26.5	7	5.4	7	S
22.	Tapaswini	6.2	5	37.5	7	6.2	7	S
23.	Luna Suvarna	0.0	0.0	0.0	0.0	0	0.0	HR

SD= smut ball/panicle, SDS=smut ball density score (0-9 scale), DI% = % disease incidence (% infected tiller), DIS = Disease incidence score (0-9 scale), CEI= Comprehensive evaluation index, CEIS=comprehensive evaluation index score (0-9 scale), CEI= (DISx60+SDSx40) / 100, DI%= (No. of infected panicle / Total no. of panicle) / 100, DR = Disease Reaction

Table 1.6. Sheath blight incidence in different accessions of *Oryza rufipogon* (*kharif*, 2016)

Sl.No.	Accessions of *Oryza rufipogon*	Pathogenic reaction	Time taken for disease symptoms appearance (in days)	Mean disease score*	Reaction
1	AC 100014	+	4	6.7	S
2	AC 100015	+	5	2.9	MR
3	AC 100102	+	7	5.7	S
4	AC 100165	+	4	5.5	S
5	AC 100166	+	4	5.2	S
6	AC 100173	+	5	6.7	S
7	AC 100263	+	4	4.2	T
8	AC 100373	+	6	6.0	S
9	AC 100380	+	7	4.6	T
10	AC 100444	+	6	3.2	T
11	AC 100492	+	5	5.5	S
12	AC 100495	+	6	5.6	S
13	Tapaswini (susc.check)	+	4	7.4	HS
14	CR 1014(res. check)	+	6	2.7	MR

*Based on 0-9 scale of SES for Rice (Anon., 1996)
R-Resistant (0-1), MR-Moderately resistant (1.1-3), T-Tolerant (3.1-5), S-Susceptible (5.1-7), HS-Highly susceptible (7.1-9).

Genotyping with cgSSR markers of *Oryza rufipogon* accessions having varying degree of sheath blight tolerance

Candidate gene sequence based SSR markers (cgSSR) were designed for twenty one biotic stress responsive genes which are non-specifically expressed at different stages of the cascade under various biotic stress situations in rice. The 18 wild rice accessions along with two rice varieties, CR 1014 and Swarna were genotyped using the designed cgSSR markers. All the twenty one primers were amplified in both *Oryza sativa* and *Oryza rufipogon* indicating the cross transferability of the designed markers. Except two markers all others were polymorphic among the accessions genotyped. A total of 106 alleles were detected with an average of five alleles per locus (Table 1.7). The number of alleles per locus varied from one for the two monomorphic markers to ten for the marker, OsAOC (LOC_Os03g32314). Though gene sequence based markers are used in the study, which are supposed to be highly conserved across species, a very high level of gene diversity was observed, with the expected heterozygosity (He) value ranging from 0 to 0.85 and an average He value of 0.59. This was mainly due to the presence of heterozygotic loci in the *Oryza rufipogon* accessions, which indicated the presence of cross pollination in the wild rice species. The markers were highly polymorphic among the accessions with the PIC value ranging from 0 to 0.85 with an average value of 0.554, indicating the usefulness of the markers in differentiating germplasm resources with varying degree of sheath blight tolerance.

Table 1.7. Details of cgSSR primers used for genotyping wild rice accessions showing varying degree of sheath blight tolerance

Gene	Locus ID	SSR motif	Position	Band size (bp)	No. of alleles	PIC value	He value
OsBRR1	Os03g12730.1	(CTC)9	CDS	315	4	0.47	0.56
OsGAP1	Os02g22130	(TC)10	5′ UTR	186	3	0.45	0.51
OsRacB	Os02g02840.1	(GA)21	5′UTR	270	6	0.71	0.75
OsRacB	Os02g02840.1	(TTC)9	Intron	224	6	0.75	0.78
OsWRKY4	Os03g55164.1	(TTC)13	CDS	167	6	0.79	0.82
OsWRKY13	Os01g54600.1	(GA)15	5′ UTR	246	7	0.80	0.83
OsWRKY76	Os09g25060.1	(TTGA)9	Intron	292	1	0.00	0.00
OsWRKY82	Os08g17400	(TA)12	Intron	189	4	0.39	0.42
OsWRKY 83	Os12g40570	(GGC)9	CDS	274	9	0.74	0.77
OsSWN2	Os08g02300.1	(AG)10	3′ UTR	178	4	0.44	0.48
Gns1/OsEGL1	Os05g31140	(TC)11	Intron	151	8	0.81	0.83
OsPR1a	Os07g03710	(TA)9	5′ UTR	240	7	0.59	0.66
JIOsPR10	Os03g18850	(TA)9	Intron	161	1	0.00	0.00
OsNPR3/NH3	Os03g46440	(GT)9	5′ UTR,	177	4	0.53	0.57
OsPR1#052	Os05g51680	(TTTA)9	Intron	300	4	0.62	0.67
OsNPR2/NH2	Os01g56200	(TC)9	5′ UTR	264	2	0.35	0.46
Cytochrome P450	Os03g40540	(GA)21	Intron	224	5	0.66	0.71
OsLOX1	Os03g49380	(GA)16	5′UTR	162	5	0.73	0.77
Pdk1	Os01g65230	(CT)14	5′UTR	207	3	0.16	0.18
OsAOC	Os03g32314	(AT)11	5′UTR	223	10	0.85	0.87
OsbHLH65	Os04g41570	(GA)13	5′UTR	173	7	0.79	0.82

The genotyping data was used to plot the dendrogram depicting the evolutionary relationships among the accessions studied (Fig. 1.5). The UPGMA clustering based on 106 marker alleles of 21 cgSSR loci grouped the twenty genotypes used in the study into three sub-groups. The most tolerant of all the accessions screened for sheath blight tolerance, the two moderately resistant wild rice accessions, AC 100444 (SES score, 2.30) and AC 100015 (SES score, 2.70) and one tolerant accession, AC 100005 (SES score, 3.40) were grouped in the same sub-group along with the tolerant check CR 1014 (SES score, 2.70). Though exhibiting contrasting phenotypes for sheath blight tolerance, the two *Oryza sativa* cultivars, Swarna and CR 1014 were grouped in the same sub-sub-group indicating their evolutionary relationships in comparison to *Oryza rufipogon* accessions. Four susceptible accessions, AC 100047 (SES score, 6.10), AC 100166 (SES score, 5.20), AC 100168 (SES score, 5.30) and AC 100174 (SES score, 6.00) were also included in the same sub-group. The wild rice accessions collected from Tripura, the sheath blight susceptible AC 100373 (SES score, 6.00) and tolerant AC 100380 (SES score, 4.60) were grouped together in the second sub-group along with susceptible accession AC 100492 (SES score, 5.10). The cgSSR markers used in the present study could not differentiate germplasm resources with contrasting sheath blight tolerance, with both susceptible and tolerant genotypes featuring in all the three sub-groups. This can be attributed mainly to the fact that sheath blight tolerance in rice is a quantitative trait governed by polygenes. However, the study showed the utility of the highly cross transferable cgSSR markers for the marker assisted germplasm evaluation involving both cultivated and wild species. The markers showing polymorphism between wild and cultivated rice species can also be used in the marker assisted introgression of biotic stress tolerance in rice.

Yellow stem borer tolerance

Twenty eight back cross derivative lines of CR 1009/*O. brachyantha* (AC 100499)//CR 1009) and one susceptible check TN 1 were screened in the net house against yellow stem borer. Ten neonate of yellow stem borer were released in all entries / lines planted in pot and tray in replications under net house condition. The entries *viz*., B2 11(4.8% score of 1) and B2 17, B2 23, B2 10, B2 24, B2 25, B2 6, B2 27, B2 36 (11-20% score of 3) exhibited less damage as against the susceptible check TN1 (43.3% score of 7).

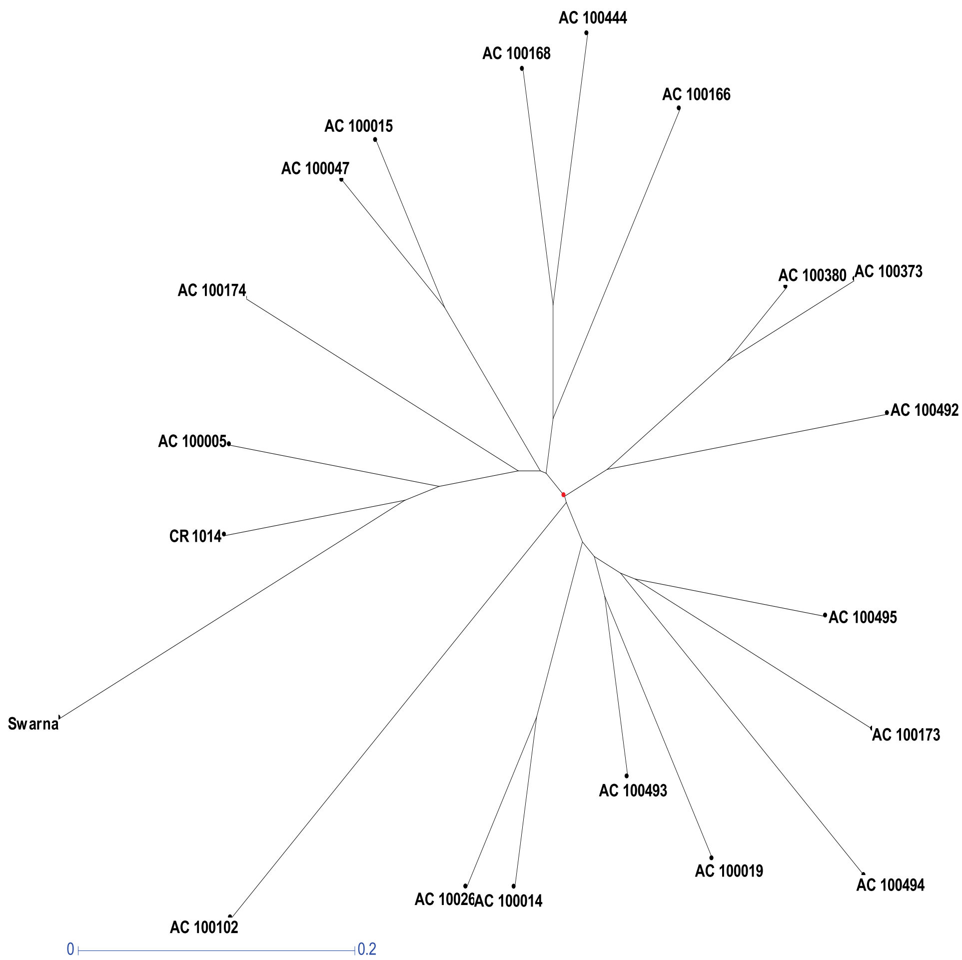
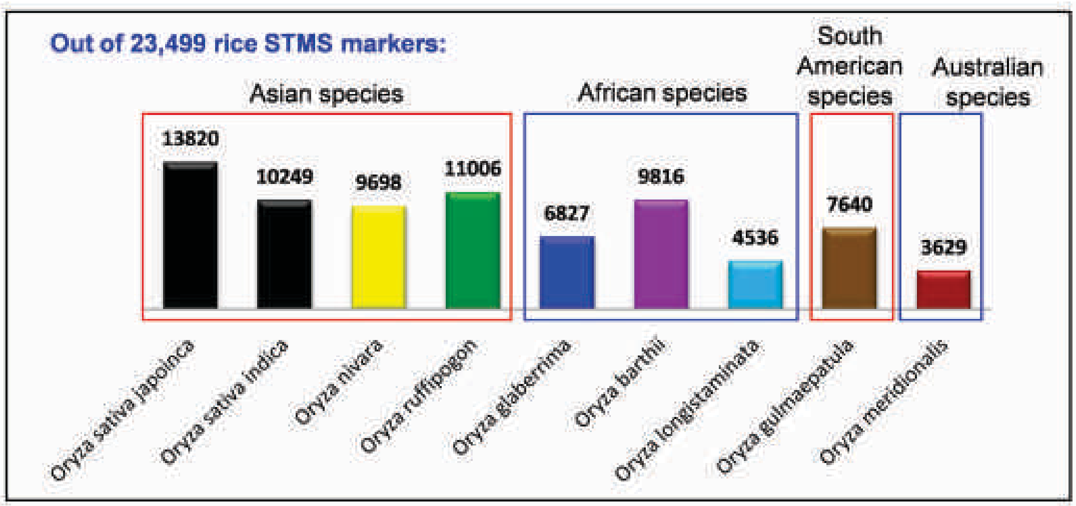


Fig. 1.5. Dendrogram based on UPGMA clustering using 106 alleles of 21 cgSSR markers for 18 *O. rufipogon* accessions and two rice cultivars.

Comparative genome analysis using molecular marker reveals co-linearity in the genic region between *Oryza sativa* and *Oryza brachyantha*

The genus *Oryza* consists of two cultivated and 22 wild species. They are grouped in four species complexes and an out-group. Among these complexes, *Oryza sativa* complex contains all the species containing AA-genome which includes cultivated Asian rice *O. sativa* with two sub tribes, *japonica* (tropical & temperate) and *indica*, cultivated African rice *O. glaberrima* and other six wild species distributed throughout the tropics. Together, these species constitute the primary gene pool of cultivated rice. Gene transfer from these species to cultivated rice is relatively easy as these species are easily crossable but the alien gene transfer was largely been impeded so far due to lack of identified cross-transferable molecular markers which can facilitate tracking the introgression event in molecular terms. To resolve this problem, a study was conducted *in silico* to assess the cross-transferability of 23,499 *O. sativa* derived Sequence Tagged Microsatellite (STMS) markers to different AA-genome species (including two sub tribes of *O. sativa*) by utilizing their whole genome sequence available in public domain. Differential cross-transferability of these markers was observed, where expectedly, the cross-transferability was higher in case of Asian species and it gradually reduced in African species followed by South American species and finally was lowest in Australian species (with minor exceptions). Conspicuous variation in the number of cross-transferable markers among species-pairs was also evident (Fig. 1.6). The cross-transferable markers identified in this study have the potential to facilitate alien genome introgression event in future.



	O. sat j	O. sat i	O. niv	O. ruf	O. gla	O. bar	O. lon	O. glu	O. mer
O. sat j	13820	10124	9596	10919	6734	9674	4446	7566	3590
O. sat I	*	10249	8575	8869	5874	8640	3885	6626	3147
O. niv	*	*	9698	8569	5803	9698	3896	6623	3134
O. ruf	*	*	*	11006	6058	8648	4049	6932	3266
O. gla	*	*	*	*	6827	5894	3001	5136	2395
O. bar	*	*	*	*	*	9816	3929	6685	3160
O. lon	*	*	*	*	*	*	4536	3522	2132
O. glu	*	*	*	*	*	*	*	7640	2793
O. mer	*	*	*	*	*	*	*	*	3629

Fig. 1.6. Cross-transferability of STMS markers in different *Oryza* species containing AA-genome.

The upper half of the panel depicts the number of STMS markers (among the total 23,499 used) which has been transferred *in silico* to different species. The lower half of the panel represents the *in silico* cross-transferability of these STMS markers form one species to another (in terms of number of markers transferred).

Evaluation of disomic fertile lines (BC_2F_7) of wide cross derivatives for yield attributes:

Thirteen Lalat/*O.nivara*//Lalat (BC_2F_7) fertile derivatives were evaluated in 10 m^2 plot with two Checks, IR 64 and Lalat with three replications in RBD design during *kharif* 2016. CR 2873-54-5-2, 384-6-1-3, 386-7-4-1, 385-7-8-3 and 389-9-17-2 gave grain yield of more than 6.33 (t/ha) against the best check variety IR64 (5.13 t ha^{-1}) and Lalat (5.22 t ha^{-1}). Thirty two entries of Apo/*O. nivara* (AC100476)//Apo (BC_2F_7) fertile derivatives were evaluated along with two Checks i.e. IR 64 and Apo with three replications in RBD design during *kharif* 2016. Apo /*O. nivara* (AC 100374, AC 100476)//Apo derivatives CR 3426-11-17-1-8, CR 3867-151-13-28-11-10 and CR3869-408-13-225 gave grain yield of more than 6.0 t ha^{-1} against the best check variety IR64 (4.9 t ha^{-1}) and Apo (4.7 t ha^{-1}). Thirty one entries of Savitri /*O. brachyantha* (AC 1086)//CR 1009 (BC_2F_7) fertile disomic derivatives were evaluated along with two Checks, Naveen and MTU1010 with three replications in RBD design during *kharif* 2016. Among the entries, CR 3993-14-5-6-2, CR 3993-12-24-3, B2 8-9, B211, B2 18-9 and B2 20-4 gave better grain yield (6.9 t ha^{-1} – 6.2 t ha^{-1}) against the best check Naveen (5.5 t ha^{-1}) and MTU1010 (5.9 t ha^{-1}). Fourteen entries were nominated to AICRIP; out of which entry CR2906-253-8 (IET No-25602) has been promoted to AVT1IM and CR3993-13-1-3 (IET 25881) has been promoted to AVT1DW.

Hybrid rice for different ecologies

Source nursery and identification of new CMS source

A total of 1127 diverse breeding lines/varieties including male sterility sources were maintained in parental lines stock. Six hundred and thirty four were screened for presence of restorer (*Rf*) genes; 48 lines found positive for *Rf* 3 and *Rf* 4, were utilized in crossing programme. Diversification of CMS sources is essential to sustain hybrid rice challenges and boost this venture in future. In view to identify alternative CMS source, a total of 50 test crosses (between 25 *O. rufipogon* accessions and two strong restorers of WA–CMS, IR 42266-29-3R and Pusa 33-30-3R) were made and evaluated. One sterile test cross (TCN 615) was found to be a new probable MS source which has been advanced in BC_2F_1 generation.

Identification of maintainer, restorer and new hybrid combinations

To test the combining, maintaining and restorer ability of promising genotypes, altogether 1075 test crosses involving eight CMS (CRMS31A, CRMS32A, CRMS51A, APMS6A, RTN 12A, PUSA 5A, IR 58025A and PMS 17A) were evaluated. The evaluation results indicated that 32 lines/pollen parents were promising maintainers and 208 lines/pollen parents (PR 115, ASG 2908, ASG 2918, CR 87-32-244, G2579, N 371, CR 149-PS78B-32B, FF3, CR 174, etc.) were effective restorers (restored > 85% fertility in respective F_1). Sixty six, out of 208 identified restorers were found good combiners with CRMS 31A, CRMS 32A, RTN 12A, PMS 17A and PUSA 5A and were re-tested for their consistency validation.

Development of new CMS lines

Shatabdi A (CRMS 53A)

A mid-early duration, good combiner WA-CMS having > 25% out-crossing ability was developed under nucleus background of Shatabdi. It had plant height of 85-90 cm and promising out crossing features like spikelets opening during flowering and dual stigma exsertion. This CMS line will be of use in development of short duration hybrids (Fig. 1.7).

Fig.1.7. Shatabdi A (CRMS 53A)

CRMS 54A: A medium duration, good combiner WA-CMS under genetic background of CR 440 (CRMS 32B/CRMS 244B) was developed. This was having purple color dual stigma exsertion, wide angle of spikelets opening and thus > 30% out-crossing. This will be of use in development of medium to long duration hybrids.

CRMS 55A: A medium duration, good combiner, Kalinga-I-CMS developed under genetic background of CR 440 (CRMS 32B/CRMS 244B). This is having purple color dual stigma exsertion, wide angle of spikelets opening and thus > 30% out-crossing. This will be of use in development of medium to long duration seedling stage cold tolerant hybrids.

During *kharif*, 2016, sixty seven sterile (fifty one sterile backcrosses-BC_3-BC_9; and 16 new sterile test crosses) crosses were advanced in backcross generation and evaluated during *rabi,* 2016-17. Some of the promising lines with stable male sterility, good out crossing, good floret opening, along with considerable panicle and stigma exsertion traits are listed in table 1.8.

Parental Line Improvement

Transfer of characters into CMS/restorer lines

In order to improve the parental lines with specific trait (s), MABC based introgression approaches were adopted. Parental lines of hybrids, Ajay and Rajalaxmi were introgressed with four BB resistant genes (*Xa 21, xa 13, xa 4 and Xa 5*). Introgression of four BB resistance genes in restorers, CRL 22R and in IR 42266-29-3R were advanced to BC_2F_3 generation. Respective CMS of these pyramided CRMS 31B and CRMS 32B lines were also introgressed and being evaluated for their suitability. Additionally, introgression of five BB resistance genes (*Xa 21, xa 13, Xa7, xa 4 and Xa 5*) into a well combiner restorer Pusa 33-30-3 are under introgression (BC_2F_1). Additionally, enhanced out-crossing features like stigma and panicle exsertion in CMS, CRMS 31A and CRMS 32A were introgressed from donors *O. longistaminata* and IR 71591B, respectively and were advanced to BC_1F_2 generation. Fertility restorers gene(s) (*Rf3* and *Rf4*) conferring complete fertility in CMS based hybrids were under introgression in four well combiner partial restorers, Akshaydhan, Azucena (BC_3F_1); INH 10001 and NP 801 (BC_2F_1).

Phenotyping of CRMS 31B lines for submergence

Submergence screening was performed in the concrete tank filled with turbid water up to 30 cm above the top of the plant canopy. A total of ten introgressed BC_3F_3 lines with *Saltol* and *sub-1* genes were screened for submergence with Swarna *sub-1* (donor parent), CRMS 31B (recipient parent) as control. Twenty one days old seedlings were submerged for 14 days and found substantial improvement as except recipient parent, all introgressed lines were survived like donor parent Swarna *sub-1*.

Identification of SNPs for assessing allele-specific gene expression in two rice hybrids, Ajay and Rajalaxmi

RNA-Seq was performed using HiSeq2000 platform using RNA library of two rice hybrids, Ajay and Rajalaxmi along with their parental lines, CRMS 31A; sterile line, CRMS 31B; maintainer line of Ajay and CRMS 32A; sterile line, CRMS 32B; maintainer line of Rajalaxmi with IR 42266-29-3R (a common restorer line of both hybrids). Two developmental stages; panicle initiation (PI) and grain filling (GF) were selected for library preparation.

Expression profiles of parents and hybrids showed that 702 and 752 genes found to be significantly expressed in CRMS 31A vs Ajay and IR42260-29-3R vs Ajay at PI stage; and 1988 and 2045 genes at GF stage, respectively. In Rajalaxmi, 146 and 163 genes were differentially expressed in CRMS 32A vs Rajalaxmi and IR42260-29-3R vs Rajalaxmi at PI stage and 2265 and 2447 genes at grain filling stage, respectively. Moreover, 696 genes were found to be co-expressed among CRMS 31A vs Ajay and IR42260-29-3R vs Ajay at PI stage and 1,836 genes at GF stage (Fig 1.8). In Rajalaxmi 139 genes were found to be co-expressed in CRMS 32A vs Rajalaxmi and IR42260-29-3R vs Rajalaxmi at PI stage and 2,110 genes at GF stage (Fig 1.9). Importantly, to check implication for significant SNP, exclusively expressed genes were mapped in both stages. Majority of significant SNP genes were found to be expressed at grain-filling stage as compared to panicle-initiation stage in both the hybrids.

Table 1.8. Promising sterile backcross derived lines advanced during 2016-17

Sl. No.	BCN No.	Recurrent parent	Source of cytoplasm	Remarks
1	$BCN^9$199A	CR 2234-1020 (WA)	WA	Good floret opening
2	$BCN^9$200A	CR 2234-1020	Kalinga-I	Good floret opening
3	$BCN^7$99A	A-180-12-1(87)	WA	Short duration, drought tolerant
4	$BCN^9$180A	CR 2234-834(WA)	WA	Good floret opening and stigma exsertion
5	$BCN^7$140A	IR 68301-11-64-3-6-6	Kalinga-I	Complete panicle emergence
6	BCN^7 862A	31B-GP-18	WA	31B Gene pyramid with 4 BLB genes
7	BCN^7 863A	32B-GP- 39	Kalinga-I	32B Gene pyramid with 4 BLB genes
8	$BCN^4$275A	CRMP1-07-1010	WA	Good floret opening, mid late
9	$BCN^4$276A	CRMP1-07-1010	Kalinga-I	Good floret opening, mid late
10	$BCN^4$118A	CRHR-330-1	WA	Complete panicle emergence
11	$BCN^3$582A	CR 25B-32B-337	WA	Mid-late duration, good floret opening and stigma exsertion
12	$BCN^3$583A	CR 25B-32B-337	Kalinga-I	Mid-late duration, good floret opening and stigma exsertion
13	$BCN^3$591A	CR 1071-C18-1840	WA	Mid-late duration, good floret opening and long stigma exsertion
14	$BCN^3$592A	CR 1071-C18-1840	Kalinga-I	Mid-late duration, good floret opening and long stigma exsertion

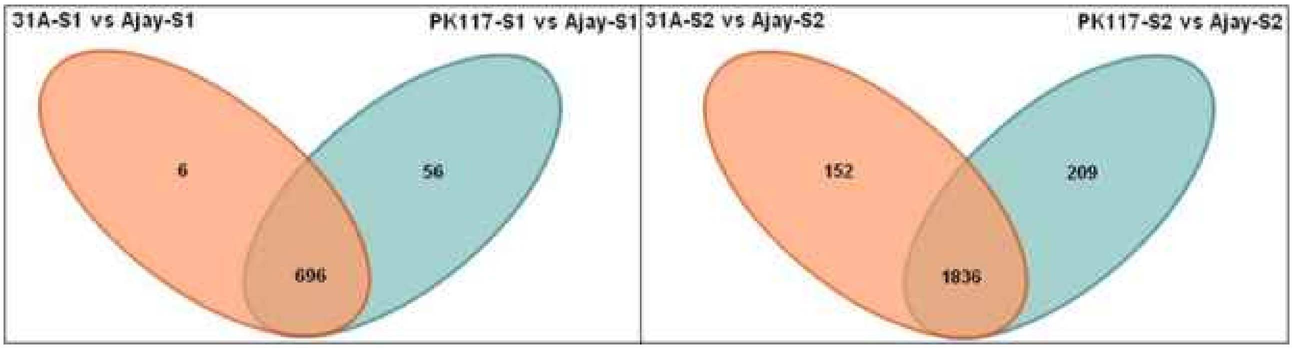


Fig. 1.8. Venn diagram showing genes expressed both at (a) panicle initiation and (b) grain-filling stages of Ajay mapped in the rice genome. PK117: IR42260-29-3R, 31A: CRMS31A, S1: PI stage, S2: GF stage.

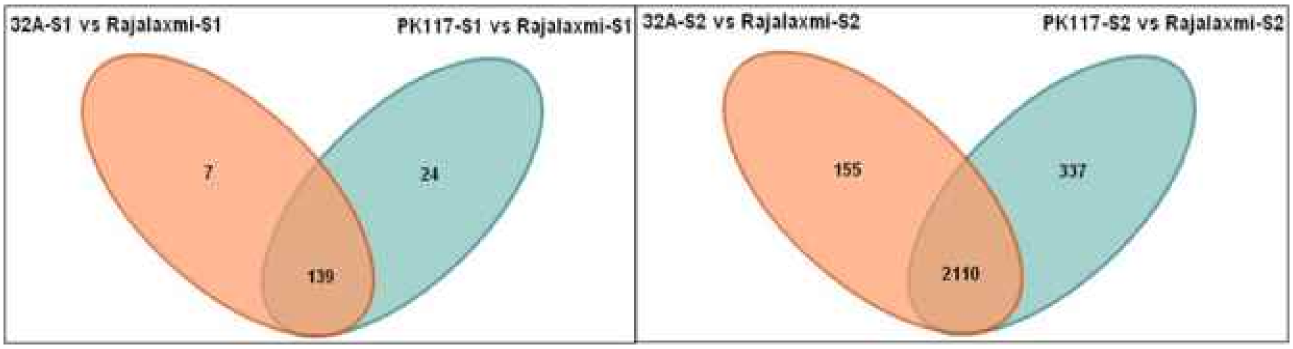


Fig. 1.9. Venn diagram showing genes expressed both at (a) panicle initiation and (b) grain-filling stages of Rajalaxmi mapped in the rice genome.PK117:IR42260-29-3R, 32A: CRMS32A, S1: PI stage, S2: GF stage.

Hybrid specific molecular markers and Rf gene screening

DNA fingerprinting of 12 hybrids and their parents was done by utilizing 30 STMS markers of which nine were found informative and could distinguish hybrids un-ambiguously. Moreover, 364 rice genotypes were screened for *Rf3* and *Rf4* genes with tightly linked markers, DRRM *Rf3*-10 and RM6100, respectively, and 23 genotypes were found positive with *Rf3Rf4*, 156 with *rf3Rf4*, 32 with *Rf3rf4* and *rf3rf4;* they are being utilized in crossing programme.

Restorer and maintainer breeding and development of Iso-cytorestorer

Four random mating maintainer populations (each population was constituted with 5 maintainers of specific trait) and two medium duration random mating restorer populations (each with five well combiner restorers) were advanced to 7th random mating generations. During *kharif* 2016, twelve new F_1 combinations of GMS with six promising restorers and six maintainers were generated for evaluation in *kharif* 2017. Altogether, 45 test hybrids generated by utilizing 15 iso-cytorestorer of BS 6444G were evaluated where seven combinations were found promising; having > 80% spikelets fertility and 1.33 to 16.1% yield heterosis over parent hybrid, consistently.

Seed production of hybrids

During the period, truthfully labeled seeds of thirteen hybrid combinations, Rajalaxmi (303.0 kg), Ajay (245.0 kg), CR Dhan 701(115.0 kg), CRHR-100 (32.0 kg), CRHR-101(24.0 kg), CRHR-102 (28.0 kg), CRHR-103 (18.0 kg) CRHR-104 (15.0 kg), CRHR-105 (17.0 kg), CRHR-106 (20.0 kg), CRHR-108 (24.0 kg), CRHR-109 (18.0 kg) and CRHR-110 (16.0 kg) were produced and distributed to the farmers and other researchers.

SVRC release and new promising hybrid

As the cultivation area of hybrid Rajalaxmi was increased, it was released by West Bengal state. Rajalaxmi is a medium duration hybrid and was bred utilizing indigenously developed Kalinga-I-CMS-CRMS 32A, having seedling stage cold tolerance and found suitable for irrigated-shallow low land and also for *boro* season. In addition, CRHR 102 (IET 25231), a long duration hybrid performed consistently well in national evaluation trials and promoted to AVT2-late in western zone. Notably, 16 new hybrids (Table 1.9) were nominated to AICRP-2017. Moreover, 28 heterotic hybrids: 15 mid-early (115-125 days), 10 medium duration (126-140 days) and three late duration (>140 days) having more than 15% yield heterosis over hybrid checks US 312, Rajalaxmi and CR Dhan 701 were also developed.

Registration of hybrids/ parental lines

During 2016, hybrid CR Dhan 701 (IET 20852, reg. No. 252) was registered with PPV& FR Authority as new variety. In addition, new application for registration of CRMS 8A has been submitted to the PPV & FR Authority.

Evaluation of AICRIP trials on rice Hybrids

During *kharif* 2016, altogether three hybrid rice yield evaluation trials, IHRT-M, HRT-MS and MLT of released hybrids were conducted to identify the suitability of the test entry in Odisha. Data were recorded, analyzed and submitted.

MoUs/Consultancy services

MoUs were signed/ renewed with two private seed companies for the production and marketing of NRRI

Table 1.9. Performance of new hybrid combinations under station trial, *kharif*-2016

Designation	DFF	Grain Type	Grain yield (t ha^{-1})
CRHR 102	110	MS	9.67
CRHR 103	110	MS	9.42
CRHR 111	110	LS	10.42
CRHR 112	109	LS	9.92
CRHR 113	110	LS	9.68
CRHR 114	110	LS	10.24
CRHR 117	107	MS	9.46
CRHR 115	105	MS	8.72
CRHR 116	103	MS	8.84
CRHR 118	102	MS	9.12
CRHR 119	104	MS	8.87
CRHR 121	85	MB	7.62
CRHR 122	85	LS	7.81
CRHR 123	92	MS	8.82
CRHR 124	92	LS	8.34
CRHR 120	89	LS	8.72
CRHR 125	99	LS	9.72
CRHR 126	98	LS	10.02
CRHR 127	99	MS	9.87
Rajalaxmi	102	LS	8.64
CRHR 32	110	MS	8.27
CD (5%)			88.20
CD (1%)			121.06
CV %			7.24

hybrids, Ajay, Rajalaxmi and CR Dhan 701. In addition, consultancy services were extended to Bharat Nursery, Sai Shradha Agronomics, Nath Biogene (I) Ltd., PAN seeds and Sansar Agropol Pvt. Ltd. for seed production of Ajay, Rajalaxmi and CR Dhan-701 as part of the MoUs signed with these companies.

Development of high yielding genotypes for rainfed shallow lowlands

Hybridization, selection and evaluation of segregating materials suitable for rainfed shallow lowlands

CR Dhan 409 (CR 2690-2-2-1-1-1) was released in the name of Pradhan dhan (IET 23110) (Fig. 1.10) for cultivation in shallow lowlands of Odisha. The maturity duration of the variety is 155-160 days and it varies due to its photoperiod sensitivity. The cultivar is a semi-tall type with non-lodging habit. Grains are long slender type possessing intermediate amylose, alkali spreading value and gel consistency. The variety has > 300 panicles per m^2 with high tillering (12-15), medium and dense panicle with moderate seed test weight (22.5g). The cultivar can tolerate one week submergence and water logging. It has also desirable quality characters like high hulling (80%), milling (71.5%) and head rice recovery (69%). The variety is moderately tolerant to leaf blast, neck blast, sheath blight, sheath rot, stem borer (both dead heart and white ear heads) and leaf folder. The variety has been showing superior performance in farmers' fields under short flash flood and moderate stagnant water logging condition.

Fig. 1.10. Field view of CR Dhan 409 (Pradhan dhan)

Six promising cultures *viz.*, CR 4039-1-1-2-1-1, CR 3816-2-1-1-1-1, CR 3988-3-1-1-1-1, CR 3985-2-1-1-2-1, CR 3985-3-2-1-1-1 and CR 3987-5-1-2-1-1 possessing submergence tolerance and bacterial blight resistance were nominated to initial variety trial, rainfed shallow lowland (IVT-RSL). IET 25971, the only entry nominated to IVT-Late trial last year was promoted to advance variety trial-1(Late).

Around 210 superior progenies of F_2 generation of ten three way crosses were grown in F_3 pedigree nursery with a population size of around 200 plants/progeny. All the F_3 progenies were transplanted along with three parents in a rainfed shallow lowland condition. Among the three parents of each cross, one line was a *tropical japonica* derivative; another was submergence tolerant parent (Savitri-*sub 1*) and third parent (CR Dhan 300) for good grain quality and better yielding ability. The ten different *tropical japonica* derivatives used in the crossing programme were CR 2683-45-1-2, CR 2683-28-12-1-4, CR 2687-2-3-5-2-1, CR 2682-2-3-1-1-1, CR 2678-5-3-2-1-1, CR 2683-15-5-2-1, CR 2683-45-1-2, CR 2683-28-12-1-4, CR 2687-2-3-5-2-1 and CR 2683-15-5-2-1. They were used for heavy panicle, high grain number, strong culm and dark green, upright flag leaf characters. A total of 350 single plant progenies were selected from the segregating material of the ten crosses. Observational yield trial for rainfed shallow lowland was conducted during wet season, 2016 to evaluate the elite lines (Table 1.10) developed for the ecology by comparing the performance with the three popular check varieties. A total of 27 promising single plant fixed progenies along with three checks were taken in randomized block design with two replications. The performance of 10 entries was observed to be better than three check varieties. The performance of the elite genotypes with more than 6 t ha^{-1} are presented.

MABC breeding for incorporation of abiotic (submergence and drought) and biotic (BB) tolerance/ resistance into popular shallow lowland varieties

Around 500 near isogenic lines (NIL) F_1 plant populations from Swarna MAS/Swarna-*sub1* cross were planted in screening tank. Submergence stress of 12 days was imposed during vegetative stage of the crop, 105 plants were found tolerant. These 105 NIL F_2 lines were raised during *dry* season for bacterial blight genotyping using *Xa21*, *xa5* and *xa13* gene specific primers. Genotyping results indicated that 17 genotypes were positive to gene combination of *sub1*QTL with *Xa21* and *xa5*.

Table 1.10. Performance of the promising genotypes in observational yield trial suitable for rainfed shallow lowland

Designation	Cross combination	DFF	Plant Height (cm)	Av.Yield (t ha^{-1})	Grain type
CR 2683-45-1-2-2-1	CRLC899/Ac.38700	132	142	7.15	MS
CR 3985-2-5-3-1-1	Reeta/NPT-158	126	131	6.92	MS
CR 3986-2-1-3-2-1	Swarna-*sub1*/CR2324 -3	121	130	6.71	MS
CR 3985-2-5-4-1-1	Swarna-*sub1*/Reeta	120	131	6.56	MS
CR 3988-5-7-9-1-1	Pooja/AC 38687	127	129	6.51	MS
CR 2690-2-2-1-1-1	Chakaakhi/AC 38687	131	127	6.37	LS
CR 491-1590-330-2-1	CR 149-5010-228/T1242	134	128	6.23	LB
CR 3838-1-2-1-4-2	Savitri/Sudhir//Varshadhan	130	132	6.19	LB
CR 3983-5-4-1	AC 38562/Niraj//Pooja	129	124	6.11	MS
CR 3987-1-7-2-1-1	Pooja/CR 3820-1-5-2-1-1	129	127	6.07	MS
Swarna-*sub1*(Check1)	-	115	116	5.57	MS
Gayatri (Check2)	-	130	124	5.78	SB
Pooja (Check3)	-	127	114	5.84	MS
CV%				13.16	
$CD_{5\%}$				0.257	

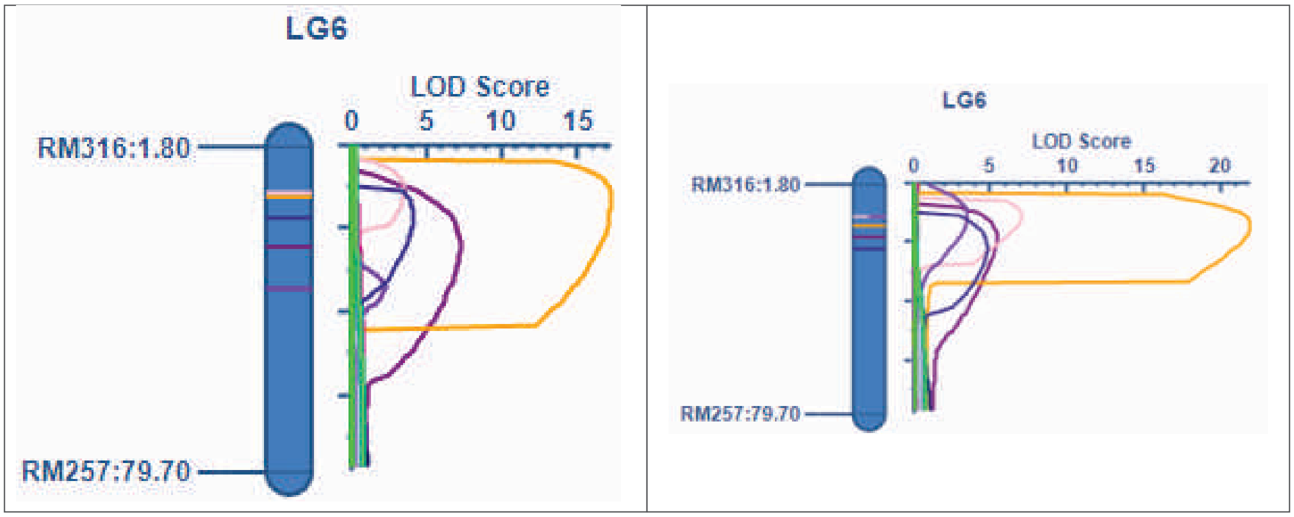
Development of mapping population and mapping genes/QTLs for reproductive stage drought stress tolerance

A total of 192 recombinant inbred lines were phenotyped for 22 morpho-physiological traits under terminal drought stress. The phenotyping results showed clear cut variations for all the parameters like biomass, harvest index, grain yield, panicle length, 1000-seed weight, spikelet fertility (%), relative water content, proline content, chlorophyll content and cell membrane stability. Bulk segregant analysis approach was followed for mapping of the reproductive stage drought tolerance parameters using ICIM software. Consistent QTLs such as harvest index (HI), spikelet fertility (SF), leaf drying (LD), leaf rolling (LR) and relative water content (RWC) were detected with high LOD values during both the years (Fig. 1.12).

Seed multiplication of elite cultures and evaluation of breeding materials under station/National (AICRIP)/International (Inger) trials

Seeds of 21 elite cultures and recently released varieties were multiplied for conducting various experiments like National, State, on station and international trials. The following evaluation trials of AICRIP and INGER were conducted at Cuttack during the season.

Advance variety trial 1-late (AVT 1 Late): This was conducted with 30 test entries including checks promoted from initial variety trial-late under zone 3. Highest grain yield of 5964 kg ha^{-1} was recorded from IET 25264 (OR2436-18) followed by 5673 kg ha^{-1} and 5523 kg ha^{-1} from IET 25252 (PNP-9984) and IET 25271(MTU 1194), respectively from top three entries



(A) (B)

Fig. 1.12. QTLs for reproductive stage drought tolerance detected using ICIM software in (A) 2013 phenotyping and (B) 2014 phenotyping for 22 morpho-physiologic traits of CR 143-2-2/Krishnahamsa RILs

while highest grain yield of 4935 kg ha^{-1} was obtained from regional check amongst the check varieties.

Initial Variety trial-late (IVT-Late): This trial was conducted with 60 test entries and four check varieties. Highest grain yield of 6310 kg ha^{-1} was recorded from IET 25952 (PNP 9557) followed by 5919 kg ha^{-1} and 5818 kg ha^{-1} from IET 25967 (Sonagathi) and 2525042 (MTU 1197), respectively while highest grain yield of 5388 kg ha^{-1} was obtained from local check (Reeta) amongst the check varieties.

Initial variety trial-rainfed shallow lowland (IVT-RSL): Initial variety trial-rainfed shallow lowland was conducted with 35 test entries including three checks of shallow lowland. Highest grain yield of 6115 kg ha^{-1} was recorded from IET 25221(CR 2315-1-1-3-1-3) followed by 5886 kg ha^{-1} and 5689 kg ha^{-1} from IET 25175 (OR 2414-1) and zonal check (Pooja), respectively from top three entries while highest grain yield was obtained from zonal check amongst the check varieties.

Development of improved genotypes for semi-deep and deepwater ecologies

Identification of new sources of submergence tolerance

Selective genotyping using STMS markers for mapping of three weeks submergence tolerance in rice

Mapping of 21 days submergence tolerance was attempted for which, AC 20431B was identified as tolerant to 21 days submergence. F_2 population was generated from the cross between Swarna-*sub1* and AC 20431B. For the mapping of gene(s), a total of 568 F_2 plants along with Swarna *sub1* and AC 20431B were submerged for 21 days following standard procedure. Out of which, 251 plants were found to survive along with AC 20431B. Further, polymorphic survey was carried out between two parents using 672 STMS markers distributed throughout the genomes. Out of which 153 markers were found to be informative. Selective genotyping was carried out by taking ten plants each of extreme tolerant and susceptible plants of F_2 plants using 153 polymorphic markers. Based on selective genotyping, a marker RM27322, located in chromosome 11 was found to be linked with trait of interest. This marker would be further validated by genotyping the whole F_2 population.

Identification of new sources of anaerobic germination tolerance and development of mapping population

After screening 236 rice germplasm from NRRI gene bank, ARC 5848 and ARC 12172 were identified as tolerant source for anaerobic germination. Further, the identified lines (donors) were crossed with Swarna-*sub1* and F_1 seeds were obtained. The F_1s were raised in net house during *rabi*, 2017 with the intension to make back cross with Swarna-*sub1* to generate mapping population and to develop multiple abiotic stress tolerant genotype for submergence and anaerobic germination.

Selection and generation advancement of available breeding material suitable for semi-deep water logged situations

Five hundred and ninety four single plant selections were made at the time of flowering and maturity on the basis of plant and panicle characters from 526 single plant progenies (F_2-F_7) along with 17 F_2 bulks grown under semi-deep water conditions during *kharif*, 2016. Further, forty seven uniform lines were also bulk harvested to see their performance in the next season (Table 1.11).

Evaluation of available advance breeding lines for yield and other traits under semi-deep and deep water conditions

Evaluation of advance breeding lines under semi-deepwater conditions (Station trial) at NRRI, Cuttack

Forty improved genotypes including three check varieties were tested in a replicated trial under semi-deep water logged condition during *kharif*, 2016. Some of them performed better than check (Varshadhan) (Table 1.12). Among the different entries, CR 3075-2-1-1-1-1 performed best with an average yield of 4.72 t ha^{-1} followed by CR 2850-8-2B-12-1-1-2-1(4.62 t ha^{-1}), CR 2851-S-1-B-4-1-1-1-1(4.40 t ha^{-1}), CR 3101-1-5-1-4-1(4.37 t ha^{-1}), CR 3089-2-2-2-1-1(4.21 t ha^{-1}), CR 3108-1-12-1-1-1(4.11 t ha^{-1}) against the best check variety Varshadhan (3.31 t ha^{-1}).

Evaluation of advance breeding lines under deepwater conditions (Station trial) at NRRI, Cuttack

Yield trial was conducted to evaluate the performance of 22 fixed entries and three checks in a randomized block design with three replications under deep water condition during *kharif*, 2016. The grain yield of nine entries was observed to be better as compared to the three check varieties. Among the entries, CR 3835-1-7-2-1-1 recorded the highest grain yield of 4.78 t ha^{-1} followed by CR 3835-1-7-2-1-1 (4.66 t ha^{-1}), CR 3836-1-7-4-1-1 (4.45 t ha^{-1}), CR 2687-3-3-1-1-3(4.42 t ha^{-1}) and CR 2304-5-7-2-3-1 (4.24 t ha^{-1}) from the station trial. Entries CR 3835-1-7-2-1-1, CR 3835-1-7-2-1-1, CR 3836-1-7-4-1-1, CR 2687-3-3-1-1-3 and CR 2304-5-7-2-3-1 were observed to possess moderate elongation ability, intermediate shattering habit with moderate kneeing ability.

Evaluation of elite cultures from national and international trials under semi-deep and deepwater ecologies at NRRI, Cuttack

National Semi-Deepwater Screening Nursery (NSDWSN)

Forty four entries including three check varieties (Sabita, Purnendu and Varshadhan) were evaluated in a randomized block design with two replications under semi-deep water conditions. Among the entries, Entry No. 703 (IET 25886; MTU 1227) performed best with an average grain yield of 5.80 t ha^{-1} followed by Entry No. 726 (IET 25907; CR 3989-1-2-1-1-1) with 5.76 t ha^{-1} and Entry No. 719 (IET 25900; CR 3038-1-7-6-1-1) with 5.60 t ha^{-1} against the best check Varshadhan (5.41 t ha^{-1}).

Initial Variety Trial-Semi Deepwater (IVT-SDW)

Sixteen entries including three check varieties (Sabita, Purnendu and Varshadhan) were evaluated in a randomized block design with three replications under semi-deepwater conditions. Among the

Table 1.11. List of breeding materials grown and selections made during *kharif*, 2016

Gen	Progenies/bulks grown	SPS	Bulks selected
F_2	17 bulks	253(17)	
F_3	107(7)	71(7)	-
F_4	108(6)	41(6)	-
F_6	264(8)	229(8)	37(7)
F_7	43(3)	-	10(3)
Total	**526(41)**	**594(38)**	**47(10)**

No. in parentheses indicate no. of crosses

Table 1.12.Performance of entries under station trial during *kharif*, 2016

Sl. No.	Designation	DFF (Date)	DFF (Days)	Pl Ht (cm)	EBT/ M^2	Yield (kg ha^{-1})	Survival (%)	Shattering	PACP
1	CR 3075-2-1-1-1-1	25.10.16	134	133.9	171	4720	98.1	3	1
2	CR 2850-8-2B-12-1-1-2-1	27.10.16	136	128.1	190	4616	79.7	3	3
3	CR 2851-S-1-B-4-1-1-1-1	31.10.16	140	121.4	190	4403	94.0	1	1
4	CR 3218-5-1-1-2-3	29.10.16	138	131.1	176	4396	98.4	5	1
5	CR 3101-1-5-1-4-1	4.11.16	144	140.5	211	4370	97.0	3	1
6	CR 3089-2-2-2-1-1	2.11.16	142	151.3	196	4211	97.3	3	3
7	CR 3108-1-12-1-1-1	4.11.16	144	108.8	218	4106	95.1	3	5
8	CR 3108-1-12-1-1-2	2.11.16	142	116.7	209	3997	97.6	3	3
9	CR 3086-2-11-2-5-3	20.10.16	129	138.1	205	3979	91.9	5	5
10	CR 2439-B-3-2-TTB 2-1	31.10.16	140	130.9	193	3936	94.9	5	3
11	Varshadhan (Check)	8.11.16	148	163.1	204	3308	98.7	1	1
	Mean	**-**	**139**	**143.6**	**197**	**3275**	**95.0**	**-**	**-**
	LSD (5%)	**-**	**0.8**	**6.6**	**31**	**1180**	**10.4**	**-**	**-**
	CV (%)	**-**	**0.3**	**2.3**	**7.7**	**17.8**	**5.4**	**-**	**-**

different entries, Entry No. 602 (IET 25212; OR 2413-9) performed best (5.49 t ha^{-1}) followed by Entry No. 607 (IET 25186; OR 2415-2) with 5.05 t ha^{-1} and Entry No. 601 (IET 25209; CR 3816-1-2-1-2-2) with 4.93 t ha^{-1} against the best check Varshadhan (4.85 t ha^{-1}).

Advance Variety Trial 1-Semi Deepwater (AVT 1-SDW)

Twelve entries including three check varieties (Sabita, Purnendu and Varshadhan) were evaluated in a randomized block design with three replications under semi-deep water conditions. Among the different entries, Entry No. 503 (IET 24519; CR 2439-B-18-1-1-1-1) performed best (5.18 t ha^{-1}) followed by Entry No. 501 (IET 24495; MTU 1172) with 5.16 t ha^{-1} and Entry No. 504 (IET 24486; MTU 1184) with 4.65 t ha^{-1} against the best check variety Varshadhan (4.24 t ha^{-1}).

Initial Variety Trial-Deepwater (IVT-DW)

Seven entries including three 1st year nominations, one 2nd year entry along with three check varieties (Jalamagna, Dinesh and CR Dhan 500) were evaluated to identify the suitable genotypes for deepwater ecology. Among the different entries, Entry No. 801 (IET 25881; CR 3993-13-1-3) performed best with an average grain yield of 3.59 t ha^{-1} followed by Entry No. 802 (IET 25882; NDGR702) with 3.49 t ha^{-1} against the best local check variety, CR Dhan 500 (2.52 t ha^{-1}).

Performance of entries nominated in AICRIP trials during 2016

Varieties identified for release during 52nd Annual rice group meeting held at Jorhat, Assam

CR Dhan 510 (CR 2593-1-1-1-1; IET 23895) developed from the cross Sarala/Varshadhan//CRMAS 2232-85 was identified for semi-deepwater ecology in the states of West Bengal and Odisha in Zone III during 52nd Annual Rice Group Meeting (ARGM) held at Jorhat, Assam during 8-11th April, 2017. CR Dhan 510 is strongly photosensitive with average maturity duration of 160-165 days. It possesses short bold grain with a long heavy panicle having moderate test weight (23.9 g). It is moderately resistant to leaf blast, neck blast, bacterial blight, stem borer (both dead heart and white ear heads) and leaf folder. CR Dhan 510 has good hulling (79.85%), milling (70.95%) and head rice recovery (66.60%) and intermediate amylose content (23.17%) and other desirable grain quality parameters. The mean yield in West Bengal and Odisha were 5.26 t ha^{-1} and 4.01 t ha^{-1}, respectively.

Variety found promising

CR 3925-22-7 (IET 25673) developed from the cross between Swarna-*sub1* and drought tolerant donor IR 81896-B-B-195 (carrying drought tolerant genes *qDTY* 2.1 and *qDTY* 3.1) was found promising for drought and submergence stress conditions in Zone III after two years (2015 & 2016) of testing.

Improved lines promoted

A total of seven promising entries have been promoted for the next level of testing under different trials conducted in semi-deep and deepwater conditions during the year 2016. One entry, CR 2439-B-18-1-1-1-1 (IET 24519) was promoted from AVT1-SDW to AVT 2-SDW. Another entry, CR 2747-14-4-3 (IET 25191) was promoted from IVT-SDW to AVT1-SDW. Other four entries viz., CR 3034-1-1-3-1 (IET 25915), CR 2745-2-6-3 (IET 25888), CR 3898-113-4-2-1 (IET 25909) and CR 3878-245-2-4-2 (IET 25913) were promoted from NSDWSN to IVT-SDW. One entry, CR 3993-13-1-3 (IET 25881) also was promoted from IVT-DW to AVT-DW.

Breeding rice varieties for coastal saline areas

Identification of donors and understanding the reproductive stage salinity tolerance in rice

Pot experiment was conducted in *kharif* 2016 using improved method for reproductive stage salinity tolerance screening for rice using soil: stone (4:1) medium. The modified method was found more precise and suitable for salinity screening as stability of desired EC level found to be better compared to only soil medium. Also, the average time to attain desired EC level (8 dS m^{-1}) was shorter (only 8 days) compared to sole soil medium (11 days). Results showed that visual scoring of stress symptom and/or SPAD reading may not correspond to the stress effect. Better phenotyping technique such as chlorophyll fluorescence imaging can show clear cut differences between salt treated and untreated rice plants at reproductive stage (Fig. 1.12).

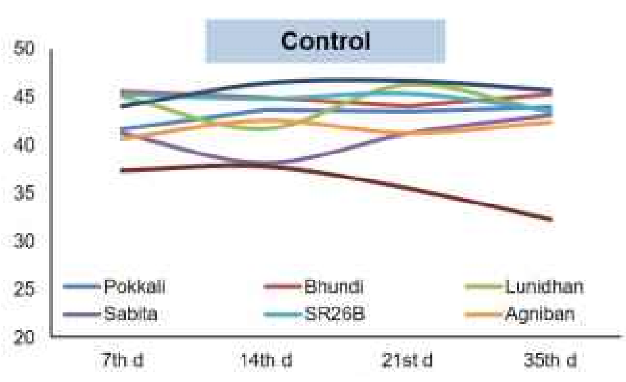
Gene expression analysis revealed that salt tolerant Pokkali (AC 41585) showed better K^+-retention and Na^+-exclusion strategies coupled with maintenance of better membrane potential (both plasma membrane and vacuolar) by induction of ATPases and PPases activities in flag leaf. Moderately tolerant genotypes *viz.*, Chettivirippu (AC 39389) and Lunidhan couldn't show any induction in either K^+-retention and Na^+-exclusion strategies, but could maintain the active energy state under salt stress.

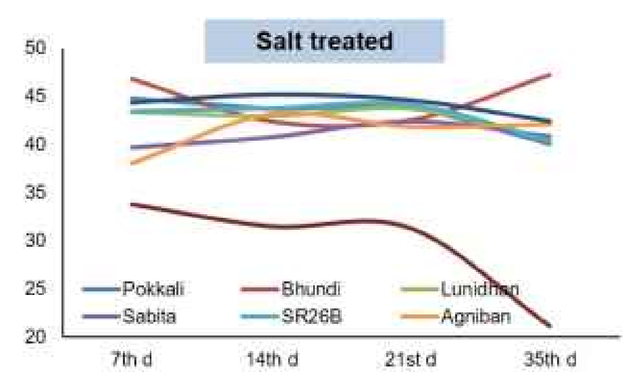
Development of mapping population

Three RIL (F_6) populations from Swarna/Rahspanjar, Savitri/Pokkali (AC 39416a) and Gayatri/AC 39416a, one BC_3F_5 population from IR 64/Pokkali (AC 41585) and two BC_2F_5 populations from Swarna/Chettivirippu (AC 39389) and Naveen/Chettivirippu (AC 39394) were developed for identification of QTLs for salinity tolerance at flowering and seedling stage and water logging tolerance.

Generation of new crosses

Attempts were made for generation of 20 different F_1s from crosses involving high yielding parents,





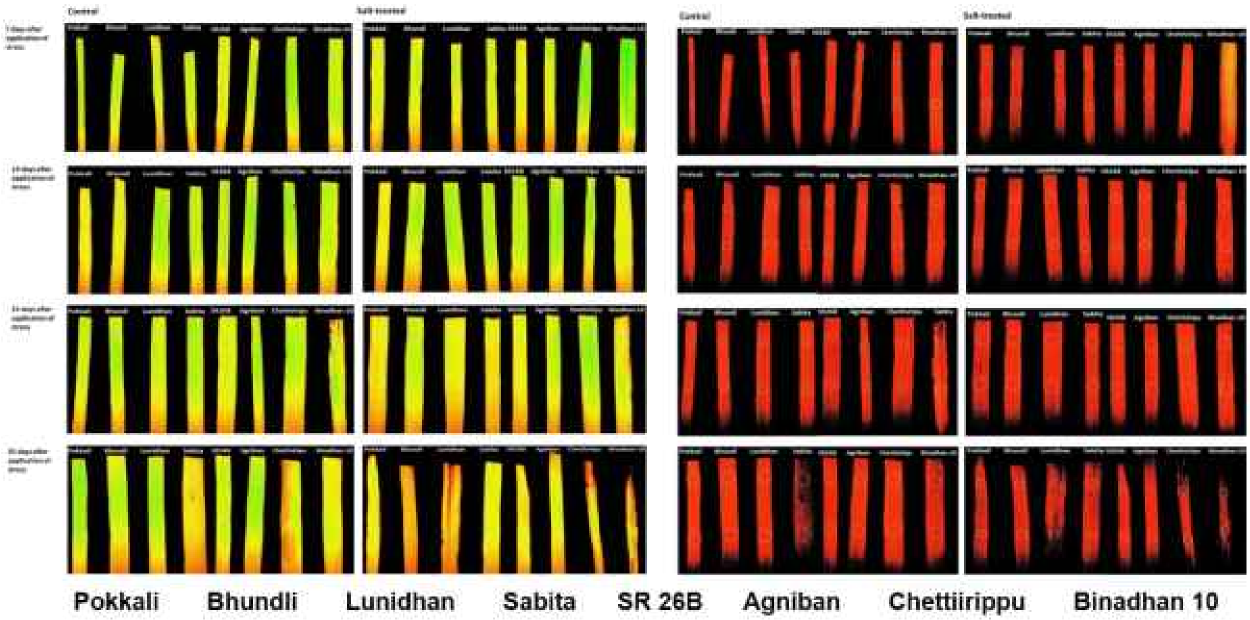


Fig. 1.12 Differential results obtained on SPAD chlorophyll meter reading and chlorophyll fluorescence imaging under salinity stress at reproductive stage in rice

Varshadhan, Savitri *sub1*, Naveen, SR 48-2-1, TJ-12-2-2 and TJ-115-3 with saline tolerant donors *viz.*, FL 478, FL 496, Luna Sankhi, Binadhan10, AC 39416, AC 39417, Bhurarati, SR 26B and CST-7-1.

Performance of elite breeding lines for coastal region in all India multilocational testing:

Three lines, IET 24426 (CR 2218-41-2-1-1-S-B3-B), IET 24434 (IR 83421-6-B-3-1-1-CR 3364-S-2B-14-2B) and IET 24430 (CR 2839-1-S-11-1-B2-B-46-2B) completed three years of testing in CSTVT. But they were not identified or released at national level due to lack of consistent performance in any one zone over the years. Another three entries IET 25053 (CR 2845-S-1-1-3B), IET 25078 (CR 2839-1-S-10-B2-B-43-3B-2), IET 25096 (CR 2838-SR-27) will be tested in AVT-1 and one entry IET 25049 (CR3903-161-1-2-2) in AVT-2 under CSTVT in 2017.

Breeding for multiple abiotic stress tolerance in wet season

Combining salinity and water logging tolerance: Salt tolerant line CR 2459-23-1-1-S-B1-2B-1 (Gayatri/Rahspanjar) performed well in water logged situation with estimated grain yield of 4184 kg ha^{-1}. This line was also promoted to AVT-1 in CSTVT trial. Salinity tolerant lines with water logging tolerance identified in 2016-17 are as follows.

- CR 2851-S-1-B-4-1-1-1-1 (Gayatri/ SR 26B) with medium slender grain yielded 4403 kg ha^{-1} in 160 days.
- CR 2850-S-2B-12-1-1-2-1-1 (Gayatri/FL 496) with medium slender grain yielded 4616 kg ha^{-1} in 160 days.

They were nominated in AICRIP trials for 2017.

Breeding lines, CR3878-245-3-11-5 (4.61 t ha^{-1}) and CR3900-193-9-4-3 (3.27 t ha^{-1}) derived from crosses using salinity and submergence tolerant donors were also nominated to CSTVT trial.

Populations derived from crosses involving salt, water logging, submergence tolerance donors are in F_3 generation and will be screened for submergence tolerance.

- CR 3477 (Swarna/Kamini//Gangasuili)
- CR 3483 (IR 64/Pokkali (AC 41585)//Gangasuili)
- CR 3444 (IR72164-186-5/FL 496// Naveen/Rahspunjar)
- CR 3452 (Varshadhan/FL 496//IR49830-7/Banskathi)
- CR 3447 (TRC229-F-41/Savitri// FL496/// Swarna/Nona Bokra)

Evaluation of Salt tolerant breeding lines in *kharif* 2016

Twenty salt tolerant genotypes with two checks (Luna Suvarna and Pusa 44) were evaluated in dry season at normal soil. The experiment was conducted in RCBD design with three replications. Highest yield was recorded in CR 3903-161-1-3-2 (7.2 t ha^{-1}) followed by CR 3900-193-9-11-1 (6.45 t ha^{-1}). Two checks, Luna Suvarna and Pusa 44 yielded 5.31 t ha^{-1} and 4.33 t ha^{-1}, respectively. They were also evaluated in wet season in saline soil. The experiment was designed in RCBD with three replications. The water EC was recorded throughout the plant growth period. The water EC ranged from 3.6-6.5 dS m^{-1}. Highest yield was recorded in CR 3878-245-3-11-5 (5.61 t ha^{-1}) followed by CR 3900-193-9-4-3 (4.27 t ha^{-1}). Luna Suvarna and Pusa 44 (Checks) gave yield of 3.76 t ha^{-1} and 2.82 t ha^{-1}, respectively.

Evaluation of breeding lines for salt tolerance in simulation tank at NRRI

A set of 165 salt tolerant genotypes along with three checks (Pokkali, FL 478 and IR29) were planted for evaluation in simulation tank under control condition. Sprouted seeds were sown and five days old seedlings were salinised for 30 days with water EC 12-14.2 dSm^{-1} for seedling stage evaluation. At reproductive stage, plants were again salinized for 30 days with water EC 6-8 dSm^{-1}. Scoring was done at both the stages. Highest yield was recorded in CR3878-245-9-4-3 (4.92 g) with 15.49% of spikelet sterility. FL 478, Pokkali and IR 29 yielded 4.75 g, 4.87 g and 0 g $plant^{-1}$ with 14.94 %, 19.64% and 0% sterility, respectively.

Seed multiplication and out-scaling

Around 350 kg seeds of Luna Sankhi, Luna Suvarna, Luna Sampad and Luna Barial were multiplied and distributed to farmers in Ersama, Astaranga and Chandbali Blocks of Odisha and 24- Parganas District of West Bengal for spreading and popularization of these varieties.

AICRIP trials

Two CSTVT trials were conducted in *kharif* 2016. Twenty nine entries and five checks were grown under IVT CSTVT. Only one entry IET 26057 out-yielded check, CST-7-1. AVT CSTVT was conducted with 26 entries and six checks. No entry could perform better than the local check, Luna Suvarna (4315 kg ha^{-1}) in this trial. Salinity level in both the trials was medium (3-6 dSm^{-1}).

Agronomic management trial

Experiment was conducted during the wet season 2016 in the farmer's field at village Kankan in Ersama block. The soil of the experimental plot was sandy clay loam with salinity ranging from 4.87 dSm^{-1}at the time of transplanting to 6.78 dSm^{-1} at the time of harvesting. Two varieties (Luna Barial, Luna Suvarna) along with Gayatri (check) were tested on puddled soil by transplanting 30 days old seedlings in the second fortnight of August. Four nutrient management treatments were also evaluated in the subplots: recommended dose of fertilizers (RDF; 60-40-40 kg $N–P_2O_5–K_2O$ ha^{-1}), RDF + Azolla (2 t ha^{-1}) and LCC based N management (with recommended P and K) and Farmers practice (28:28:0 kg NPK at the time of transplanting). Results revealed that among the two tolerant varieties Luna Suvarna significantly gave higher grain yield (4.59 t ha^{-1}) over Luna Barial (4.05 t ha^{-1}) and check variety Gayatri (3.66 t ha^{-1}). Treatment with LCC based N management significantly gave maximum grain yield of 5.39 t $ha^{-1}$and was 60 % higher over farmers fertilizer management practice. Inclusion of Azolla with RDF gave 9.51 % higher grain yield when compared with RDF. Similar trend was followed by yield attributing characters *viz.*, no. of panicles m^{-2}, grains per panicle and 1000 grain weight.

Development of Super Rice for different Ecologies

Identification and evaluation of promising elite lines from existing New Plant Types and others for irrigated and favourable upland

During *kharif* 2016 in AYT-1, 35 genotypes, selected previously from a set of 80 New plant type (NPT) selections were evaluated for grain yield and other quantitative parameters with CRBD design in two replications along with four checks (Swarna, IR 64, MTU 1010 and Annada). Culture CR 4117-3-1 (1^{st}) and CR 3299-1-1-1-1-1 (2^{nd}) recoded highest grain yield of 7.61 t ha^{-1}each, followed by CR 3728-2-2 (6.81 t ha^{-1}) (3^{rd}), CR 3624-2 (5.69 t ha^{-1}) (4^{th}) and CR 2997-3-2-1 (5.3 t ha^{-1}) (5^{th}) registering at least 30% yield increment over best check Swarna. The reason of higher yield in the highest yielding cultures could be due to the higher grain number (1st and 5th) and higher 1000 grain weights (2nd, 3rd and 4th) as well as moderately high tiller numbers. These cultures can directly be utilized as promising parents for hybridization. Similarly, genotype CR 2997-3-2-1 was found to have stay green character along with high yield.

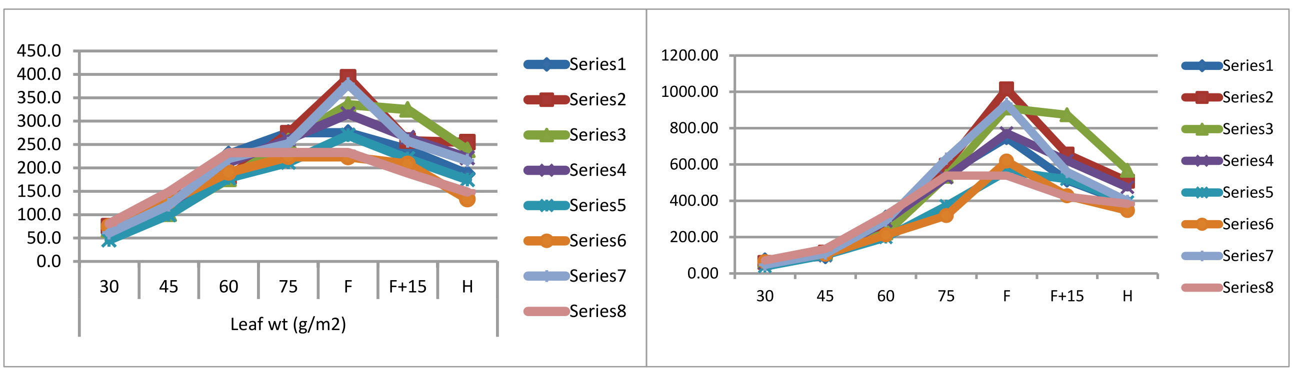
Physiological efficiency of Super rice lines:

Eight super rice lines were tested for their physiological efficiency under favourable irrigated system. The culture CR 3856-44-22-2-1-10-1-5 (3) had high grain yield (7.63 and 8.17 t ha^{-1}) in both dry and wet season with high HI (0.49-0.50) and high photosynthetic rate (34.3 U mol.CO2 cm^{-2} s^{-1}) at flowering stage. Leaf and stem biomass increased up to flowering and then declined during grain filling, while panicle biomass increased linearly till maturity. Culture No.3 had slow partitioning during milking stage and increased thereafter, while CR 3936-11-1-1-1-1-1(2) and Swarna had sharp partitioning during milking stage (Fig. 1.13, 1.14).

Critical investigations on morpho-physiological traits in Tropical japonicas and its derivatives:

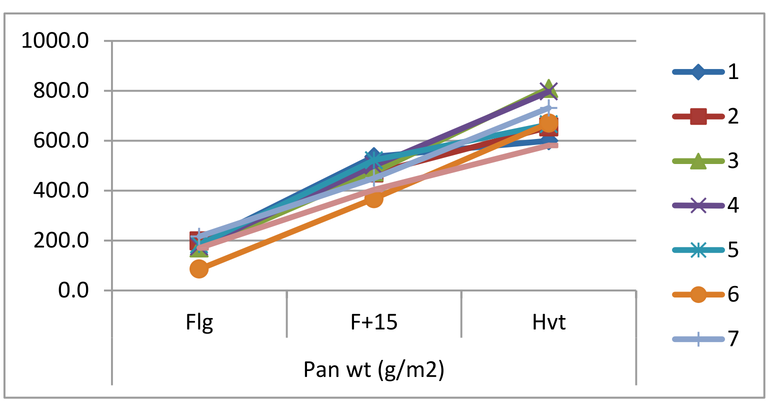
The best forty *TJ* lines were selected from a set of 450 lines grown during previous season and were evaluated in AYT for grain yield and other quantitative traits. EC 4913281 recorded highest grain yield of 8.5 t ha^{-1}, followed by EC-491375(8.05 t ha^{-1}), and EC-496929 (7.78 t ha^{-1}). Table 1.13 describes the best performing *TJ*s along with critical yield attributing traits. Apart from grain yield the more important thing is critical quantitative traits *viz.,* plant height and tiller numbers and maturity duration. In this context, EC-496929, EC-491300 and EC-496927 were found most important for prospective donors. Moreover, EC-496927 possesses many traits *viz.,* semi dwarf, erect, wide and stay green leaf and appreciably high grain yield. Several other genotypes were also identified with trait specific advantage are as below:

Plant height: Range of 100 cm: EC 497036 (515.82 g),



(A) (B)

Fig. 1.13. Rate of biomass partitioning from 30 days after planting till maturity, a. Leaf, b. Shoot



List of cultures, 1:CR 3856-44-22-2-1-11, 2: CR 3936-11-1-1-1-1-1, 3: CR 3856-44-22-2-1-10-1-5, 4: CR 3856-44-22-2-1-7-1, 5: CR-3938-2-2-1-1-1-2-2, 6: CR-3938-2-2-1-1-1-4-1, 7: MTU 1010(check), 8: Swarna(check)

Fig. 1.14. Panicle growth rate during grain filling

EC497023 (504.0 g), EC 497015 (495.6 g), and EC 496931 (423.4 g); Range of 110-120 cm: EC 491146 (618.8 g), EC 496927 (755.35 g) and EC 496907 (528.0 g).

No. of effective tillers: EC 491172 (11.6), EC 491335 (11.03), EC 491203 (11.1), EC 491172 (10.5), EC 491221 (10.4), EC 496860 (10.4) and EC497121 (9.6).

No. of fertile grains/panicle: EC 491179 (247.2), EC491436 (227.6), EC 491180 (209), EC 496927 (193.6), EC491169 (192.3), EC 497036 (190.9), EC 497180 (179.9) and EC 491146 (176.3).

1000 grain weight: EC 491379 (42.73 g), EC 491385 (39.84 g), EC 491313 (38.67 g), EC 491372 (37.92 g), EC 491319 (36.82 g) and WC 273 (36.32 g).

Erect Leaves: EC 491234, EC- 491163, EC-491375, EC-491393 and EC 491152.

Top leaf length and width: EC 491384 (FLL, 57.0 cm, FLW, 2.04; SLL, 71.0 cm SLW, 1.6 cm), EC 491379 (53.2 cm, 2.04 cm; 57.0 cm, 1.8 cm), EC491328 (56.0 cm, 2.22 cm; SLL 76.2 cm, 2.08 cm), EC 491435 (53.8 cm, 1.6 cm; 64.6 cm, 1.5 cm) and EC 491358 (49.6 cm, 2.3 cm; 70.0 cm, 2.0 cm).

Preliminary yield trial and seed multiplication for nomination to AICRIP Potential Selections for super rice

Seventy five genotypes were evaluated in RBD during *kharif* and *rabi* seasons of 2016-17. During *kharif*, genotype CR 3856-44-22-2-11-1-3 performed best with 8.57 t/ha, followed by CR-3967-51-2-1-1-1(.25 t ha^{-1}), CR-3967-8-3-2-2-1 (6.90 t ha^{-1}) and C-409-15-2-2-1-1-1-1-1(6.82 t ha^{-1}) having 46.49%, 23.91%, 21.61%, and 20.73% increment over best check, respectively. The higher grain number in first, second and fourth; higher tiller number in fourth resulted in higher grain yield. Similarly during *rabi*, 2016 CR 3938-22-1-1-1 recorded highest grain yield of 7.13t/ha, followed by CR 3938-6-2-1-1-1(7.06 t ha^{-1}), CR 3856-44-11-2-1-3-2-1 (6.87 t ha^{-1}) and CR 3939-2-1-1-2-1 (6.74 t ha^{-1}) with 40.5%, 39.0%, 35.3% and 32.8% yield increment over the best check. The higher grain yield was attributed by higher 1000 grain weight (1st case), higher plant population m^{-2} (2nd, 3rd) and higher grains/panicle as well as grain fertility (4th case). These genotypes have been nominated to the national testing. CR 3856-44-22-2-1-11-3 performed exceedingly well under Participatory farmers' evaluation in Cuttack district, Odisha where it reported grain yield of 10.8 t ha^{-1} in comparison to check variety Swarna with 8.0 t ha^{-1} (35% yield improvement over check).

AICRIP Promotion

IVT NPT trial: IET 26418 (CR 3969-24-1-2-1-1): It recorded an overall mean yield of 7521 kg/ha with 101 days to 50% flowering and LS grain type. It showed 122.84, 33.92, 23.84, 2.72 and 34.23% yield superiority over NC1, NC2, ZC, HC and LCs, respectively. It ranked first in Zone VII with 41% and ninth in Zone III with 5% yield superiority over the best check. It performed well in Tamil Nadu with 43.51% yield superiority over the best check. Highest yield was recorded 13.94 t ha^{-1} in TN. Another two entries, IET 26409 (CR 3856-29-14-2-1-1-7-1) and IET 26420 (CR 3856-44-22-2-1-10-1-5) recording an overall mean yield of 6420 kg ha^{-1} and 6516 kg ha^{-1}, respectively, were also promoted.

IVT *Boro*: IET 25688 (IR 72158-154-3-2-1-CR3624-1-2-2) from the cross BG 92-2/IR 67962- 84-2-2-2 and IET 25692 (IR 82489-7-2-2-2-CR 3724-1) from the cross IR 72967-12-2-2-3/PR 31090-33-2-1 recording 5808 kg ha^{-1} and 5788 kg ha^{-1} mean grain yield, respectively were promoted to AVT 1.

Introgression of BLB and submergence resistance/tolerance genes through molecular approach

Elite NPT line, CR 3856-44-22-2-1-11-1(SR1) was susceptible to BLB. Therefore, *xa5, xa13* and *Xa21* genes were introgressed to SR1. Three way crosses were made using Swarna MAS, SR 1 and IRBB-60 with *Xa21, xa13* and *xa5* genes. Marker assisted backcrossing was done where fore ground selection was done for BC_1F_1 for the presence of genes. Several promising recombinants (Fig. 1.15) were identified with two gene combinations (Table 1.14).

Hybridization of potential genotypes, selection and generation advancement

More than 100 biparental and multiparental crosses were made during dry and wet season of 2016-17 involving either promising and popular varieties or elite cultures with diverse genotypes *viz.*, tropical japonicas (with "wc" genes) and aromatic derivatives followed by generation advancement. In this context, 825 F_2, 920 F_3s, 304 F_4s, 380 F_5s, and 70 F_6s single plant

Table 1.13. Best performing Tropical japonicas (TJs) with critical quantitative traits

Desig.	Gr. yield (t ha^{-1})	Days to 50% flow	Height	Flag Leaf Len.	Flag Leaf Wid.	2nd Leaf Len.	2nd Leaf Wid.	Panicle Len.	Till No.	Culm Dia	Panicle Wt.	Fertile grains/ panicle	No. of chaffs/ panicle	1000 gr Wt
EC-491381	8.50	131	158.9	39.9	2.21	54.5	1.68	28.50	6.7	5.62	3.46	86.50	47.20	33.75
EC-491375	8.05	138	170.3	50.4	2.70	69.7	2.13	28.70	7.8	3.22	3.88	84.75	20.55	36.55
EC-496929	7.78	147	117.2	24.0	2.51	59.6	2.16	27.20	7.9	2.80	3.40	145.65	10.40	19.98
EC-491305	7.01	143	153.3	36.1	1.96	50.5	1.61	23.40	7.1	5.55	3.16	88.75	19.80	26.39
EC-491300	6.99	128	128.2	37.2	2.09	51.8	1.29	25.10	9.3	3.03	3.51	97.95	17.25	30.28
EC-496927	6.58	149	113.9	29.7	2.08	51.4	1.54	25.50	7.6	2.82	3.81	154.90	20.45	18.37
EC-491379	6.40	138	160.8	47.3	2.38	57.8	1.80	27.30	8.5	3.03	4.12	89.85	18.25	35.08
EC-491459	6.39	140	168.1	63.4	2.28	69.3	1.76	27.70	6.9	3.05	3.10	60.20	12.55	39.00
EC-497180	6.34	131	133.2	37.0	1.67	48.4	1.55	27.10	7.9	2.92	3.11	137.15	14.70	20.75
Swarna (Check)	5.85	119	104.6	31.9	1.80	36.7	1.63	27.00	6.7	2.76	3.45	143.40	13.75	21.24
C.D (0.05)	0.62	2.80	6.22	3.20	0.19	4.2	0.23	2.10	1.3	0.32	0.28	12.66	5.60	2.12

(A)

(B)

Fig. 1.15 Plant type of SR A6/3-26-1 showing ideal plant traits of a super rice including ideal height, leaf orientation Fig. 1.15(a), panicle size and grain number (Fig. 1.15 (b))

selections were done and progeny rows were advanced through pedigree method. Some cultures *viz.*, CR 4113-3-2-1(8.93 t ha^{-1}), CR 748-2-1-1-1 (8.6 t ha^{-1}), CR 4023-2-1-2-1 (7.59 t ha^{-1}), CR 4024-8-2-1-1 (7.37 t ha^{-1}), CR 4026-15-2-2-1-1-1-1(7.30 t ha^{-1}) and CR 3856-45-11-2-1-1-2 (7.01 t ha^{-1}) recorded yield more than 7.0 t ha^{-1} (at least more than 25% than the best check) during *rabi*. Similarly, during *kharif*, 2016 cultures *viz.*, CR 3856-44-22-1-1-4-2-1(6.76 t ha^{-1}), C 690-2-1-1-1-1(6.3 t ha^{-1}), C 538-136-1-1-2-1-1 (6.09 t ha^{-1}) and C 386-18-2-1-1-1-1-1(6.05 t ha^{-1}) recorded more than 6.0 t ha^{-1} with at

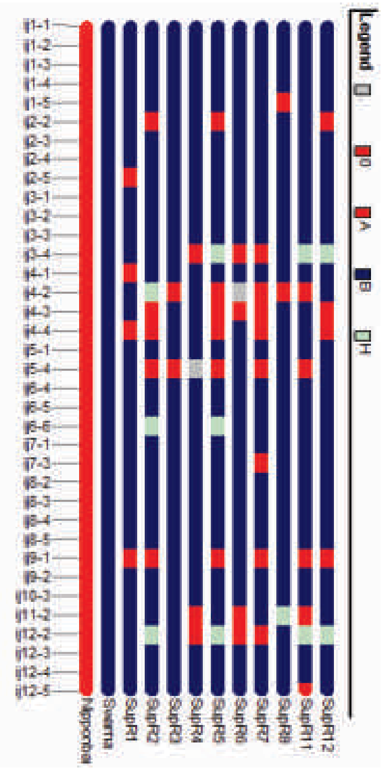
Table 1.14. Performance of BLB resistance gene introgressed plants in CR 3856-44-22-2-1-11 background (BC^2F^2)

Genotype	Flowering Duration	heig ht (cm)	Tiller No.	Genes	Panicl e wt	Grains/ Panicle	Chaffs/ panicle	Grain Wt/plant
SR A6/3-26-1	110	105	19	xa5	5.98	204	44	60.90
SR A6/3-37-5	101	106	16	xa5, Xa21	5.78	247.5	40.5	47.79
SR A6/3-26-3	109	102	14	xa5	4.17	215	48	41.71
SR A6/3-21-1	112	117	21	-	6.97	308.5	67	100.38
Sr A6/3-23-4	114	108	10	Xa5, Xa 13, Xa 21	6.12	269	32	32.87

least 20% higher yield than the best check Swarna.

Delineation of Super Rice genome using *Indica/Japonica* specific Indel markers

In super rice cultures many *tropical japonicas* have been used for hybridization with *indica* parents. However, the final product which is acceptable by the farmers and consumers is *indica* type only. In this context, 10 different super rice lines derived from *indica* and *tropical japonicas* were genotyped for presence of *japonica* genome. A total of 36 markers from 12 chromosomes were used to distinguish *indica-japonica* specific genome in 10 super rice cultures. The banding pattern was analysed utilising graphical genotyping software GGT 2.0 and it was found that in the high yielding super rice, *japonica* genomic region were ranged from 2.7 to 22.2% (Fig. 1.16). Moreover, the *japonica* genome contribution was different in each cultures and contribution of japonica genome was not common to any of the super rice cultures.



Sample ID	Genotype	Remarks
SupR1	CR 3976-2-2-1-1-1	High yielder
SupR2	CR 4030-6-1	High yielder
SupR3	CR 4113-3-2-1	High yielder
SupR4	CR 3856-44-22-2-1-11-5	High yielder
SupR5	CR 4030-6-2	High yielder
SupR6	CR 3856-44-22-2-1-11-3	High yielder
SupR7	CR 3856-29-2-1-1-2	High yielder
SupR8	CR 3939-2-1-1-2-1	High yielder
SupR11	CR 3967-11-1-1-1-1-1	Low yielder
SupR12	C 3856-47-12-1-1-1-1	Medium yielder

Fig. 1.16 Graphical genotyping showing contribution of japonica genome in super rice cultures

Screening for Biotic stresses

Sheath Blight

Out of 65 super rice genotypes screened, three lines (SR 8-3-1-32, SR 8-3-1-63 and SR 25-5-1-4), showed moderately resistant reaction (disease score of 1-3), eight showed tolerant reaction (score of 3.1-5) whereas, 42 were found to be susceptible (with score of 5.1-7) and 12 genotypes to be highly susceptible (with score of 7.1-9).

Evaluation of super rice for favourable upland

The segregated breeding lines derived from different crosses (CR Dhan 40 / NPT PSR 12, Anjali x NPT PSR 14, CR Dhan 40 / NPT PSR 14 and Sahbhagidhan / NPT PSR 18) were advanced (F_2 to F_6) in both the locations at NRRI (*rabi*) and CRURRS (*kharif*). Altogether, 118 breeding lines derived from five crosses of F_6 generation were evaluated during *kharif* 2016 and 81 lines were selected based on NPT. Highest yield was obtained from CRR 790-71 (7.275 t ha^{-1}) under transplanted condition followed by CRR 790-31 (6.9 t ha^{-1}), CRR 790-87 (6.875 t ha^{-1}), CRR 790-55 (6.375 t ha^{-1}) and CRR 790-33 (6.25 t ha^{-1}). Similarly, under dry DSR condition, the culture CRR 790-87 was recorded with highest grain yield of 6.25 t ha^{-1} followed by CRR 790-71 (5.5 t ha^{-1}), CRR 790-33 (5.375 t ha^{-1}), CRR 790-1 (5.275 t ha^{-1}) and CRR 790-52 (5.0 t ha^{-1}). In both the situations the cultures *viz.,* CRR 790-87, CRR 790-71 and CRR 790-33 were found promising (Table 1.15).

Resistance breeding for multiple insect-pests and diseases

Bacterial Blight resistant variety developed through Marker Assisted Backcrossing

CR Dhan 800 (Swarna-MAS; CRMAS 2232-85): This was developed from the cross between Swarna and IRBB 60 through marker assisted selection by pyramiding of three bacterial blight resistance genes (*xa5, xa13* and *Xa21*) into popular variety Swarna. This variety is suitable for growing in the "Bacterial blight" endemic areas in the state of Odisha. It has medium slender grains, high head rice recovery with intermediate amylose content having 140-145 days duration. This was released in 2016 by SVRC, Odisha (Fig. 1.17).

Fig.1.17. Field view of CR Dhan 800 (Swarna-MAS; CRMAS 2232-85)

Table 1.15. Performance of fixed advance breeding materials under favourable upland

Sl	Entry	Direct seeded (Dry DSR)			Transplanting (TP)		
	Genotypes	Days to Flowering	Height (cm)	Grain Yield (kg ha^{-1})	Days to Flowering	Height (cm)	Grain Yield (kg ha^{-1})
1	CRR 790-87	80	84.2	6250 ^{I}	85	88.2	6875 ^{III}
2	CRR 790-71	86	112.4	5500 ^{II}	91	119.4	7275 ^{I}
3	CRR 790-33	85	110.2	5375 ^{III}	93	119.4	6250 ^{V}
4	CRR 790-1	82	88.0	5275 ^{IV}	87	114.0	6000
5	CRR 790-52	84	107.2	5000 ^{V}	90	111.0	5750
6	CRR 790-31	84	118.2	4550	92	122.2	6900 ^{II}
7	CRR 790-55	85	85.0	4250	90	114.4	6375 ^{IV}
	Sahbhagidhan (check)	85	88.7	3550	92	105.5	4850

Generation of breeding materials for resistance to multiple insect-pests and diseases

Improvement of elite varieties Naveen and Pooja for BLB and Blast disease resistance

During *rabi*, 2016, BC_3F_2 progenies of the cross Naveen/ CRMAS 2231-37 // Naveen/ CRMAS 2620-1were grown along with recurrent and donor parents. From these progenies promising plants with targeted genes were selected based on morphological characters and molecular analysis. During *kharif*, 2016, selected (20) BC_3F_3 progenies were grown. From these progenies twelve plants with all targeted genes were selected based on morphological characters and molecular analysis for further evaluation.

During *kharif*, 2016 BC_2F_2 progenies of the cross Pooja/*CRMAS 2232-71*/// CRMAS 2619-9 were grown along with recurrent and donor parents. On the basis of morphological and molecular analysis, fifteen plants with desired characters were selected for further analysis.

Improvement of promising varieties for BPH, Sheath blight and RTD disease resistance

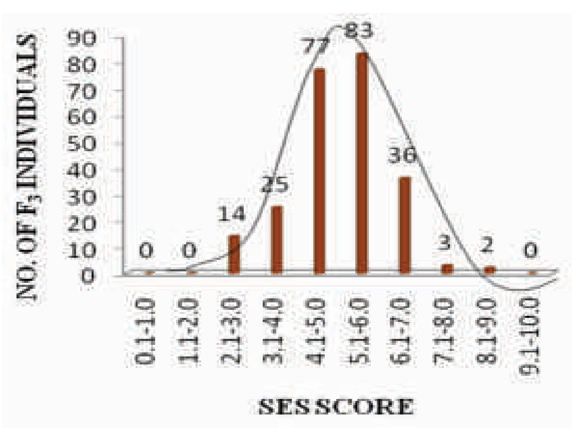
The backcross populations were developed among elite varieties Naveen, Pooja, Swarna *sub1*, Tapaswini and promising donors for BPH, tungro and sheath blight disease. IET 16952 and Vikramarya were taken as the resistant donors for tungro disease, CR 1014, Tetep, IET 19346, IET 17885, ADT 39 and Jogen were used for sheath blight and CR 3006-8-2 (derived from a cross combination of Pusa 44 / Salkathi), IR 65482-7-216-1-2 (Bph 18) and IR 71033-121-15-B (Bph 20 and Bph 21) were taken for BPH resistant donors.

Evaluation of germplasm and breeding lines for diseases/ insect-pests under screening nurseries

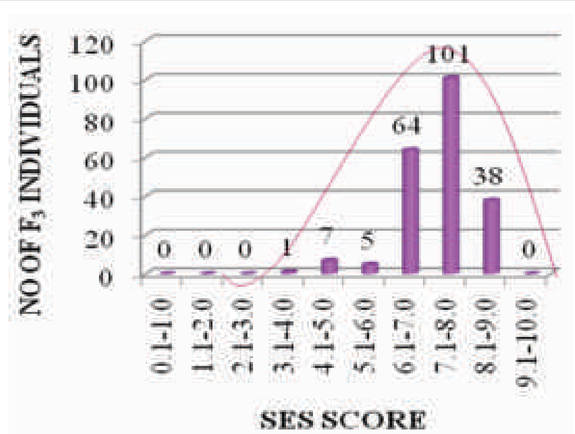
The $F_{2:3}$ population (216 F_3 lines) of Swarna *sub1* (sheath blight susceptible variety) / CR1014 (sheath blight tolerant variety) along with the parents were screened against sheath blight under artificial inoculation following the methodology given by Yoshimura and Nishizawa (1954) in both *rabi* and *kharif*, 2016 and average score of 10 plants per line was calculated (Fig. 1.18 a & b).

The back cross populations of different crosses in the background of Naveen and Pooja were screened against sheath blight under artificial innoculation. The crosses Naveen / IET 17885, Pooja / IET 17885, Pooja / ADT 39, Pooja / Jogen were found to be promising for sheath blight resistance. The plants showing sheath blight tolerance with good plant types were selected for further validation.

Selected F_4 lines derived from the cross MTU 1010 / IR 75870-8-1-2-B-6-1-1-B were screened against BPH and blast under artificial inoculation. Thrteen lines were found to be highly resistant to BPH with score 1 while eight lines were with score 3. One hundred F_3 lines from the cross Swarna / IR 75870-8-1-2-B-6-1-1-B were also screened against BPH and blast under artificial innoculation. Three lines were found to be highly resistant to BPH with score 1 and eight lines were found to be resistant to blast with score 3.



(A)



(B)

Fig.1.18. Screening of F_3 lines of Swarna *sub1* / CR 1014 for sheath blight resistance in *rabi*, 2016 (a) and *kharif*, 2016 (b)

Performance of entries in AICRIP trials during 2016

CR 3808-13 (IET 25997), a selection from male sterility facilitated recurrent selection population was promoted to AVT-1 (IM) based on its superior performance in both zone IV (North Eastern region) and V (Central region) in IVT-IM. It was ranked 1st in zone V (Central region) and ranked 3rd in zone IV (North Eastern region with 1st position in Tripura).

CR 2711-76-13-1 (IET 26018), a selection from Tapaswini / Dhobanumberi (BPH tolerant donor) was promoted to AVT-1 (IM) based on its superior performance in zone VI (Western region). It was ranked 3rd in zone VI.

Performance of entries under AVT 2-NIL-Blast (AICRIP Trial)

Twelve entries including four improved lines for bacterial blight and blast resistance and eight check varieties, which include four donor parents *viz.,* C101 A51, Tetep and DHMASQ 164-2B and RP Bio Patho2 and four recurrent parents *viz.,* Swarna, Samba Mahsuri, Improved Samba Mahsuri and Akshya dhan were evaluated in a randomized block design with three replications under irrigated conditions. Among the different entries, recurrent parent Swarna (Entry No. 4202) performed best with an average yield of 6.28 t ha^{-1} followed by Entry No.4201 (RP 5960 Patho 7-5-9) with 5.05 t ha^{-1} and Entry No. 4208 (Improved Samba Mahsuri) with 4.73 t ha^{-1}.

New nominations for AICRIP trials

CR 3942-2-2-1-1 for IVT-IM, CR 4122-8-3-1-2, CR 4123-16-2-1-1, CR 3941-15-3-1-1 for IVT-RSL, CR 3941-4-2-2-1 for IVT-MS and CR 3808-60-9-2-1 for IVT-IME were nominated for AICRIP trials of 2017.

Breeding for Higher Resource use Efficiency

Improving genetic potential of rice for direct seeded condition

Evaluation of rice germplasm for early seedling vigour under direct seeded condition

A set of 741 Assam Rice Collections (ARC) were evaluated under direct seeded condition along with checks (Varshadhan, IR64, Prabhavati, Brown gora, Kasalath, Dular, Basmati 370, GM 217, Jalamagna and IR36) for seedling vigour based on IRRI SES score during *kharif* 2016. Among them, genotypes ARC 10831, ARC 11769, ARC 12004, ARC 11385, ARC 7308 and ARC 10845 exhibited higher seedling vigour than checks (Table 1.16). The above mentioned lines accumulated higher biomass of more than 1 gm and found superior over the efficient check Brown gora. A mini core population of one hundred and twenty lines were selected to study their performance in *rabi* 2017.

The selected ARC lines were raised during *rabi* 2017 and their performance was studied under direct seeded condition. Among the 112 lines, ARC11553, ARC11587, ARC11691, ARC11695 and ARC11568 (Table 1.17) exhibited significantly higher crop growth rate with medium plant height. Therefore, these lines can be utilized in breeding program as donors to infuse seedling vigour trait into high yielding varieties.

Developing varieties adaptive to water limited situation

Evaluation of selected early seedling vigour (ESV) genotypes for yield performance under aerobic condition

Fifty three genotypes found to posses early seedling vigour (ESV) trait were tested under aerobic condition to know their yield performance during *rabi* 2017 (Table 1.18). Among them, genotypes ARC 10969, ARC 11721, ARC 10944 and ARC 10859 exhibited significantly higher yield than the general mean of 6.78 g $plant^{-1}$.

Evaluation of advanced breeding lines under aerobic condition during *rabi*, 2017

Thirty six entries of advanced breeding lines with five aerobic varieties Pyari, CR Dhan 202, CR Dhan 203, CR Dhan 204 and CR Dhan 205 were tested under aerobic condition with two replications. Among them, grain yield was recorded significantly higher in four entries namely 377-2-1, GSR-16, CR-4003-302-1-1 and CR-4006-564-3-1-1 compared to that of superior check Pyari 4.37 t ha^{-1} (Table 1.19). These best performed five entries were nominated for AICRIP 2017 trial.

Table 1.16. Performance of ARC lines for early seedling vigour under direct seeded condition during *kharif*, 2016

Genotype	Seedling ht. (cm)	Tiller no.	Leaf no.	Culm thickness (mm)	SPAD value	Dry wt. (g)
ARC 10831	69.87	3.00	8.33	3.40	36.30	1.296
ARC 11769	68.50	4.00	15.00	2.71	34.52	1.278
ARC 12004	51.70	6.00	22.00	3.33	33.18	1.172
ARC 11385	53.10	2.00	7.00	2.01	32.33	1.085
ARC 7308	77.13	3.33	13.33	2.84	42.07	1.082
ARC 10845	62.87	3.33	12.33	4.00	38.87	1.004
Brown gora	58.93	4.33	16.67	2.12	33.43	0.930
General Mean (n=741)	46.64	2.60	10.28	2.80	35.85	0.312
CD 5%	0.96	0.07	0.28	0.16	0.28	0.013

Table 1.17. Performance of selected ARC lines for early seedling vigour under direct seeded condition during *rabi*, 2017

Genotype	14 DAS			28 DAS				CGR (g m^{-2} day^{-1})	AGR (cm day^{-1})
	PH	Leaf No.	Wt (g)	PH	Tiller no.	Leaf No.	Wt (g)		
ARC11553	11.63	3.00	0.0096	31.34	2.40	7.60	0.235	0.536	1.408
ARC11587	11.77	2.90	0.0097	29.42	2.20	6.40	0.221	0.503	1.261
ARC11691	10.99	3.00	0.0097	31.72	1.80	6.80	0.220	0.501	1.481
ARC11695	11.75	2.70	0.0129	31.16	1.40	7.80	0.201	0.447	1.386
ARC11568	11.91	3.00	0.0096	29.52	1.60	6.20	0.190	0.430	1.258
Mean (n=112)	11.25	2.94	0.010	24.68	1.63	5.85	0.078	0.161	0.959
CD 5%	0.17	0.03	0.000	0.51	0.09	0.29	0.007	0.018	0.038

Table 1.18. Performance of selected ARC lines under aerobic condition

Genotype	Grain yield g plant^{-1}
ARC 10969	14.64
ARC 11721	13.54
ARC 10944	13.52
ARC 10859	13.32
ARC 7039	11.16
ARC 6043	10.74
ARC 6156	10.40
ARC 11064	10.30
ARC 11822	10.04
Mean (n=53)	6.78
CD 5%	0.86

Table 1.19. Performance of advanced breeding lines under aerobic condition during *rabi*, 2017

Genotypes	Yield t ha^{-1}
377-2-1	4.97
GSR-16	4.84
CR-4003-302-1-1	4.79
CR-4006-564-3-1-1	4.76
Pyari	4.37
C-534-3-1-4	4.24
CR-400-1-97-2-2-1	4.14
CR-4007-547-11-2-1-2	4.12
CR-3998-8-IR 91648-B-89-B-5-1	3.98
Mean(n=36)	3.64
CD 5%	0.24

To understand the performance of yield contributing genes (*Gn1a/OsSPL14/SCM2*) in aerobic condition, 43 early maturing introgressed lines in the back ground of MTU1010, Swarna and Samba Mahsuri were tested during *rabi*, 2017. The entries were tested in two replications. Among the 43 entries, IR121047 and IR121055 of MTU1010 and IR121043 of Swarna derivatives recorded higher yield compared to general mean of 0.451 kg m^{-2} (Table 1.20).

Table 1.20. Performance of yield enhancing introgressed early lines under aerobic condition during *rabi*, 2017

Pedigree	Yield (kg m^{-2})
IR 123309-1-22-4	0.393
IR 113011-2-8-6	0.419
IR 121045-1-2-9	0.393
IR 121045-3-3-5	0.393
IR 121055	0.440
IR 121051	0.440
IR 121047	0.548
IR 121045	0.405
IR 121043	0.524
IR 121055	0.595
IR 113013-38-4-1-7	0.417
IR 123342:6-2	0.393
IR 113013	0.429
IR 113013	0.417
IR 113015	0.560
Mean (n=43)	0.451
CD 5%	0.035

Similarly, 112 numbers of Savitri x Pokkali doubled haploid (DH) anther culture derived fixed lines were tested under aerobic condition in augmented design during *rabi,* 2017. Among them, 75 lines flowered within 90 days of sowing and seven entries (DH-79, DH-113, DH-94, DH-100, DH-1, DH-106 and DH-19) exhibited more than 200 g/0.42 m^2 (Table 1.21). The better performed introgressed lines and DH lines will be tested again in the subsequent season.

Creation of variability through hybridization and backcrossing, selection and evaluation of new and existing segregating materials suitable for aerobic and direct seeded situation

To target aerobic rice situations, 15 F_1s were obtained by cross combination of one upland drought tolerant parent with high yielding irrigated/low land variety with good grain quality during *rabi,* 2017. From the ongoing 56 lines of F_2 generation, single plant

Table 1.21. Performance of promising DH lines of derived from of Savitri x Pokkali during *rabi*, 2017

Genotype	Yield (kg/ 0.42 m²)
DH 79	0.386
DH 113	0.296
DH 94	0.291
DH 100	0.291
DH 1	0.225
DH 106	0.223
DH 19	0.210
DH 5	0.195
DH 110	0.195
DH 90	0.193
DH 14	0.190
DH-43	0.190
DH 36	0.186
DH 17	0.185
DH 103	0.183
DH 29	0.176
DH 18	0.175
DH 116	0.175
Mean (n=75)	0.135
CD 5%	0.014

progenies were selected and 42 lines were advanced to F_3 generation. In another set, 124 F_4 lines were advanced based on single plant progenies to F_5 generation. Twenty two promising lines of F_8 generation were bulked for next season initial yield evaluation trial.

Identification and hybridization of drought tolerant lines with existing HYVs of irrigated ecosystem for moisture stress situation – for vegetative/reproductive/both the stages

Introgression of three *qDTY* QTLs into Satyabhama

The objective of this activity was to introgress three *qDTY* QTLs into a drought tolerant popular variety Satyabhama to improve further tolerance level. Initially, hybridization was initiated between Satyabhama and Way Rarem to transfer *qDTY12.1*. of this cross, 35 F_1 seeds were obtained and these were further hybridized with N-22 (*qDTY1.1* and 2.1) to produce F_1'. Further, backcrossing of these F_1 plants will be done in the upcoming season with Satyabhama to bring all DTY QTLs in single back ground of Satyabhama. The improved version of Satyabhama will be nominated and further it can be used as donor.

Marker Assisted backcross for introgression of blast and drought tolerance genes into N22

Similarly, the popular drought tolerant donor N22 has been crossed with CRMAS2620-1 to introgress blast resistance gene *Pi9* and three qDTYs (*qDTY12.1*, *qDTY2.3*, *qDTY3.2*) through MABC approach. At present, 112 BC_2F_{2s} were generated, among them 15 were found to have *Pi9* gene and three *qDTYs* (*qDTY12.1*, *qDTY2.3*, *qDTY3.2*) with >85% recurrent genome. Once the homozygous lines are identified with more than 95% genome recovery, the lines would be used as donor for crossing.

Improving genetic potential of rice for efficient use of nutrients

Identification and hybridization of phosphorus use efficient (PUE) lines with existing HYVs of irrigated ecosystem for aerobic situation

During *kharif*, 2016, 685 Assam Rice Collection (ARC) lines were screened @ 16.7 kg ha^{-1} of P under field condition in augmented design with checks Varshadhan, IR64, Prabhavathi, Browngora, Kasalath, Dular, Basmati 370, GM 217, Jalamagna and IR36. Based on biomass accumulation, seedling height, tiller number, leaf number, culm thickness and SPAD value at 35 days after sowing, genotypes ARC 12356, ARC 12451, ARC 12184 and ARC 12131 were found superior than the checks with more than a gram dry weight (Table 1.22). Therefore, from these 685 lines, 115 better performing lines were selected and raised again during *rabi,* 2017 to validate their performance under same level of P. Based on biomass accumulation after 14 and 28 days after sowing, ARC 11331, ARC 11356 and ARC 6249 were found to have accumulated higher biomass with medium plant height (Table 1.23). Further, these lines will be validated again in forthcoming season.

Table 1.22. Performance of ARC lines under moderate level of P in field condition during *kharif*, 2016

Genotypes	Seedling ht. (cm)	Tiller no.	Leaf no.	Culm thickness (mm)	SPAD value	Dry wt. (g)
ARC 12356	59.50	4.00	11.00	2.78	26.97	1.669
ARC 12451	52.00	3.50	13.00	1.64	25.41	1.263
ARC 12184	50.40	4.00	12.00	2.38	23.24	1.260
ARC 12131	63.40	3.00	11.00	1.62	23.68	1.146
ARC 12194	55.40	4.00	14.00	1.75	26.47	0.979
ARC 13236	50.50	3.00	12.00	1.89	39.20	0.901
ARC 11497	54.20	4.00	12.00	2.53	28.47	0.884
ARC 11734	54.40	4.00	14.00	2.45	26.40	0.851
ARC 12188	45.50	4.00	12.00	2.57	30.21	0.841
ARC 12366	52.70	3.00	11.00	1.31	21.02	0.817
Mean (n=685)	37.46	1.47	6.34	2.06	29.13	0.155
CD 5%	0.66	0.04	0.14	0.10	0.28	0.010

Table 1.23. Performance of selected ARC lines under direct seeded condition during *rabi*, 2017

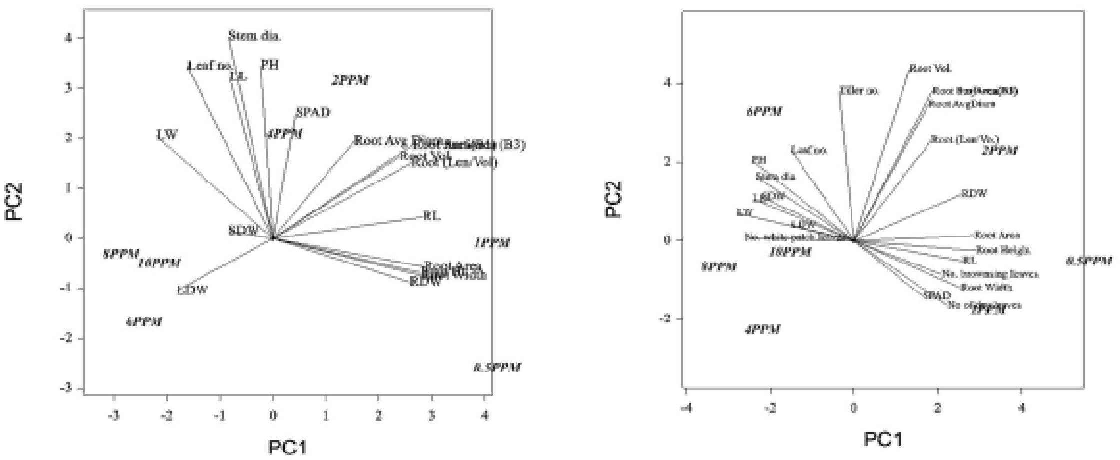
Genotypes	14 DAS			28 DAS				CGR	AGR
	PH	Leaf No.	Wt (g)	PH	Tiller No.	Leaf No.	Wt (g)		
ARC 11331	15.67	3.00	0.0098	27.27	3.00	9.80	0.1680	0.3767	0.8286
ARC 11356	15.13	3.00	0.0108	31.43	3.00	10.20	0.1436	0.3162	1.1643
ARC 6249	13.83	3.00	0.0232	28.61	3.00	10.10	0.1558	0.3157	1.0557
ARC 6220	11.39	3.00	0.0094	21.39	1.10	5.50	0.1293	0.2855	0.7143
ARC 6234	12.58	3.10	0.0177	23.58	3.00	10.80	0.1367	0.2833	0.7857
ARC 6235	12.95	3.00	0.0132	27.41	3.20	11.50	0.1311	0.2807	1.0329
Mean(n=115)	13.53	3.05	0.0178	27.86	2.97	10.02	0.0788	0.1473	1.0238
CD 5%	0.24	0.02	0.0017	0.55	0.08	0.22	0.0048	0.0119	0.0414

Forwarding of mapping population for low P

A phosphorus tolerant AC 100219 line was crossed with MTU 1010 to generate RIL population during *rabi*, 2016. The F_1 of the cross was raised in *kharif* 2016 and further F_2 population was raised under low P @ 10.9 kg ha^{-1} to know their performance. The population was found to be normal to moderately skewed for all the traits except plant height and panicle length (Table 1.24).

To determine the threshold level of P and to identify the trait responsible for low P variation, genotypes (Dular, Kasalath, IR 64-*pup1*, Sahbhagidhan, GM 217) possessing *PSTOL1* were raised under different concentrations of P (0.5, 1.0, 2.0, 4.0, 6.0, 8.0 and 10.0 ppm) in hydroponics. IR 64 has been used as negative control. Shoot length, root length, root surface area, number of leaves, leaf bronzing, root dry weight, root volume, tiller number, stem diameter, leaf weight and SPAD value were observed during 14 and 28 days after sowing (DAS). The biplot (Fig. 1.19) depicts that on both 14 and 28 DAS, all root related traits were clustered together and plotted on right side of the plot, whereas shoot related traits were plotted on left side of the plot. The P concentrations like 0.5, 1.0, 2.0 and 4.0 ppm were plotted on right side with root traits and

Screening *PSTOL1* possessing under different concentration of P in hydroponics



14 Days after sowing　　　28 Days after sowing

Fig. 1.19. Performance of plants possessing PSTOL1 under different concentration of P in hydroponics

Table 1.24. Evaluation of F_2 population under low phosphorus condition

Genotypes	45 DAS			Maturity stage			
	Seedling ht. (cm)	Tiller no.	Leaf no.	Plant ht. (cm)	Panicle lt. (cm)	EBT	Yield/pl. (g)
AC 100219	22.32	2.56	8.78	74.61	23.15	13.44	16.25
MTU 1010	26.56	2.67	10.27	75.74	23.50	9.00	8.78
F_2 (mean)	24.82	3.80	13.65	75.79	22.00	9.82	14.68
CD 5%	0.37	0.15	0.53	0.94	1.22	0.37	0.66
Skewed	-0.562	0.742	0.631	-1.453	14.734	0.234	0.997
Range	6 – 37.5	1 – 9	3 - 31	24.3 -98.5	8.2 -25.4	1 -24	1.51 -49.38

concentrations six and more than six are plotted on left side with shoot traits. This suggests that, low P articulated root growth and high P induces shoot growth. On the other hand, the 4 ppm concentration was found to be peculiar at 28 DAS. At 14 DAS, 4 ppm plotted on right with root traits and later after 28 DAS, it was plotted separately. Therefore, this needs further investigation to understand the role of P in older seedlings.

Breeding for aromatic rice and grain quality improvement

Development of high yielding aromatic genotypes with good grain quality and biotic resistance

In order to develop high yielding aromatic genotypes, ten new crosses were made involving elite varieties NDR 359, Pusa 44, Naveen and CR Dhan 300 with aromatic donors, Gobindabhog, CR Sugandh Dhan 907, Geetanjali, Basmati 386. Four hundred nineteen lines belonging to eighteen cross combinations in F_3 to F_7 generations were evaluated in irrigated condition and three hundred twenty six single plant selections and fifty nine bulks were made based on their uniformity, agro-morphological characters and aroma. Further, eight F_1s made during last year using popular high yielding varieties and aromatic genotypes as parents were generation advanced. In an advance yield station trial, twenty two advance breeding lines along with two aromatic check varieties were evaluated in a replicated trial under irrigated conditions during *kharif*, 2016. CR 2948-2-4-6 performed best with an average yield of 4.85 t ha^{-1} against best check variety Chinikamini (3.86 t ha^{-1}).

Maintenance and collection of Aromatic Short Grain rice

One hundred twenty six aromatic short grain rice landraces of Odisha and 226 aromatic short grain rice germplasm belonging to different states of India were acquired, regenerated and evaluated. Pimpudibasa, Jaiphul, Karpurakranti, Kalajoha, Randhunipagal, Jaiphool were identified as donors.

Evaluation of biofortified breeding material: 236 segregating lines belonging to fifteen cross combinations in F_4 to F_6 were advanced and 142 single plant selections and 42 bulks were made. CR 2616-3 and CR 2007-6 were nominated to IVT Biofortification trial.

Demonstration of aromatic varieties: Field demonstrations of ten aromatic varieties developed by NRRI (Geetanjali, Ketekijoha, Nua Kalajeera, Nua Dhusara, Nua Chinikamini, Poornabhog, CR Sugandh Dhan 907, CR Sugandh Dhan 908, CR Dhan 909 and CR Sugandh Dhan 910) were made for the farmers/visitors and the variety Poornabhog was found to be the highest yielder (5.2 t ha^{-1}).

Evaluation of elite cultures in national trials at NRRI, Cuttack

a) Advance Variety Trial 1-Aromatic Short Grain (AVT 1- ASG)

Twelve entries including six check varieties National (Shobini), Zonal (CR Sugandh Dhan 907), quality (Dubraj, Ketekijoha, Kalanamak) and local (Poornabhog) were evaluated in a randomized block design with three replications under irrigated conditions. The experimental mean yield was 4.81 t ha^{-1} with 112 average days to flowering, plant height 125 cm and 254 panicles m^{-2}. Among the different entries, the entry No. 3105, IET 24617 (MGD 1402) performed best with an average grain yield of 5.53 t ha^{-1}, against the best check Poornabhog with 5.24 t ha^{-1}.

b) Initial Variety Trial-Aromatic Short Grain (IVT-ASG)

The trial was conducted with 18 test entries generated at different centers of the country along with six check varieties National (Shobini), Zonal (CR Sugandh Dhan 907), quality (Dubraj, Ketekijoha, Kalanamak) and local (Poornabhog). The experimental mean yield was 4.95 t ha^{-1} with 116 average days to flowering, plant height 115 cm and 315 panicles m^{-2}. Highest grain yield of 6.6 t ha^{-1}was recorded from entry No 3206 (CR 2713-64) followed by CR 2033-572 with grain yield of 6.29 t ha^{-1}, in comparison to best check Poornabhog (5.39 t ha^{-1}).

c) Advance Variety Trial 2- Rice Biofortification (AVT 2 -Biofort)

Sixteen entries including checks Kalanamak, Chittimuthyalu, IR 64 and Samba Mahsuri were evaluated in a replicated trial under irrigated conditions. The experimental mean yield was 4.21 t ha^{-1} with 115 average days to flowering and plant height 106 cm. Among the different entries, the entry No. 3516 (NP 9685) performed best with an average grain yield of 4.97 t ha^{-1} against the best check Samba Mahsuri (5.12 t ha^{-1}).

d) Advance Variety Trial 1-Rice Biofortification (AVT 1 -Biofort)

Seventeen entries including four checks were evaluated in a replicated trial under irrigated conditions. The experimental mean yield was 5.02 t ha^{-1} and among the different entries, the entry No. 3615 (R RHZ SM-14) performed best with an average grain yield of 6.95 t ha^{-1} against the best check Samba Mahsuri (5.12 t ha^{-1}).

e) Initial Variety Trial- Rice Biofortification (IVT -Biofort)

Thirty six entries including four checks Kalanamak, Chittimuthyalu, IR 64, and Samba Mahsuri were evaluated in a replicated trial under irrigated conditions. The experimental mean yield was 4.39 t ha^{-1} and among the different entries, the entry No. 3711 (RP Bio 4981) performed best with an average grain yield of 5.71 t ha^{-1} followed by 3730 (HPR 2720) with yield of 5.88 t ha^{-1} against the best check variety (Samba Mahsuri) 3.52 t ha^{-1}.

f) Advance Variety Trial Medium Slender Grain (IVT-MS)

Thirty two entries including five checks National (WGL-14, BPT 5204), Zonal (Improved Samba Mahsuri), Hybrid (DRRH 3) and (Chinikamini) were evaluated in a replicated trial under irrigated conditions, the entry No. 3926 (RGL 7011) performed the best with an average grain yield of 6.55 t ha^{-1} followed by 3932 (ad 13121) with 6.25 t ha^{-1} against the best check Chinikamini (5.41 t ha^{-1}).

g) Initial Variety Trial Medium Slender Grain (IVT-MS) RP Bio 226

Sixty four entries including five checks National (WGL-14, BPT 5204), Zonal (Improved Samba Mahsuri) and local (Chinikamini) were evaluated in a replicated trial under irrigated conditions, the entry No 4043 (TRC 2016) performed best with an average grain yield of 6.94 t ha^{-1} followed by MTU 1029 (6.99 t ha^{-1}) against the best check WGL 14 (6.34 t ha^{-1}).

Performance of entries nominated in AICRIP trials during 2016

The aromatic genotype CR 2713-64 was promoted from IVT ASG to second year of testing to AVT1ASG. The culture CR 3505-7-1-1-1-2-1 with MS grain and desirable quality characteristics was promoted for third and final year of testing in AVT 2-MS based on yield superiority over checks.

New nominations for AICRIP trials

Five promising high yielding, semi dwarf aromatic cultures CR 2979-1-4-1, CR 2948-2-4-6, CR 2618-3-2-1, CR 2982-2-4-6 and CR 2963-2-6-1 having grain yield potential of more than 4.5 t ha^{-1} and good grain quality were nominated for AICRIP trial IVT-ASG.

Release of variety

The aromatic short grain rice variety CR Sugandh dhan 910 was released by State Variety Release Committee (SVRC), Odisha in 2016 for irrigated late and favourable shallow low lands. It has maturity duration of 145 days, plant height of 101.0 cm, medium slender grain, and desirable grain characters with grain yield potential of 5.5 t ha^{-1} (Fig. 1.20).

Fig. 1.20. Field view of aromatic short grain rice variety CR Sugandh Dhan 910

Breeding for high protein rice

Release of nutrient rich rice

Nutrient rich rice variety, Mukul (CR Dhan 311) with an average 10.1% protein and 20 ppm Zn content reported in biofortification trial under AICRIP was released by the State Variety Release Committee, Odisha in 2016 (Fig. 1.21). This is a backcross derived line from the cross between Naveen and high protein donor, ARC 10075. The plant type and duration (125 days) are similar to its recurrent parent, Naveen. It has long bold grain type with average yield at national level is 4.33 t ha^{-1} and in Odisha it is 5.54 t ha^{-1}.

Fig. 1.21. Field view of nutrient rich rice variety Mukul (CR Dhan 311)

Performance of biofortified rice in multilocational testing

- IET 24783 (CR 2829-PPLN-32) with an average grain yield of 5164 kg ha^{-1} and 9% GPC was identified promising in Kerala and Maharashtra.
- Three high protein lines in Swarna background were promoted to the second year of testing in Biofortification trial. They are IET 26380 (CR 2830-PLS-156), IET 26385 (CR 2830-PLS-30), IET 26398 (CR 2830-PLS-17) with average 93-98 cm plant height and 105-107 days to flowering as compared to Swarna with 94 cm and 105 days , respectively. The average yield of these lines at national level was 5141- 5494 kg ha^{-1} with 9.05–9.50% GPC and with 487.07- 507.64 kg ha^{-1} protein yield as compared to national check IR 64 and local check Swarna with 353.84 kg ha^{-1} and 432 kg ha^{-1} protein yield, respectively.
- Another line IET 26373 (CR 2819-1-5-3-B-8-2B-1) with 5 t ha^{-1} grain yield and high Zn content (20 ppm) was promoted to AVT-1.
- CR 2830-PLS-118 and CR 2830-PLS-146 having yielding ability higher than Swarna (5.6 t ha^{-1}) was nominated for Biofortification trial in 2017.

New breeding programme

To improve high yielding varieties for protein and micronutrients (Zn) three way crosses were made and F_1 seeds were harvested from six cross combinations involving high yielding quality rice varieties as well as donors for Zn and grain protein content such as Samba Mahsuri *sub 1*, CR Dhan 310, CR2830-PLS-17, Bindli and Kalinga III.

Improvement of rice through *in vitro* and transgenic approaches

Androgenesis in generation of green plants from a popular quality rice hybrid, 27P63

The androgenic protocol standardized for rice hybrid, 27P63 in *kharif*, 2015 was tested to check the reproducibility of androgenesis and generation of more number of DHs in *rabi*, 2015-16. The established callusing media, N6 semi-solid media supplemented with auxin-to-cytokinin ratio of 4:1 showed its reproducibility by producing 17.92% callus induction when the anthers were cultured at the mid-late uninucleate stages of the microspore after 3-4 weeks of culture. Similarly' light brown calli cultured in MS media along with cytokinin-to-auxin ratio of 2:1 responded to 69.27 % green shoot regeneration after 2-5 weeks of culture. Subsequently, the green shoots elongated after four weeks of culturing. A total of micro shoots formed a high percentage (100%) of roots grown in MS media supplemented with auxin and cytokinin in 10:1 ratio. In *rabi*, 2015-16' a total of 232 green plants were generated and transferred to net house for ploidy evaluation. It showed that though the media combinations responded for androgenesis of *rabi* grown rice hybrid, better response for callusing and shoot regeneration of anthers were observed lower as compared to *kharif* grown rice.

Establishment of method for generation of DHs from F_1s of Chakhao x IR20

The F_1 seeds were produced from the crosses of Chakhao (Manipuri black rice) and a cultivar, IR20 (medium duration, semi dwarf, high yielding, acceptable grain quality) during *kharif*, 2015 to develop a rice line with enhanced yield potential and antioxidant properties of Chakhao. The anthers containing the mid-uninucleate microspores of F_1 (Chakhao x IR20) were used to generate doubled haploids during *kharif*, 2016 which showed 28% callus response in modified N6 semi-solid media supplemented with auxin-to-cytokinin ratio of 4:1 after four weeks of culture. Further, the calli cultured in MS media along with cytokinin-to-auxin ratio of 2:1 responded to 80% green shoot regeneration after two weeks of culture (Fig.1.22). A total of 32 green plants were generated after rooting in the microshoots. Evaluation of 32 green plants based on morphology and seed set, 27 plants were found to be fertile diploids and further assessment through SSR markers confirmed all diploids as doubled haploids.

Fig.1.22. Green shoot regeneration in F_1s of Chakhao x IR20

Evaluation of ploidy status of green plants derived from rice hybrid, 27P63

A total of 232 green plants developed through anther culture were evaluated to confirm the ploidy status after seed set of which, 184 plants were found to be diploids, while 13 green plants were haploids. Though other 65 green plants showed normal morphological stature like parents, there was no seed set on maturity. A large range of variability in morpho-agronomic characters like days to flowering (68-122), plant height (38-130 cm), ear bearing tiller (5-32) and panicle length (13-24 cm) were noticed in all DHs in A0 generation (Fig. 1.23). Interestingly, no polyploids were found in the green regenerants in this culture. All the diploids were found to be DHs and was confirmed through SSR markers.

Fig.1.23. Discrimination of diploids and haploids based on morphological characters

Efficiency of callusing/regeneration using spikes from main culm *vis-a-vis* secondary culm of rice hybrid, 27P63 through anther culture

The efficiency of callusing/regeneration in main culm *vis-a-vis* secondary culm of rice hybrid, 27P63 through anther culture were studied in *kharif*, 2016, from which it was observed that the anthers derived from the secondary culm showed lower response (4.8%) for callus growth than the main culm (11.7%) cultured in the N6 semi-solid media supplemented with auxin-to-cytokinin ratio of 4:1 along with 3% sucrose after 3-4 weeks of culture. Subsequently, shoot bud regeneration was found to be 57.14% from the calli derived from the main stem, while the shoots regenerated from the calli of the secondary culm was 42.85% after 2-3 weeks of culture. This shows that the spikes collected from main culm is better than secondary culm derived spike for generation of a large number of DHs through androgenesis.

Preliminary evaluation for selection of promising DHs derived from the rice hybrid, 27P63

A preliminary evaluation of 50 DHs derived from a popular quality hybrid, 27P63 were made during *kharif*, 2016 to select the promising DH lines. All the individual DHs were planted in augmented design and morpho-agronomic characters were recorded. A large variability was observed within the DHs (Fig. 1.24). Days to 50% flowering, plant height, ear bearing tiller, length of flag leaf, panicle length, fertility (%), test weight and L/B ratio varied from 68-124, 54-124 cm, 11-21, 27-56 cm, 16-28.5 cm, 85.71-100, 10.2-18.3 gm and 2.82-5.36 mm, respectively. On the basis of these characters, 16 promising DH lines were selected for further evaluation (Fig. 1.25).

Fig.1.24. Large variation in DHs of 27P63

Assessment of parental allelic contribution in doubled haploids, derivatives BS6444G

A total of 650 SSR markers were screened to survey the hybridity in BS6444G out of which, 38 pairs were identified. Further, all 38 markers were used in characterizing 200 DHs generated from BS6444G for allelic distribution. Based on the χ^2 test at $p < 0.01$ and 0.05 of all 38 markers, 11 markers (28.94%) showed distorted segregation and 27 markers (71.05%) skewed favoring parental alleles which revealed the expected 1:1 ratio for the parental alleles at $p<0.05$ (Fig. 1.25). Out of the 11 distorted markers, three markers (7.89%) and eight markers (21.05%) showed distorted segregation at $p<0.05$ and $p<0.01$, respectively; these eight markers located on eight regions at seven chromosomes exhibited sequence segregation distortion at $p< 0.01$. Genotyping of the 200 DH lines revealed the expected 1:1 ratio for the alleles showing complete homogeneity for alleles of either parent, suggesting that DH lines are true representatives of the gametic constitution and are derived from the F_1 pollen of BS6444G.

From the total loci characterized from 200 DH lines, 50.5 % of the alleles were of the first allele type, while 49.5% were of the second parent type. Among these 27 markers, no segregation deviating from the expected 1:1 ratio was observed, indicating that an equal amount of genetic material from each parent has been transmitted to the progenies through anther culture, which is evident from the even distribution of alleles in the DH population confirmed through Chi-square test.

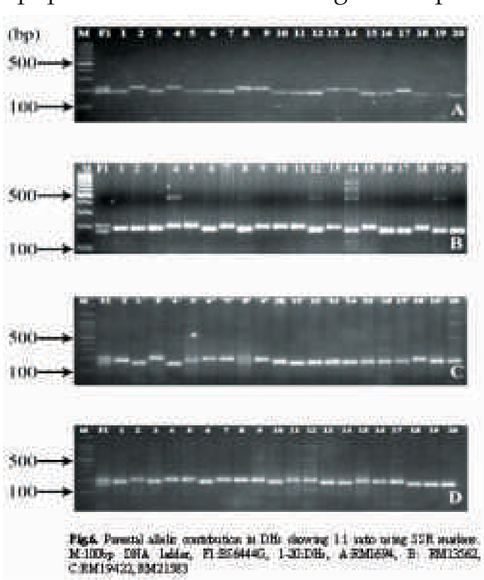


Fig.1.25. Composition of parental alleles in DHs derived from BS6444G

Large Field yield trial of Doubled Haploids of CRHR32 and BS6444G in *rabi* 2015-16 and *kharif* 2016

A total of 10 DHs, six from CRHR 32 and four from BS6444G were selected based on the yield performances in the replicated trial which were subsequently tested in large scale yield trial to compare the yield performances with the DHs derived parents (CRHR 32 and BS6444G) along with the HYV check (Naveen).

During *rabi*, 2015-16, six DHs derived from CRHR 32 were tested in large plot (area 96.3 m^2) out of which CR 2-1 (4153.69 kg ha^{-1}) and CR 9-1(3873.31 kg ha^{-1}) showed higher grain yield than the hybrid (CRHR32, 2647.98 kg ha^{-1}) and the check. While compared with CRHR32, CR 6-1 produced 2733.11 kg ha^{-1} which was at par with the yield of the parent. In case of the DHs of BS6444G, all the four DHs such as PA80-02 (4464.29 kg ha^{-1}), PA27-1 (4027.78 kg ha^{-1}), PA66-3 (3707.34 kg ha^{-1}) and PA139-4 (3601.19 kg ha^{-1}) out yielded the parent hybrid (3100.20 kg ha^{-1}) along with the check (2976.19 kg ha^{-1}).

Further yield evaluation of 10 DHs (four DHs- PA 27-1, PA 66-3, PA 80-2 and PA 139-4 of BS 6444G; six DHs–CR 9-1, CR 2-1, CR-2-5, CR 6-1, CR 1-1, CR 3-2 of CRHR 32 were made in large plot (108.00m^2) in *kharif*-2016. These entries were evaluated along with respective parent hybrids and varietal check, Naveen where DHs PA 27-1 (5984.66 kg ha^{-1}) followed by PA 66-3 (5879.00 kg ha^{-1}) recorded at par yield i.e. 98.6%, 96.75% of parent hybrid BS 6444G (6070.42 kg ha^{-1}). Among the DHs of CRHR-32, CR 2-1 (5233.26 kg ha^{-1}) followed by CR 9-1 (5166.48 kg ha^{-1}) recorded at par (98.5%, and 97.17%, respectively) yield of parents hybrid CRHR 32 (5313.02 kg ha^{-1}).

Evaluation of *Rf* genes in selected promising DHs of CRHR32 and BS6444G

Cytoplasmic male sterility is a maternally inherited trait caused by the incompatibility between the nucleus and cytoplasm, resulting in the inability to produce fertile pollen. This phenotype is prevented by the presence of a fertility restorer (RF) gene in the nuclear genome. To assess the fertility restoration potency of *Rf* genes (*Rf4* and *Rf3*), a total 20 and 13 selected promising DHs of CRHR32 and BS6444G were evaluated along with the parents.

The parent hybrids were found positive for *Rf4* gene and negative for *Rf3* gene. Similarly, 10 DH lines of CRHR32 and 7 DH lines of BS6444G possessed the dominant fertility restorer gene *Rf4* where no *Rf3* was detected. The *Rf4* allele showed the band size of 180 bp (+ve control), whereas 161bp (-ve control) was found for non-restoring (*Rf3*) gene. Overall, it was observed that *Rf4* played a major role in fertility restoration. Further, the DHs carrying the *Rf4* gene were test crossed with different CMSs and showed substantial heterosis. Therefore, these could be utilized in development of new rice hybrids.

Nutritional Quality of Promising DH lines derived from rice hybrid, CRHR32

A total of 24 selected promising DH lines derived from a long duration rice hybrid, CRHR32, were screened for nutritional quality in grains for which protein, phytic acid, Fe and Zn contents of the grains were studied. The protein content in brown rice ranged from 9.3% to 12.12%, while the protein content in milled rice showed the range from 7.27 to 10.59%. The phytic acid was found maximum (1.98%) in CR 32-12 and minimum (0.48%) was recorded in CR 32-8. The range of Fe content in all the 24 DHs varied from 1.7 to 5.1 ppm. The highest (CR 32-20) and lowest (CR 32-8) content of Zn was found to be 23.5 ppm and 14.3 ppm, respectively. A single DH line (CR 32-8) showed the considerable amounts of protein, phytic acid, Fe, Zn and also grain yield of 6 t ha^{-1}. This line could be utilized as nutritional rich rice cultivar after further validation.

A specific non-synonymous substitution in the DNA Binding Domain of heat shock transcription factor *HsfA2a* in rice is fixed in *aus* type accessions

Transcription factors regulate the expression of genes and initiates stress response in organisms. Heat shock transcription factors (*Hsfs*) elicits heat stress response in organisms. Higher group of plants consist of multiple *Hsfs* compared to few in lower group of plants and non plant organisms. *HsfA2* is one of the important *Hsfs* which plays a predominant role in heat stress response and acquired thermo tolerance in plants. There are only one or few *HsfA2* in dicot crops compared to four or more in monocots. Moreover, since molecular divergence of *HsfA2s* in plants is not known, an attempt was made to study the type-I and type-II molecular divergence of *HsfA2* in five monocots and seven dicot plants. It shows that *HsfA2* emerged in *Amborella* and diverged in number and sequence between the monocots and dicots (Fig. 1.26). Besides, *HsfA2s* showed type-I and type-II divergence between the characteristics secondary structure of DNA Binding domains (DBD), nuclear localization signal (NLS) and transcriptional activation (AHA) motifs. There were nine non-synonymous substitutions identified in the five *HsfA2s* of rice. One of the non-synonymous substitutions changing the amino acid aspartate into glutamate in the alpha 1 helix of DBD of *OsHsfA2a* was found to be specifically fixed in aus type rice accessions. Thus, this study provided the preliminary *in silico* prediction of domains and motifs showing divergence in *HsfA2* in plants. The novel allele of *OsHsfA2a* identified in this study needs further evaluation for adaptation to stress tolerance in rice.

Transgenic approaches for sheath blight resistance

Sheath blight is one of the important pathogens causing significant yield loss in rice. There is no known genes/QTL for imparting resistance to sheath blight in rice. *Trichoderma harzianum* is considered as one of the biocontrol agents to control plant diseases. Alpha glucanase gene has been reported to confer tolerance to sheath blight pathogen. Total RNA from *T. harzianum* was isolated using Trizol reagent and cDNA was used to amplify the alphaglucanase gene. Also, one constitutive promoter, rice actin and one green tissue specific promoter, maize ppdk, were amplified for controlling expression of alphaglucanase (Fig 1.27). The cloning of the gene and promoter in a construct will be performed for development of transgenic rice lines with resistance to sheath blight.

New nominations for AICRIP trials

CRAC 3994-9-17, CRAC 3995-139-4 and CRAC 399-66-3 for IVT-IME; CRAC 3994-3-2 and CRAC 3994-2-5 for IVT-Biofort; CRAC 3995-80-2-1 for IVT-L; and CRAC 3994-2-08 for SBST were nominated for AICRIP trials of 2017.

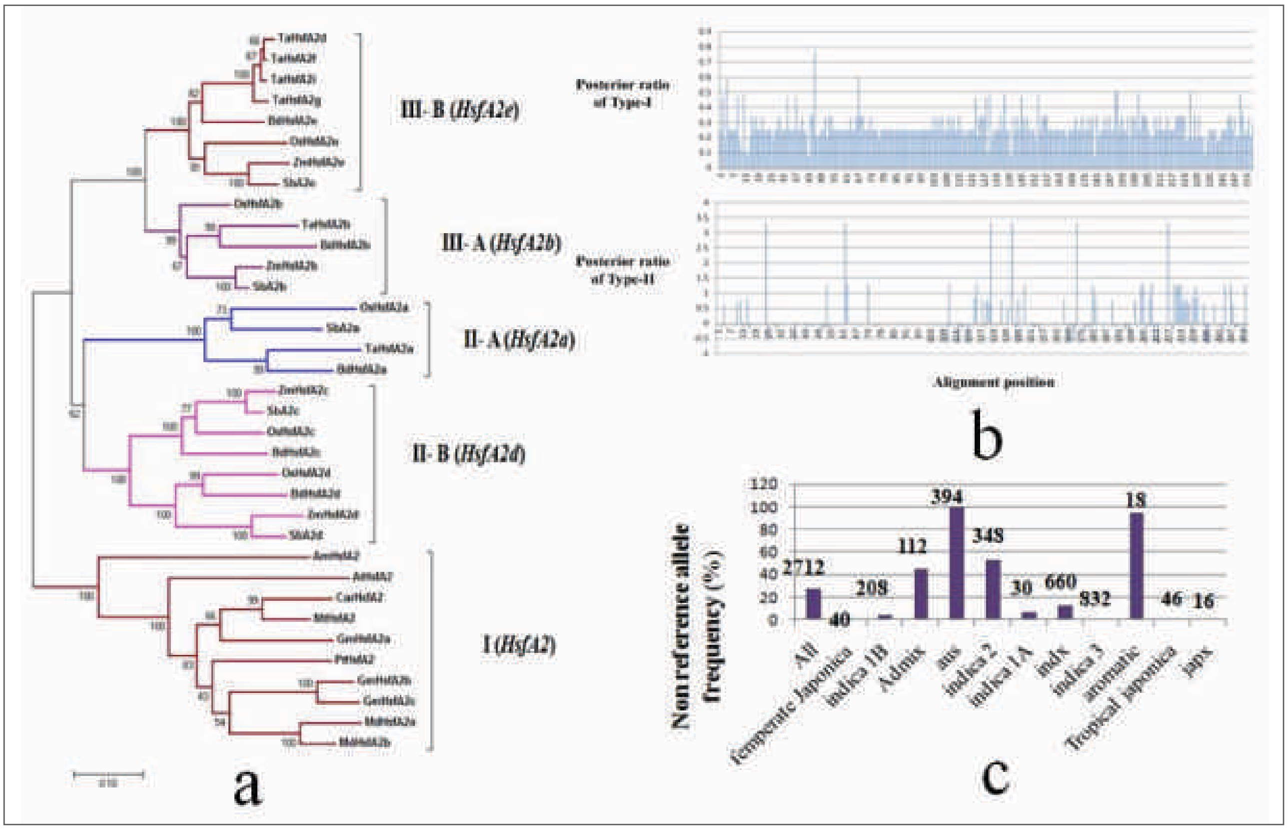


Fig. 1.26 a. Phylogenetic analysis of HsfA2 gene in plants.b. posterior ratio of Type-I and Type II divergence, c. non reference allele frequency of non synonymous substitution in different populations of rice

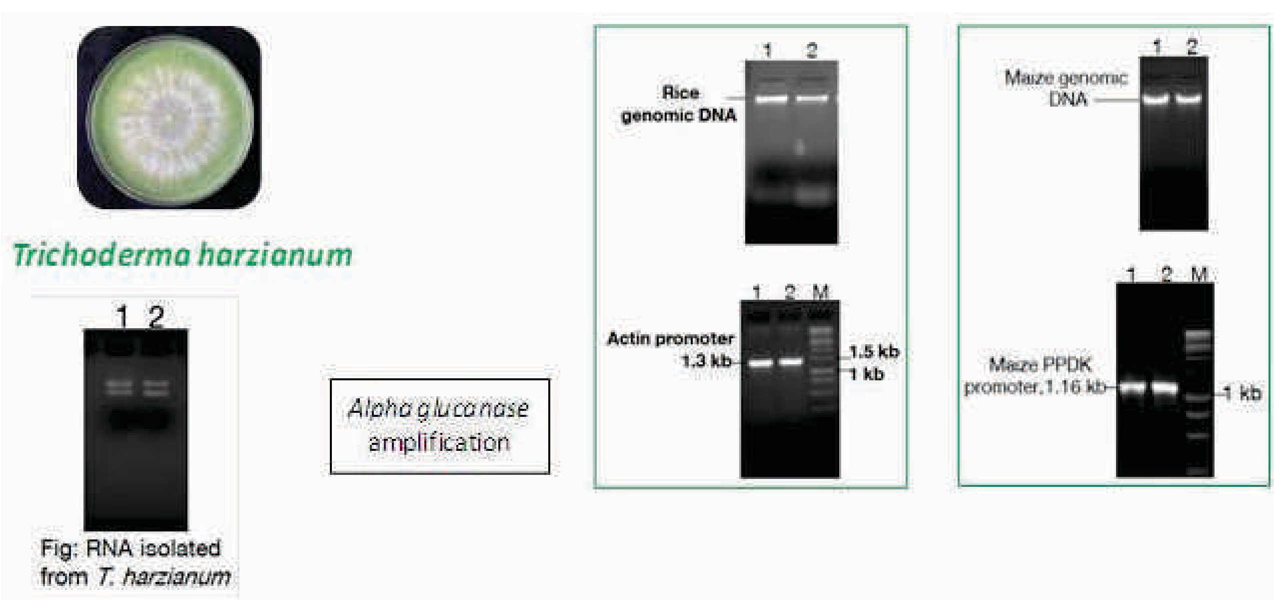


Fig.1.27. Cloning of gene and promoters for developing transgenic rice for sheath blight resistance

Development and use of genomic resources for genetic improvement of rice

Whole genome re-sequencing of elite cultivars and donors

Two elite cultivars Heera, TN1 and two donors PDK Shriram (high grain number) and Salkathi (BPH resistant) were sequenced using NGS technology. Short-reads from the genome of each cultivars were mapped to the 93-11 (*indica*) and Nipponbare (*japonica*) reference genomes. The sequencing depths of the uniquely mapped reads varied from 18.6X (PDK Shriram) to 25.4X (TN1) with an average coverage of 21.15X. More than 99% of the whole genome sequences were covered with either 93-11 or Nipponbare reference genomes. The total number of SNPs and InDels varied from 1,885,399 (TN1) to 2,081,058 (Salkathi) with 93-11 genome. As against the Nipponbare genome, the total number of SNPs and InDels varied from 4,573,981 (PDK Shriram) to 4,957,114 (TN1) (Fig. 1.28). The uneven distribution of SNP and InDel regions were detected throughout the genome in all the cultivars. The unmapped reads were assembled into contigs, re-mapped to *indica* and *japonica* reference genomes and annotated using BLASTn algorithm against plant genome nucleotide database, which facilitated the identification of 400 genes with greater than 90% identity.

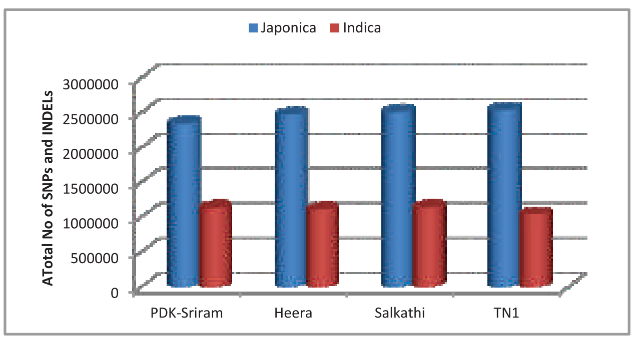


Fig. 1.28. DNA polymorphisms (SNPs and InDels) detected in HYVs and donors with respect to *indica* and *japonica* reference genomes

Identification of QTLs associated with yield and related traits

The RIL mapping population from PDK Shriram/Heera was grown in the field following Alpha Lattice design. Grain number, chaff number, 1000 grain weight and other yield related traits were recorded. The RIL population showed normal distribution for grain number, 1000 grain weight and other yield related traits. The RIL population was genotyped with 50 SSR markers and linkage analysis was done to identify QTLs associated with high grain number.

Development of mapping population for fine mapping of QTLs associated with BPH resistance Salkathi

TN1 and Salkathi were hybridized to develop F_1 seeds, which were grown and selfed F_2 seeds were collected. F_2/F_3 population containing 500 lines will be used to fine map QTLs associated with BPH resistance in Salkathi.

Allele mining of grain shape trait gene (*GS2*) in selected germplasm

Grain size is one of the major components of yield. And yield is a complex trait governed by many QTLs. It is further determined by grain length, width and thickness. The *GS2* gene explained 72% of grain length variation and 36% of grain width variation, therefore 17.8% grain yield per plant increased; the 3825bp gene size encoding growth regulatory factor 4 and transcriptional regulator. Four pair of primers (Fig. 1.29) were designed for whole gene sequencing and validated the in 69 genotypes of diverse grain size.

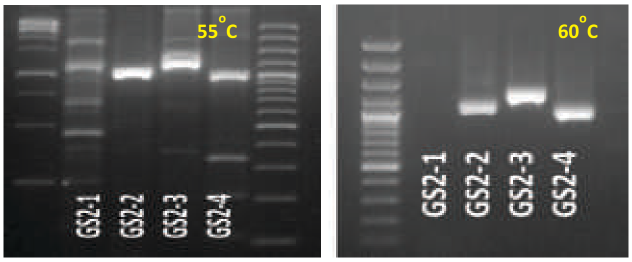


Fig. 1.29. Amplification with gene(GS2) specific markers in selected rice genotypes.

Allele mining of genes related to heat stress tolerance

Two hundred and twenty four genotypes were screened for heat stress tolerance during dry season 2016. In each genotype, around nine panicles were randomly selected, spikelet sterility and number of grains per panicle were counted. The maximum temperature during the anthesis period reached up to 37°C. The analysis showed that spikelet sterility varied from 4.7-90.8% among the genotypes. Additionally, maximum number of varieties showed spikelet sterility around 20-30% (Table 1.25).

Table 1.25. Frequency distribution of genotypes showing spikelet sterility under heat stress conditions

Spikelet sterility (%)	No. of varieties
0-10	12
10.1-20	58
20.1-30	79
30.1-40	43
40.1-50	19
50.1-60	10
60.1-70	0
70.1-80	1
80.1-90	1
90.1-100	1

Allele mining for lodging resistance

Field survey conducted for non-lodged, partially lodged and lodged cultivars at 28 DAF or later led to identification of two resistant (Varshadhan, SR30) and four moderately resistant (N308, Maudamani, Gopinath, N-333-1) genotypes. *Insilco* analysis was carried out for five genomic regions of genes/QTLs (*SCM2, SCM3, LRT5, PRL5, BSUC11*) for lodging resistance. Allele mining was targeted for *SCM3 (OsTB1)* and *SCM2 (APO1)* genes controlling section modulus and primers were designed for *indica* homologues.

Functional validation of candidate genes for abiotic stress tolerance in rice

a) Analysis and expression studies of *OSCA1* gene family associated with drought tolerance

OSCA1 gene is identified as a possible osmosensor in *Arabidopsis* and plays important role in osmotic Ca^{2+} signaling in guard cells and root cells, in water transpiration regulation and in root growth in response to osmotic stress. Therefore, analysis of *OSCA1* homologous genes in rice and expression of different members of the family in response to drought stress is necessary to find the suitable gene for using in future drought tolerant breeding programme. A total of 11 *OSCA* genes were found in rice and their structural details were analyzed.

In silico analysis of 2 Kb upstream region of each gene were analyzed. Number of transmembrane domain in each *OSCA* protein was analyzed using TMHMM Server v. 2.0 and found a range of 6-10 helices per protein. Using psRNATarget, putative miRNAs targeting the *OSCA* genes were identified. It would assist in deciphering the post-transcriptional control of gene regulation during physiological and stress-induced cellular responses. In order to analyze the expression of all 11 *OSCA* genes in rice in response to artificial drought treatment, 21 days old drought susceptible and tolerant rice varieties were treated with 20% PEG-6000 solution. Real time PCR has been performed to quantify the mRNA levels in leaf and roots at different points. Rice tubulin gene was used to normalize all data. Result of expression analysis revealed a complex regulation of *OSCA* gene expression in response to osmotic stress (Fig. 1.30).

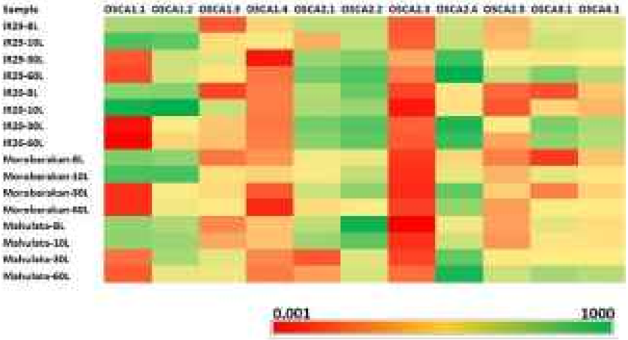


Fig. 1.30. Heat map showing expression of different rice OSCA genes in leaf (BL- Before treatment, 10L, 30L & 60L- 10 min, 30 min and 60 min post treatment)

b) Identification and analysis of candidate gene based SSR (cgSSR) markers from disease responsive genes

A total of 296 different rice disease responsive genes were selected on the basis of literature survey. Sequence for each gene was downloaded from database and mined for SSR. A total of 177 genes were found to contain SSR. Among the 177 genes, primer for 35 genes were designed and synthesized. Tri-nucleotide motif was found to be predominant followed by di- and tetra-nucleotide. Most of the motif was found in the intron region followed by CDS, 5'UTR and 3'UTR. Genotyping of 25 different rice genotypes (tolerant/susceptible for different diseases) were done using the novel disease responsive cgSSR.

Development of resilient rice varieties for rainfed direct seeded upland ecosystem

Hybridization, generation and evaluation of breeding lines

During *kharif,* 2016 about 818 advance breeding lines from 77 crosses in F_5 to F_7 generations were evaluated under rainfed direct seeded conditions. Among these lines days to 50% flowering ranged from 59 to 82 days, plant height ranged from 50.8 to 176.5 cm and grain yield 5 to 240 g/plot (0.8 m^2). Based on duration, plant type, grain type and grain yield, 229 progenies were selected for further evaluation and all the selected lines were either long slender or long bold grain type. Eighty nine lines of F_6 generation derived from six crosses were grown both under dry direct seeding (DSR) and transplanted (TP) conditions. The best entry CRR 789-24 yielded 5250 and 7000 kg ha^{-1}, followed by CRR 789-34 yielded 4875 and 6450 kg ha^{-1}, under DSR and transplanted conditions, respectively (Table 1.26).

Table 1.26. Performance of promising breeding lines under DSR and transplanting (TP) during *kharif*, 2016

Entry	Days to 50% flw.		Plant height (cm)		Grain yield (kg ha^{-1})	
	DSR	TP	DSR	TP	DSR	TP
CRR 789-24	80	90	112.4	122.4	5250	7000
CRR 789-33	80	92	98.0	99.6	4875	6450
CRR 789-25	82	91	114.4	122.8	4750	6350
CRR 789-26	81	92	109.4	126.0	4500	6250
CRR 789-19	81	90	118.6	122.4	4825	5750
CRR 663-500-2-B-1	75	80	108.0	149.8	4550	5250
CRR 663-500-3-B-2	59	68	116.6	127.2	4000	4500
CRR 663-500-7-B-4	63	75	117.0	144.4	4375	4750
CRR 792-7-B-1	75	83	133.2	138.2	3750	4250
CRR 792-22-B-5	84	93	140.0	147.8	3500	4800
CRR 793-1-B-1	55	62	90.0	94.4	3950	5000
CRR 793-26-B-12	73	82	123.4	126.0	3600	4850
CRR 793-28-B-14	75	85	82.8	99.6	3250	4750
CRR 173-1-B-1	75	84	108.6	126.4	4250	4650
CRR 173-5-B-3	73	85	99.6	104.2	3500	4925
CRR 791-4-B-4	75	82	109.6	116.6	4125	4550
CRR 791-5-B-5	76	85	111.8	131.0	3825	4375
CRR 791-26-B-13	78	85	112.8	136.2	3975	4350
Sahbhagidhan (Check)	*85*	*92*	*88.7*	*105.5*	*3550*	*4850*

Entries promoted and new nominations in AICRIP trials

CRR 363-36 (IET 19251): Derived from the cross Gaurav/ Kalinga III, is one of the extra early cultures developed at CRURRS, Hazaribag, maturity duration 80-85 days, strongly aromatic with extra long slender grains. This elite line was tested in AICRIP trial during 2005 under direct seeded very early trial. During the year 2016 it has been released as Gangavati Emergency (Fig. 1.31) for the irrigated ecology of zone 3 in Karnataka for summer season.

Fig.1.31. Field photograph, grain and milled rice of CRR363-36 (Gangavati Emergency)

CRR 484-2-1-1-1-1(IET 24334): It was derived from the cross- RR165-1160/ Krishna bhog; days to 50% flowering 93 days with short bold grains. It ranked 5th in AVT2-IME trial with a yield advantage of 14%, 7% and 8% over national, zonal and local checks, respectively. State-wise its performance was consistently superior in Chhattisgarh for all three years, hence, this entry was found promising for irrigated mid-early situations in the state of Chhattisgarh. Considering yield advantage over best check, three entries *viz.,* IET 26337 (CRR747-12-3-B), IET 26347 (CRR 753-5-1) and CRR708-1-B-2-B-B-1 were promoted to AVT1-E-DS.

Nine new entries developed at the station were nominated for initial varietal testing under AICRIP trials during *kharif,* 2017.

Identification of novel sources of resistance to drought and associated biotic stresses and improve popular varieties for major abiotic (drought) and biotic (blast) stresses through introgression of known QTLs/genes through MAB/MAS

Evaluation of Anjali drought NILs *(qDTY12.1)* under rainfed condition

Ten introgression lines for grain yield under stress QTLs q*DTY12*.1along with recurrent parent Anjali were evaluated under rainfed direct seeded condition during *kharif,* 2016 . Four NILs significantly out-yielded Anjali by 32.8 to 54.7% (Table 1.27). The best NIL gave a yield of 1941 kg ha^{-1}. These NILs with stress QTLs q*DTY12*.1 had also lower canopy temperature than the recurrent parent Anjali.

Evaluation of Vandana NILs with drought QTL and blast R gene *(qDTY12.1+Pi2)*

Introgression of q*DTY12.1* from Way Rarem into Vandana earlier led to marked improvement in its yield performance under reproductive stage drought. To improve it further for leaf blast tolerance broad-spectrum resistance gene *Pi2* was introgressed using MAB. Ten NILs (*DTY12.1+Pi2*) along with parent Vandana were evaluated under rainfed direct seeded conditions during *kharif* 2016. Under the moderate grain filling stage drought stress, six NILs gave significantly higher yield than recurrent parent, Vandana by 30.4 to 47.9%. One NIL, CRR747-3-7-B gave highest yield of 1957 kg ha^{-1}. The introgression lines are of the same flowering duration and plant height as that of recurrent parent.

Evaluation of BPT 5204 blast NILs (*Pi 9* and *Pi b*) for agronomic performance

Twenty two BPT 5204-NILs (*Pi9/Pib*) along with parent were evaluated for grain yield and other traits done under irrigated transplanted conditions during *kharif,* 2016. For grain yield, 12 NILs significantly out-yielded the recurrent parent BPT 5204 with yield advantage of 46.7 to 89.6 per cent. The highest grain yield was recorded in CRR741-22-2-71 (6017 kg ha^{-1}) followed by CRR741-22-2-93 (5975 kg ha^{-1}). Screening of the NILs in the uniform blast nursery showed that carrying *Pi9* were, however, highly resistant and had no disease in the field plots. Promising lines were identified for further testing.

AICRIP trials conducted

- **AVT-1E-DS:** Eleven (11) entries including checks were evaluated in randomized block design under rainfed upland direct seeded condition. The highest grain yield was obtained from the entry RCPR-16 (4591 kg ha^{-1}) followed by CR3951-3-2-2-1-1 (3858 kg ha^{-1}) and CRR616-B-66-2-1 (3736 kg ha^{-1}) as compared to the best check Sahbhagidhan (3724 kg ha^{-1}).
- **IVT-E-DS**: Forty two (42) entries including checks

Table 1.27. Performance of Anjali NILs *(qDTY12.1)* lines under rainfed during *kharif* 2016

Entries	Days to flw.	Plant ht. (cm)	Grain yield (kg ha^{-1})	Harvest index	NDVI	Canopy temperature	% improve RP
ANIL 1/39	59	89.6	1912	0.29	0.43	28.8	52.3
ANIL 2/63	66	98.6	1225	0.19	0.47	29.4	-2.3
ANIL 3/225	65	96.2	1725	0.24	0.49	29.8	37.5
ANIL 4/256	63	91.3	1588	0.14	0.41	29.7	26.6
ANIL 5/325	63	99.5	1696	0.24	0.49	29.2	35.2
ANIL 6/337	68	89.1	863	0.12	0.60	30.1	-31.2
ANIL 7/342	66	97.5	1667	0.24	0.46	29.5	32.8
ANIL 8/359	66	92.7	1202	0.17	0.53	30.5	-4.2
ANIL 9/365	65	84.1	1314	0.18	0.46	29.8	4.7
ANIL 10/460	66	82.3	1941	0.23	0.49	29.9	54.7
Anjali	64	93.4	1255	0.18	0.45	30.0	
LSD 5%	1.7	10.8	285	0.04	0.12	1.0	
CV (%)	1.5	6.9	11.2	11.0	14.2	2.0	

were evaluated in IVT-E-DS under rainfed direct seeded condition. The top yielding entries in this trial are ORJ 1327 (3807 kg ha^{-1}), CRR 693-28-B (3693 kg ha^{-1}) which out yielded check, Sahbhagidhan (3466 kg ha^{-1}).

- **AVT-2-E-TP:** Altogether, 13 entries including four checks (Gontra Bidhan 3 (NC), Narendra 97 (ZC), US 314(HC) and Anjali (LC) were evaluated under transplanting during *kharif,* 2016. Only two hybrid entries, HRI-184 (7500 kg ha^{-1}) and SVZ-1109_hyb (7219 kg ha^{-1}) were better than best check Gontra Bidhan 3 (7088 kg ha^{-1}).

- **AVT-1-E-TP:** Altogether, 10 entries including four checks (Gontra Bidhan 3 (NC), Narendra 97 (ZC), US 314 (HC) and Anjali (LC) were evaluated in RBD with three replications under transplanting condition during *kharif,* 2016. In this trial also hybrids were found as top yielders. SL-8 (7050 kg ha^{-1}) was the best entry followed by NK-17508_Hyb (6525 kg ha^{-1}) and Siri-2266_Hyb (6375 kg ha^{-1}), as compared to best check Gontra Bidhan 3 (5888 kg ha^{-1}).

- **IVT-E-TP:** In this trial 61 entries along with three checks (Gontra Bidhan 3 (NC), Narendra 97 (ZC), US 314(HC) and Anjali (LC) were evaluated in RBD in two replications under transplanting condition during *kharif,* 2016. No entry was found superior than national check Gontra Bidhan (7088 kg ha^{-1}).

- **AVT-2-IME:** Eight entries with three checks *viz.,* IR64 (NC), Lalat (ZC), US 312 (HC) and Abhishek (LC) were evaluated under transplanting during *kharif* 2016. The hybrid KPH 473 (8288 kg ha^{-1}) was the top yielder but at par with best hybrid check US312 (8138 kg ha^{-1}).

- **AVT2 NIL-DRT:** Five NILs with DTY QTLs in the background of Swarna *sub1* (3) and Samba Mahsuri *sub1* (2) along with recurrent parents, donors and sensitive checks were evaluated both under stress and control conditions during *kharif* season. As there was continuous rain during the crop growth period, stress trial experienced only mild stress during grain filling stage (20% yield reduction). IET 25673 (4409 kg ha^{-1}) was the best NIL followed by IET 25667 (4221 kg ha^{-1}) under stress trial. Best NIL, IET 25673 gave 7 and 42 % more yield over RP under stress and control, respectively.

Development of rice genotypes for rainfed flood-prone lowlands

Development of mapping population for cold tolerance

Mapping population (Geetanjali/Sahbhagidhan) developed for seedling stage cold tolerance is in F_6 generation. About two hundred lines were carried out through SSD method.

Maintenance and collection of rice germplasm

A total of 779 accessions of rice germplasm were maintained during *kharif* 2016. Observations on days to 50% flowering, plant height and grain yield were recorded. Four aromatic rice accessions, *viz*., Pilpiliajoha, Kola joha and Kunkunijoha from Udalguri district and 'Bhog' from Dhubri district of Assam were collected. One *ahu* rice accession known as 'Puthiya' was collected from Dhubri district.

Generation advancement of segregating materials

Pedigree nursery of 124 F_6 progenies of four crosses was raised during *sali* season for development of rainfed lowland (semi-glutinous and soft) rice and F_7 seeds were bulked for further selection and evaluation. BC_1F_5 of 31 crosses were raised for improvement of rainfed shallow lowland rice and plants were bulked to BC_1F_6. For development of *boro* rice, 59 single plant progenies selected from 28 crosses were grown in F_7 nursery during *rabi* 2015-16 and F_8 seeds were bulked for further evaluation and selection. For the development of pre-flood *ahu* rice, F_6 nursery of five crosses were raised during *ahu/kharif* 2016 and F_7 seeds were bulked for selection in the next generation.

Maintenance of elite breeding material

During *sali/kharif* 2016, 27 nos. of elite breeding lines for rainfed shallow lowlands were maintained, whereas during *boro* 2015-16, 4 nos. of elite breeding lines were maintained.

Performance of CR Dhan 909 in the Farmers' Field

CR Dhan 909 developed from the cross between Pankaj and Padumoni is a promising variety under aromatic short grain category developed at RRLRRS, NRRI, Gerua (Assam). The variety was tested for the 2nd year in Darrang district of Assam during *sali/kharif* 2016. The location was village-2 No. Mazgaon. Aromatic rice variety 'Ketekijoha' was used as the local check. CR Dhan 909 yielded 6.08 t ha^{-1} as against 3.20 t ha^{-1} of the local check.

Evaluation of breeding materials in National (AICRIP) Trials

During *kharif* 2016, a total of 165 entries were evaluated in different trials *viz.,* AVT1-RSL (11), AVT1-SDW (12), IVT-SDW (16), IV-DW (7), AVT1-IME (34), IVT-L (64) and AVT2-NIL-*sub* (21).

Breeder seed production

During *kharif*, 2016 a total of 57 quintals of breeder seed of three varieties *viz.,* Chandrama, Naveen and Swarna-*sub1* were produced against the indent of 47 quintals (Table 1.28).

Table 1.28. Breeder seed production at RRLRRS, Gerua during 2016

Sl. No.	Variety Name	Indent (qtls)				Actual Seed Production (qtls)				Reasons for shortfall, if any
		DAC	State	Any other	Total	DAC	State	Any other	Total	
1	Chandrama (IET 9354, 10419)	20.0	---	---	20.0	25.0	---	---	25.0	---
2	Naveen (IET 14461)	25.0	---	---	25.0	30.0	---	---	30.0	---
3	Swarna-*sub1*	---	---	2.0	2.0	---	---	2.0	2.0	---
	Grand Total	**45.0**	---	**2.0**	**47.0**	**55.0**	---	**2.0**	**57.0**	---

PROGRAMME : 2

Enhancing Productivity, Sustainability and Resilience of Rice Based Production System

Effective and eco-friendly utilization of resources like soil, water, nutrient and labour and managing the abiotic and biotic stresses are the key to sustainability, productivity and profitability of rice production systems. This programme was aimed to develop, validate and disseminate environmental friendly technologies to enhance productivity, profitability and sustainability of rice based systems and to provide food, nutritional and livelihood security to farming community and related stakeholders.

Enhancing nutrient use efficiency and productivity in rice based system

Soil organic carbon sequestration in lowland rice soil under long term fertilizer experiment (LTFE)

Agricultural soil is a potential sink for atmospheric carbon. The soil organic carbon sequestration is affected by cropping system and adopted management practices. A long-term experiment to study the combined effect of inorganic fertilizers and organic manure in lowland rice (*Oryza sativa* L.) was begun in 1969 at CRRI, Cuttack. After the 41st harvest, soil samples were collected from six treatments [control, nitrogen (N), nitrogen-phosphorus-potassium (NPK), farm yard manure (FYM), N+FYM and NPK+FYM], at four soil depths (0–15, 15–30, 30–45 and 45–60 cm), to assess the changes in soil organic carbon (SOC) content and carbon (C) sequestration resulting from long-term chemical fertilizer and manure addition. The result from this study revealed that the SOC concentration and stocks have increased significantly with the input of chemical fertilizer and manure as compared to control in the long term intensively cultivated rice. As compared to the initial value (13.7 Mg ha^{-1}), the SOC stock at 0-15 cm depth increased under control and all other fertilized treatments during 41 year period (Fig. 2.1). In the soil profile, distribution of SOC concentration and stocks mainly occurred in the upper 15 cm of the soil depth, whereas at greater depths these differences were less evident. The rate of increase in SOC stock due to fertilizer application alone varied between 57 and 89 kg ha^{-1} yr^{-1}, while for FYM addition the rate of increase was 61 to 138 kg ha^{-1} yr^{-1}, highest being in NPK+FYM. The increase in C stock may be attributed to the C input added through the incorporation of only roots and stubble under the control treatment which may be sufficient to maintain or even enhance the C stock in rice soil. The variation among the treatments in sequestering different amounts of C was mainly due to the differential inputs of C from left over root and stubble biomass and the addition of manure. In conclusion, it can be inferred that the C input only from left over rice roots and stubble is sufficient to complement the C loss through organic matter decomposition in lowland rice and C sequestration can further be enhanced with the addition of chemical fertilizers and manure particularly in sub-humid tropics.

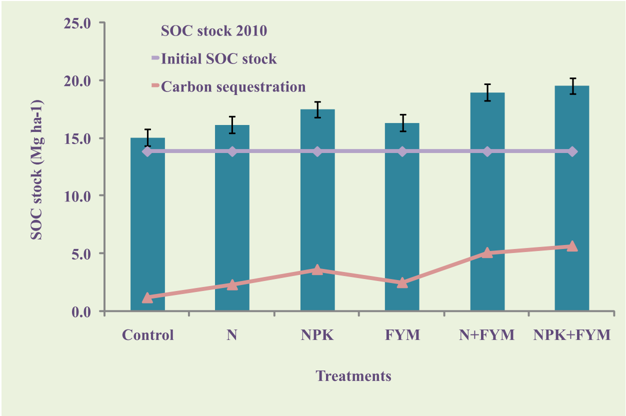


Fig. 2.1. Soil organic carbon (SOC) stocks and carbon sequestration (0–15 cm soil depth) after 41 years of inorganic and manure fertilization in a sub-humid tropical rice-rice system.

Potassium supplying capacity of soil under LTFE

Long-term effect of fertilization and manuring on soil-K fertility status was assessed in terms of K fractions, K-thresholds, quantity-intensity relations, release kinetics and K-fixation capacity after 45 years of rice-rice cropping in the surface soil (0–15 cm) of an Aeric Endoaquept. Fertilizer treatments involved: control (unfertilized), N (nitrogen fertilizer), NP (N+ phosphorus fertilizer), NK (N+ potassium fertilizer), NPK (N+P+K fertilizer), FYM (farmyard manure), N+FYM, NP+FYM, NK+FYM and NPK+FYM. Forty five years of rice-rice cropping with or without K application significantly altered the water soluble, exchangeable (K_{ex}) and non-exchangeable K (K_{nx}) fractions except the total K content, with lowest values being observed under NP treatment (Table 2.1). Lower cumulative K release, equilibrium activity ratio, and labile K content and higher K-fixation capacity were observed in the K-skipped treatments (i.e. control, N and NP) than the K-fertilized ones. Lowest values of release (1.25 mg L^{-1}) and fixation threshold concentration (11.79 mg L^{-1}) were observed in NP, which was unbalanced treatment in respect of K supply. Relative abundance of clay minerals did not show significant relation with K-thresholds, while K_{ex} and K_{nx} did. This fact implies that in soils of a particular taxon (here Aeric Endoaquept) with same origin and basic mineralogy, K-threshold values are decided not by distribution of clay minerals, but by the amount of K_{ex} and K_{nx} present in the soil. Omission of K in fertilization schedule caused considerable decline in K-fertility status or supplying capacity of the surface soils after 45 years of rice-rice system.

Effect of seedling age and nitrogen application on submergence tolerance of rice

Flooding is an environmental stress that can affect crop at any stage. It seriously affects crop establishment leading to severe yield loss. The study was undertaken to understand the response of age of seedlings and nitrogen application on submergence tolerance of rice with *sub1* and non-*sub1* cultivars. Seedlings of various ages, *viz.*, 15, 20, 25, 30, 35 and 40 days old, of IR64 *sub1* and Swarna *sub1* and their recurrent parents were grown in pots for the study.

The fertilization treatments were comprised of no-N application (No-N), application of basal N (NB), post-flood N application (PF-N) and application of both basal and post-flood-N (NB+PF-N). 80 mg Urea, SSP 114 mg and MOP 30 mg were applied to each pot as per the treatments as N, P and K source, respectively. Nitrogen was applied in 3 equal splits, basal, post-

Table 2.1. Effect of different fertilization treatments on the distribution of soil K fractions after 45 years of rice-rice cropping

Treatment	Soil K fractions (mg kg^{-1})			
	K_{ws}#	K_{ex}	K_{nx}	K_T
Control	20.3^{BC*}	68.6^{DEF}	649^{ABC}	20581
N	19.6^{BC}	69.2^{CDEF}	641^{ABC}	20301
NP	14.9^{D}	62.3^{F}	577^{D}	20153
NK	21.6^{BC}	76.4^{BC}	657^{AB}	20869
NPK	20.9^{BC}	73.7^{BCD}	643^{ABC}	20722
FYM	22.6^{B}	72.9^{BCDE}	626^{BC}	20490
N+FYM	19.3^{BC}	68.7^{DEF}	616^{C}	20509
NP+FYM	18.3^{CD}	66.4^{EF}	628^{BC}	20751
NK+FYM	28.2^{A}	87.2^{A}	656^{AB}	21064
NPK+FYM	22.9^{B}	79.2^{B}	661^{A}	20913

K_{ws} – water soluble K; K_{ex} – exchangeable K; K_{nx} – non-exchangeable K; K_T – total K

* Values in each column with no common letters among them are significantly different from each other (P<0.05)

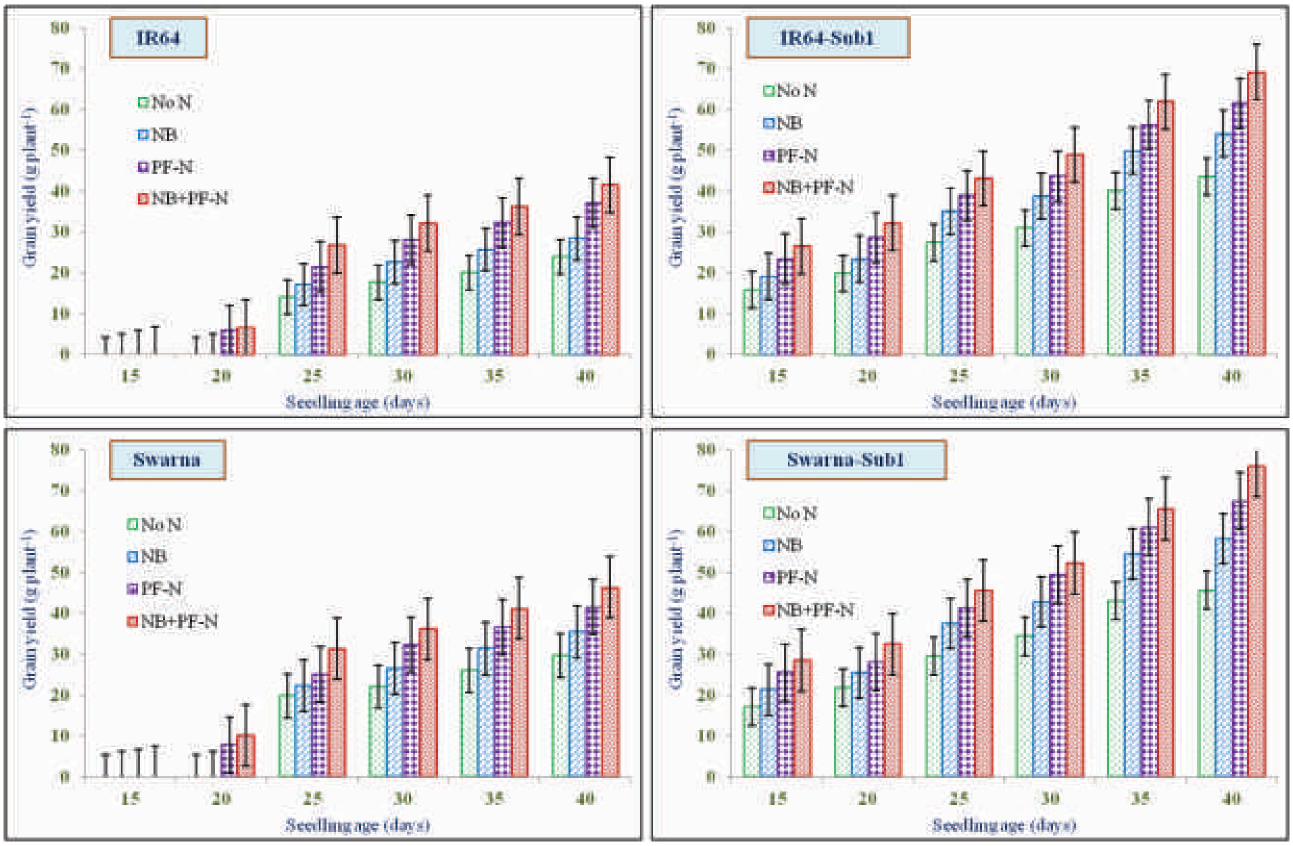


Fig. 2.2. Grain yield of IR-20, IR-64 sub1 and Swarna sub1 at harvest under clear and turbid water submergence (vertical bars in each column and line represents standard error). P-phosphorus, N-nitrogen, B- broadcasting, S-spray.

flood (after de-submergence) and panicle emergence. Basal dose was applied 5 days after seeding and second split which was needed to be applied at maximum tillering was applied after 48hrs of desubmergence. Post-submergence N was applied as 2% urea spray and rest of N was broadcasted. In susceptible cultivars, seedlings of 15 and 20 days old could not survive and survival was also lower among 25 and 30 days old seedlings. Across the cultivars, plant survival of 40 days old seedlings was 50-fold higher over 15 days old seedlings. Post-flood N application contributed positively towards higher survival; basal N along with post-flood N showed a positive response on older seedlings but response was quite negative on younger age seedlings. Plant survival was 58.1 and 53.8% higher with the application of post-flood N with basal N and without basal N, respectively, over no N application, irrespective of the cultivar and age of seedlings. In the susceptible cultivars, 15 and 20 days old seedlings could not contribute to yield and the yield of older seedlings was also reduced due to submergence. Older seedlings (40 days old) of tolerant cultivars produced the higher yield which was around 169 and 119% higher in IR64-*sub1*, 167 and 129% higher in Swarna-*sub1* over 15 and 20 days old seedlings. Nitrogen as a primary nutrient significantly contributed to the higher grain yield; especially when applied as post-flood. As an interaction effect, it can be said that 40 days of old seedlings of Swarna-*sub1* resulted in highest grain yield with the application of post-flood and basal N (Fig. 2.2).

Nutrient management to cope up with multiple abiotic stresses

The experiment was carried out under natural conditions during 2016-17 with seven rice cultivars, *viz.*, IR 42, IR 64, IR 64 *sub1*, IR 64 *drt*, IR 64 *sub1* + *drt*, Swarna *sub1*, Swarna *sub1* + *drt*. Submergence and drought stresses were imposed simultaneously in two sets, in first set (S_1) plants were subjected to drought at active tillering (AT) and submergence at panicle initiation (PI) stage; in second set (S_2) plants were subjected to drought at PI and submergence at AT stage.

Table 2.2 Grain yield (gm plant^{-1}) of different rice varieties as influenced by nutrient application under multiple stress condition

	S_1				S_2			
	F_1	F_2	F_3	F_4	F_1	F_2	F_3	F_4
IR 42	5.7	7.1	8.6	9.6	12.6	15.2	17.8	20.7
IR 64	6.6	8.6	10.1	11.6	14.3	16.6	19.7	22.8
IR 64 *sub1*	52.7	54.9	58.4	63.1	70.7	72.8	77.9	81.1
IR 64 *drt*	49.5	51.7	55.7	58.1	68.6	70.8	76.5	77.0
IR 64 *sub1 + drt*	62.0	63.2	68.3	71.3	80.6	81.7	86.6	89.0
Swarna *sub1*	58.9	60.4	65.9	67.5	77.2	81.0	83.1	85.2
Swarna *sub1 + drt*	70.5	71.3	76.8	78.3	90.6	92.7	96.8	99.4
LSD $_{P=0.05}$	13.25							

Plants were submerged for 12 days, and subjected to drought for 10 days. Drought stress was maintained at -60KPa. The fertilization treatments were comprised of recommended NPK (RDF), RDF+20% additional P (RDF+$P_{120\%}$), RDF+ post-flood N application (RDF+PF-N) and RDF+20% additional P+PF-N (RDF+$P_{120\%}$+PF-N). Submergence tolerance on survival, allometry, growth, metabolic changes, photosynthetic rate (Pn) and grain yield was evaluated. Stress conditions reduced plant survival of all the cultivars with significantly greater effects on susceptible cultivars. After stress, survival followed the trend as IR-64 *sub1*>IR-64 *sub1 + drt*>Swarna *sub1*>Swarna *sub1+drt*>IR-64>IR-64 *drt*>IR 42 (Table 2.2). Highest plant survival was recorded when plant was submerged at active tillering stage and faced drought at PI stage, irrespective of the cultivars. Application of post-flood N and 20% additional P contributed positively to plant survival of all the cultivars. On an average, post-flood N and 20% additional P resulted in 27.4 and 32.3% higher plant survival over RDF under S_1 and S_2, respectively. Stress conditions reduced the grain yield as of plant survival of all the cultivars with significantly greater effects on susceptible cultivars. Grain yield followed the trend as Swarna *sub1+drt*>IR 64 *sub1 + drt*>Swarna *sub1*> IR 64 *sub1*> IR 64 *drt*> IR 64> IR 42. Highest grain yield was recorded when plant submerged at active tillering stage and drought at PI stage, irrespective of the cultivar. Application of post-flood N and 20% additional P contributed positively to yield of all the cultivars. On an average, post-flood N and 20% additional P resulted in 14.7 and 17.6 % higher grain yield over RDF under S_1 and S_2, respectively.

Role of VAM and Phosphorus (P) application on drought tolerance

Drought can occur at any stage of crop growth and periodically in all rainfed rice production areas. It hampers proper nutrient management for rainfed lowland rice, however the recently released drought-tolerant varieties are expected to respond to nutrient input to increase yield even under moisture stress. Variation in intensity and severity of drought from season to season and place to place requires the use of different rice varieties and different nutrient management strategies. This study evaluated physiological response of contrasting rice cultivars (Sahbhagidhan, IR 64 and IR 64 *drt*) to the VAM and P application under well watered and drought stress conditions at vegetative and reproductive stage.

Table 2.3. Yield (t ha^{-1}) of rice varieties as influenced by VAM and P application under different moisture stress condition

		No VAM		VAM	
		P_0	P_{40}	P_0	P_{40}
Sahbhagidhan	well watered	4.85	5.29	5.09	5.64
	Veg. stage	3.79	4.24	4.48	4.91
	Rep. stage	2.59	3.01	3.35	3.76
IR 64	well watered	4.71	5.15	4.96	5.51
	Veg. stage	1.58	2.01	2.20	2.66
	Rep. stage	1.03	1.46	1.60	2.02
IR 64 *drt*	well watered	4.90	5.33	5.14	5.65
	Veg. stage	3.83	4.26	4.63	5.06
	Rep. stage	2.71	3.12	3.45	3.88
$LSD_{P=0.05}$		0.414			

Dry matter accumulation and remobilization, drought tolerance indices, wax and proline accumulation, antioxidant enzyme activity and photosynthesis were assessed. Control plots were kept continuously flooded with 2-3 cm water throughout the growth period, while plots subjected to drought were given irrigation upto 21 d after sowing, then irrigation was withdrawn for one month or more based on treatment and plants were irrigated only when soil water potential reached -60 KPa; monitored using tensiometers placed at soil depths of 20 cm. Under well-watered conditions, the grain yield was at par, but under drought conditions yield was significantly reduced with prominent effects under drought at reproductive stage. Results of the study revealed that with imposition of drought stress, maximum decrease (213.9%) in grain yield was observed in IR64 as compared to IR 64 *drt* (36.6%) and Sahbhagidhan (42.2%) over well-watered conditions. Application of VAM and P contributed positively to grain yield under both the conditions but effect was more significant under drought conditions. On an average, VAM and P application resulted in 5.9 and 25.1%; 9.9 and 14.7% higher yield under normal and stress conditions, respectively (Table 2.3).

Effect of urea briquette applicators on nitrogen volatilization and leaching

Seven different treatments *viz.,* control (no nitrogen), prilled urea broad casting (PUB), prilled urea manual placement (PUMP), urea briquette manual placement (UBMP), urea briquette application by three row briquette applicator (TRBA) (basal)+ urea briquette manual placement (1st split) + urea briquette manual placement (TRBA+UBMP) (2nd split), urea briquette manual placement (basal) + top dressing applicator (1st split)+ urea briquette manual placement (UBMP+TDA) (2nd split), three row briquette applicator (basal) + top dressing applicator (TDA) (1st split) + urea briquette manual placement (TRBA+TDA) (2nd split) were tested in field. It was observed that the treatment TRBA+TDA had the highest yield @ 6.71 t ha^{-1} and 5.47 t ha^{-1} in the wet and dry seasons, respectively, (Fig. 2.3) with the highest agronomic N use efficiency (36.3 kg kg^{-1}). Average methane emission was higher (19.2-27.1%) in wet season than the dry season and the trend is just opposite in case of nitrous oxide (3.6-11.8%). The treatment TRBA+TDA recorded the lowest emission of nitrous oxide among the treated plots.

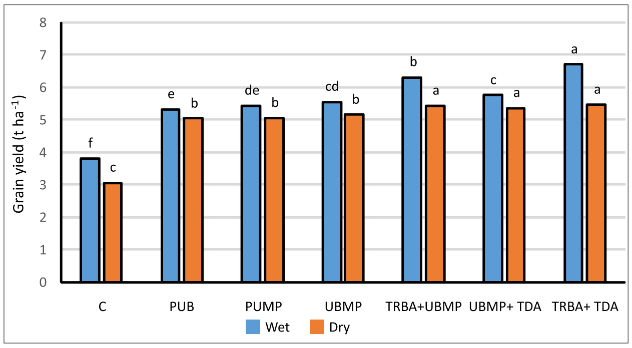


Fig. 2.3. Yield during wet and dry seasons under seven N management treatments (Means followed by the same letter in each bar are not significantly different at 0.05 level of probability by Duncan's Multiple Range Test (DMRT)

The largest amount of ammonia was lost through volatilization after basal application of urea, followed by top dressing at the end of maximum tillering stage and panicle initiation stage. The population of nitrite oxidizers and heterotrophs were highest in PUB. Soil dehydrogenase activity was highest (148.0 -160.0 µg TPF g^{-1} soil d^{-1}) in UBMP+TDA treatment, while the urease activities were less in urea briquette applicator treated plots. The larger size of urea briquette and applicator based placement reduced the lossess of N through ammonia volatilization and nitrous oxide emission, thus enhancing nitrogen use efficiency. Moreover, the mechanical placement of briquette in tropical flooded rice is more precise and less labour intensive, hence, this is an efficient environment friendly approach of N management.

Transformation of aluminosilicates in long-term puddled rice soils

The effect of long-term fertilizer treatment on transformation of aluminosilicates in puddle rice-rice cropping system was studied. The treatments were *viz.*, unfertilized control (CTRL), farmyard manure (FYM), N, NP, NK, NPK, N + FYM, NP + FYM, NK + FYM and NPK + FYM. The application of inorganic fertilizer was done @ 60-40-40 and 80-40-40, N-P_2O_5-K_2O kg ha^{-1} for wet and dry seasons, respectively as per the requirement of the respective treatments. The FYM was applied @ 5 t ha^{-1} in wet season only. Clay, clay-humus complex and silt were separated by the standard procedure. It was observed that the total oxalate extractable oxides (TOEO) were highest in both clay and silt in NP+FYM treated plots. The content of TOEO was 1.5-2 times higher in clay than that of silt. Application of FYM increased the production of ferrihydrite. The soils of NRRI long-term fertility experiment were composed of three major minerals, *viz.*, kaolinite (45.1-54.4%), mica (32.7-43.1%) and smectite (10.6-17.0%). Potassium fixation capacity was more in K skipped and NP applied plots (Fig 2.4). Clay-humus complex showed less K fixation than that of clay at the same treatment. Application of FYM reduced fixation capacity of potassium.

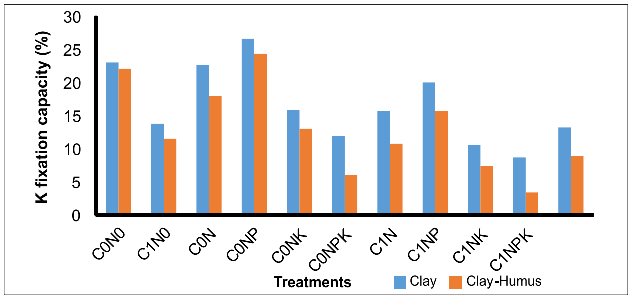


Fig. 2.4. Potassium fixation capacity of clay and clay humus complex in rice-paddy soil under LTFE

Impact of long term organic nutrient management on soil phosphorus dynamics in tropical flooded rice soil

A field experiment comprising of organic amendments *viz.*, control (without any organic manure or inorganic fertilizer), farmyard manure (FYM), green manure (GM), FYM + GM (1:1 on N basis), FYM + azolla (1:1 on N basis), rice straw (RS @ 5 t ha^{-1}) + GM, azolla + GM (1:1 on N basis) and rice straw (RS @ 2.5 t ha^{-1}) + GM was conducted in experimental farm of NRRI.

Study revealed that under the treatment FYM microbial biomass carbon and phosphorus were highest, RS 2.5 t ha^{-1} + GM showed highest microbial biomass nitrogen. The dominant fraction of inorganic P was non-occluded Al and Fe-P followed by Ca-P and occluded P.

Carbon mineralization in soil as influenced by application of rice husk biochar

Field experiments were conducted at the institute, to study C mineralization pattern as affected by sequential application of rice husk-biochar (RHB) in soil. The treatments were recommended dose of fertilizers RFD (T_1), RFD+ 0.5 t ha^{-1} RHB (T_2), RFD+1 t ha^{-1} RHB (T_3), RFD+2 t ha^{-1} RHB (T_4), RFD+4 t ha^{-1} RHB (T_5), RFD+8 t ha^{-1} RHB (T_6), and RFD+10 t ha^{-1} RHB (T_7). After three years of experimentation, an incubation study suggested an increase in cumulative

CO_2-C emission with increasing RHB rates. However, the mineralization rates (dC/dt) with RHB application were similar to that of no RHB application at the end of incubation period (90 days). In addition, microbial quotient and % RHB-C utilization showed a decreasing trend with increasing rates of RHB application indicating higher carbon sequestration potential (Fig 2.5). Although it was hard to determine a positive or negative priming effect on C mineralization, a declining trend in lability index with RHB application implied a definite role of RHB towards shift of soil C from labile to non-labile pool in the long run (Table 2.4). An increase in rice grain yield was also recorded with increasing rates of RHB. Results indicated that RHB application not only enhanced C sequestration, stabilized the SOC, it also restored the primary productivity in rice soil.

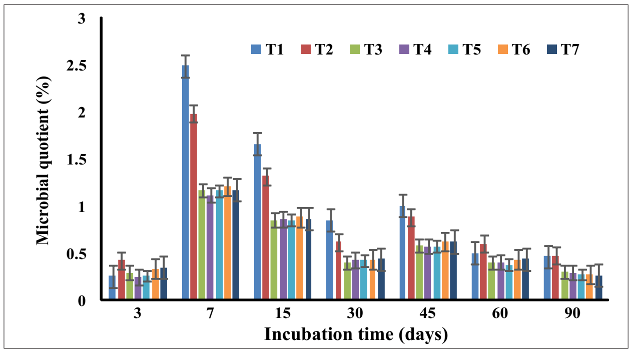


Fig 2.5 The effects of biochar addition on the microbial quotient (qMB) during the incubation NOTE: T_1=RFD, T_2=RFD+0.5 t ha^{-1}, T_3=RFD+1.0 t ha^{-1}, T_4=RFD+2 t ha^{-1}, T_5=RFD+4 t ha^{-1}, T_6=RFD+8 t ha^{-1}, T_7=RFD+10 t ha^{-1}

Agro-management for Enhancing Water Productivity and Rice Productivity under Water Shortage Condition

Growth stage based irrigation scheduling in aerobic rice

A field experiment was conducted during *rabi*, 2017 to identify the optimum irrigation scheduling for aerobic rice. The experiment was laid out in the split plot design with three replications. The treatments comprised of four main plots *i.e.* before panicle initiation (BPI) irrigation with 40 mm + after panicle initiation (API) irrigation with 40 mm, BPI irrigation with 60 mm + API irrigation with 60 mm, BPI irrigation with 40 mm + API irrigation with 60 mm and BPI irrigation with 60 mm + API irrigation with 40 mm and two subplot treatments i.e. IW/CPE ratio 1.2 and IW/CPE ratio 1.5. Among the main plot treatments, highest yield and yield attributes were recorded when aerobic rice was irrigated with 40 mm water both BPI + API. Among the two IW/CPE ratios, significantly maximum yield and attributes were recorded under the treatment at IW/CPE ratio 1.5 as compared to the treatment IW/CPE ratio 1.2. Further the water productivity was highest in the treatment where crop was irrigated with 40 mm water both BPI + API. Thereby, reducing the irrigation water depth from 60 to 40 mm in aerobic rice when grown with same amount of water enhances the yield by 24.1% and the water productivity by 17%. Therefore, the irrigation depth of 40 mm is optimal for scheduling

Table 2.4. Impact of rice husk biochar treatments in total organic carbon, microbial biomass carbon and C lability index of soil at field condition after consecutive five rice crop seasons

Treatments	Total Organic C (%)	Microbial Biomass C (mg kg $^{-1}$ soil)	C lability index (LI)
T_1 (control)	1.21^e	120.97^b	1.54^a
T_2 (0.5 t ha $^{-1}$ biochar)	1.74^d	164.73^a	1.70^a
T_3 (1.0 t ha $^{-1}$ biochar)	2.80^c	173.57^a	1.11^b
T_4 (2.0 t ha $^{-1}$ biochar)	2.81^c	117.10^b	1.06^b
T_5 (4.0 t ha $^{-1}$ biochar)	2.86^c	165.33^a	1.07^b
T_6 (8.0 t ha $^{-1}$ biochar)	3.12^b	196.11^a	0.96^b
T_7 (10.0 t ha $^{-1}$ biochar)	3.26^a	203.90^a	0.99^b
LSD (P<0.05)	0.12	39.76	0.23

irrigation in dry season. Highest water productivity (0.61 kg m^{-3}) and grain yield (3.94 t ha^{-1}) was achieved in the treatment combination where crop was irrigated with 40 mm at IW/CPE ratio of 1:2.

Development of sustainable production technologies for rice based cropping systems

System based nutrient management in rice based cropping system

A field experiment was carried out to study the effect of system based nutrient management options on yield, system productivity and nutrient status in rice-maize-cowpea and rice-groundnut-cowpea cropping system. The experiment was laid out in a split plot design with two cropping systems i.e. rice-maize-cowpea and rice-groundnut-cowpea in main plots and five system based nutrient management options i.e. control-control-control, RDF - RDF - RDF, RDF_{75} (75 % of recommended dose of fertilizer) + Crop residue incorporation of previous crop (CRI) - RDF - RDF, RDF_{75}+CRI - RDF + straw mulch (SM) - RDF and RDF_{75}+CRI-RDF+SM-RDF_{50} in subplots replicated thrice. The varieties, Naveen (rice), Super 36 (maize) and Banamali (cowpea) were used in the experiment. Rice yield did not differ significantly with respect to different systems in wet season in third year of the system. But among system nutrient management treatments, except control the bean yield of cowpea was significantly lowered in rice–groundnut– cowpea compared to rice – maize – cowpea cropping system. System productivity (Rice Equivalent Yield) achieved in rice - groundnut – cowpea and rice - maize - cowpea cropping system was at par but the higher net returns of Rs. 81,988/-per hectare and returns per rupee invested of 1.98 was achieved with Rice-maize-cowpea cropping system. Straw mulching significantly increased grain yield of maize but could not prove its superiority in groundnut in dry season. Incorporation of cowpea residue with 75% of RDF to rice + straw mulching with RDF to maize/groundnut + RDF_{50} to cowpea produced significantly highest REY of 14.84 t ha^{-1} and recorded 15.8% yield advantage over RDF to each crop of the system. Rice-maize-cowpea cropping system removed higher P and K but similar amount of N compared to Rice-groundnut-cowpea cropping system. After two cycles of the system, available N, P and K content of the soil did not change with the cropping systems but available N, P and K of residue applied plots was significantly higher or at par with RDF applied plots.

Crop and varietal diversification of rainfed rice based cropping systems under changing climatic scenario

The field experiment was conducted at the institute (20° 26′ N, 85° 56′ E; elevation 24 m above mean sea level) during 2016-17 to examine the performance, system productivity and economics of different rice varieties and dry season crops under different rice establishment methods. The two main cropping seasons at experimental site include a *kharif* season from June to November *rabi* season from November to March. Weather conditions were generally stable, maximum temperature varied from 25-36°C (average 30.8°C) and minimum temperature ranged from 14-37°C (average 24.2°C) and crop received 1200 mm of rainfall during the study period. Rice establishment methods and rice variety were kept in main and sub-plots, respectively and dry season crops were kept in sub-sub plots. Results of the study revealed that during *kharif* season, among the crop establishment method, transplanting produced the highest yield, which was around 27.2 and 8.7% higher over dry-direct sown rice (DSR) and wet-DSR, respectively, irrespective of the cultivars (Fig. 2.6). Among the cultivars, yield of Swarna-*sub1* was highest but it was at par with Naveen. The long duration of Swarna-*sub1* affected its yield due to dry spells occurred at reproductive stage of the crop. Over the years (2014-2017), Naveen performed consistently better under prevailing weather conditions, enabling Naveen based systems providing significantly higher output and returns. Performance of *rabi* crops was severely affected when sown after Swarna-*sub1* because of its late harvesting and non-availability of residual moisture for establishment and growth of succeeding crops. Yield of toria, green gram and black gram was decreased up to 139, 116 and 95% when sown after Swarna-*sub1* over sowing after Naveen and Sahabhagidhan, respectively. In the *rabi* season, black gram performed better and results were more positive when sown after Naveen and Sahabhagidhan. Among the *rabi* crops, toria recorded lowest seed yield might be due to prevailing weather conditions. System productivity was maximum in the system of Naveen (TPR) – black gram followed by Sahabhagidhan (TPR) – black gram. As per the benefit: cost ratio, Naveen (TPR) – black gram was most profitable (2.14) due to higher yield of both the crops followed by Sahabhagidhan (TPR) – black gram (2.12), lowest net returns and B: C ratio was recorded for Swarna-*sub1* in *kharif* and toria in *rabi* season because of their lower yield and high cost of cultivation.

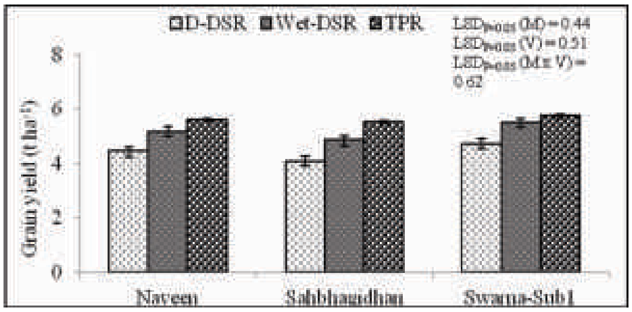


Fig. 2.6. Grain yield of rice as influenced by different rice varieties and crop establishment methods under limited irrigation

Conservation Agriculture based resource management in rice – maize cropping system

A field experiment was carried out to study the effect of different nutrient management options on the rice-maize cropping system under conventional and zero/minimum tillage situations to develop conservation agriculture based nutrient management. The experiment was laid out in a split - split plot design with two tillage systems i.e. conventional and zero/minimum tillage in main plots and three residue management system i.e. RDF + no residue, RDF + residue mulching (3 t ha^{-1}) and RDF + residue mulching (6 t ha^{-1}) to maize in subplots and two N levels to rice i.e. LCC based (75% recommended dose of N (RDN) and LCC based (100% RDN), replicated thrice.

The varieties Pooja (rice) and Super 36 (maize) were used in the experiment. Significantly lower grain yield in rice was recorded in zero tillage compared to conventional tillage. About 7.7% grain yield reduction was observed in zero tillage rice compared to conventional tillage. Grain yield of maize did not differ significantly in zero tillage compared to conventional tillage. Significantly higher grain yield of 12.7% was recorded with straw mulching with 3 t ha^{-1} but was at par with 6 t ha^{-1} (Table 2.5). However,

Table 2.5. Effect of tillage, crop residue and N levels on productivity of rice – maize cropping system

Tillage in Maize/Rice	Maize Grain Yield (t ha^{-1})	Rice Grain Yield (t ha^{-1})	System REY (t ha^{-1})
Conventional Tillage	8.32	6.61	14.33
Zero Tillage	8.19	6.10	13.70
CD (p =0.05)	NS	0.55	NS
Residue management in Maize			
RDF + No Residue	7.70	6.20	13.35
RDF + Residue Mulching (3 t ha^{-1})	8.68	6.54	14.60
RDF + Residue Mulching (6 t ha^{-1})	8.26	6.33	14.00
CD (p =0.05)	0.71	NS	1.03
Nutrient management in Rice			
LCC based (75% RDN)	7.95	6.07	13.45
LCC based (100% RDN)	8.56	6.64	14.58
CD (p =0.05)	0.52	0.37	0.91

the residual effect of straw mulching in maize on rice could not make significant difference in grain yield. Application of 100% of recommended dose of N (RDN) produced significantly higher rice yield compared to 75% of RDN and also recorded higher grain yield of maize compared to 75% RDN applied to rice. System productivity in terms of rice equivalent yield of zero tillage system was at par with that of conventional tillage in rice -maize cropping system.

Rice canopy level radiation interception studies under different establishment methods and date of sowing in rice

Present study was executed for consecutively five years (*kharif* season of 2012-2016) to determine whether planting time improves the radiation absorption and use efficiency in different duration rice cultivars. We evaluated the difference in plant growth and yield under different planting time, which related to radiation incidence and interception. In the main plots, rice was grown under the three different establishment methods *viz*., conventional transplanted rice (CTPR), surface-seeded rice on puddled soil (Wet DSR), and system of rice intensification (SRI) with certain modifications.

Two rice cultivars were sown on four different dates, i.e. 1st week of June (D1), 3rd week of June (D2), 1st week of July (D3) and 3rd week of July (D4). Two Indica rice cultivars, Pooja and Naveen, were used in the experiments, because of their different duration of growth. The ambient maximum and minimum daily

Table 2.6. Effect of establishment methods and date of sowing on grain yield (t ha^{-1}) of Pooja and Naveen during 2012-2016

	2012	2013	2014	2015	2016	Mean
Method of establishment (M)						
Wet DSR	5.44c	4.81c	5.08c	5.20c	4.85c	5.07
TPR	5.74a	4.91b	5.36a	5.36a	5.31a	5.34
SRI	5.65b	5.01a	5.20b	5.25b	4.97b	5.22
Date of sowing (D)						
Jun 1st wk	5.57c	4.77c	5.07c	5.14c	4.88c	5.11
Jun 3rd wk	5.86a	5.13a	5.61a	5.62a	5.44a	5.53
Jul 1st wk	5.76b	5.01b	5.29b	5.27b	5.13b	5.27
Jul 3rd wk	5.25d	4.72d	4.88d	5.05d	4.72d	4.92
Variety (V)						
Pooja	6.13a	4.74b	5.92a	5.99a	5.77a	5.71
Naveen	5.09b	5.08a	4.51b	4.56b	4.31b	4.71
MxD $_{P=0.05}$	*	*	*	*	*	-
MxV $_{P=0.05}$	*	*	*	*	*	-
DxV $_{P=0.05}$	**	**	**	**	**	-
MxDxV $_{P=0.05}$	*	ns	*	*	ns	-

temperatures during the study period in rice growing season (from June to November) were averagely 31.1°C and 24.2°C over the five years, respectively (with average daily temperature of 27.7°C). The average sunshine hours during crop growth (over five years) were 4.5 hrs.

The average photosynthetically active radiation (PAR) ranged from 225 to 724 µmoles $m^{-2} s^{-1}$ during the growing season. The experiment was laid out in split split-plot design with three replications and at plot size of 30 m^2. Results revealed that the PAR interception was affected with crop duration and time

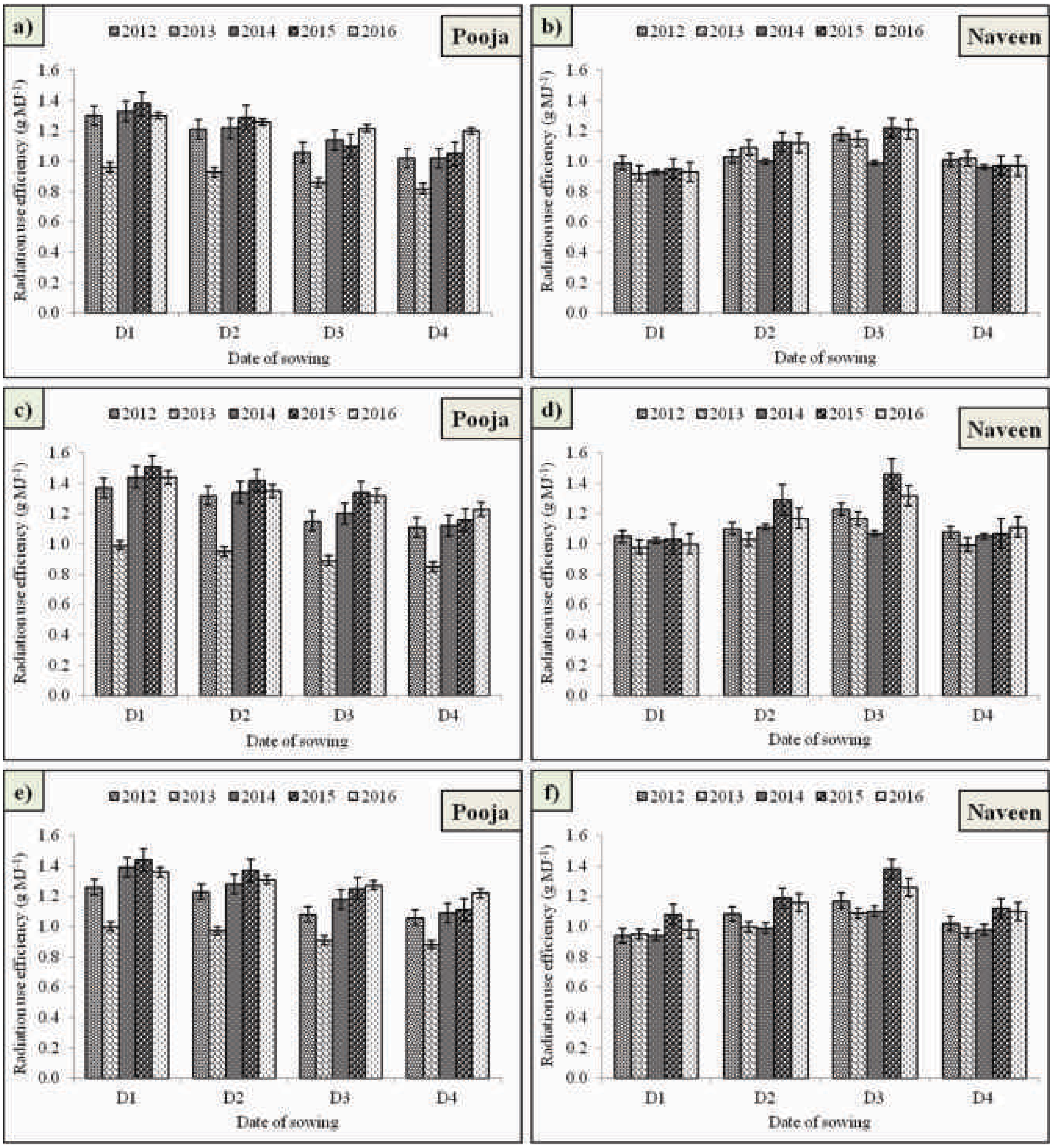


Fig. 2.7. Radiation use efficiency (g MJ^{-1}) of a) wet DSR_Pooja, b) wet DSR_Naveen, c) CTPR_Pooja, d) CTPR_Naveen, e) SRI_Pooja and) SRI_Naveen as influenced due to date of sowing

of planting; the intercepted PAR values were relatively stable and mostly ranged between 0.93 to 1.23. PAR interception in Naveen was higher when planted in the month of July as compared to June planting. On an average, Pooja, intercepted more PAR as compared to Naveen, but the comparative absorption of radiation on same date was higher in Naveen. Radiation use efficiency (RUE) was computed as above ground biomass over intercepted radiation, which was higher for cv. Pooja. RUE in Pooja was ranged from 1.02-1.51 g MJ^{-1} (Fig. 2.7). However, in cv. Naveen, it ranged from 0.92 to 1.46 g MJ^{-1} over the years. On an average, grain yield in CTPR was 2.3 and 5.1% higher over SRI and wet DSR, respectively. Crop planted in June third week recorded the highest yield followed by July 1st week; yield reduced when planted after first fortnight of July. Grain yield of rice planted in July third week was reduced by 3.8, 12.3 and 6.9% over June first and third week and July first week, respectively, over the years (Table 2.6). Irrespective of the years, Pooja recorded 28.8% higher grain yield as compared to Naveen, but in 2013, yield was 7.2% higher in Naveen due to prevailing weather conditions.

Farm implements and post-harvest technology for rice

Field performance of modified single row dry land power weeder

Single row dry land weeder fitted with roller type depth control wheel to get uniform depth of intercultural operation was tested with width of blades of 14 cm in Naveen variety of rice sown with row spacing of 20 cm, 25 cm, and 30 cm. Depth of operation was set at 50 mm for all operations (Fig. 2.8). For field testing at average operation speed of 1.45, 1.51, and 1.63 km h^{-1}, field capacity was found 0.029, 0.030, and 0.049 ha h^{-1} with weed control efficiency of 70%, 61%, and 50%, respectively for 20, 25 and 30 cm row spacing. No plant damage was found during operation. It was observed that 14 cm wide blade was best suited for controlling weeds without any damage to crop plant for 20 cm row to row spacing. It was also observed that weeder can work at higher depth of control i.e. 5 cm in favorable soil moisture condition (conducive soil moisture condition), whereas it was not able to take load at this depth of operation in dry soil condition.

Fig. 2.8. Power operated single row dry land weeder

Modification and field testing of self propelled single row wet land weeder

Belt and pulley system was replaced with chain and sprocket system in self-propelled single row weeder to solve belt slipppage problem over pulley of ground wheel shaft. And presently weeder could work smoothly even under higher load. Transmission system modified to get the optimum forward speed. Arragements for blade covering units were designed and fixed in such a way that the amont of soil cut by cutting blades settle near covering unit. Covering unit does not allow any soil thrown out, results in more comfort to operator. Two side clutches with control lever at the handle were provided for easy turning. Main feature of power transmission of machine are 1.03 KW, petrol start kerosene driven engine, 3600 rpm engine speed, 7.3 times speed reduction through bevel gear and gearbox, 492 rpm available at rotor shaft, speed reduction of 37.9 times through belt and pulley sprocket to ground wheel shaft, ground wheel speed 19.12 rpm, cage wheel diameter 71.5 cm, wheel base 80 cm, width of pad strip of cage wheel 11.5 cm (Fig 2.9).

The weeder was tested in line sown Naveen variety of rice with row spacing of 20 cm. It was tested with 6 cm and 7 cm wide L type blades fitted on the rotor plate facing L face in opposite direction alternatively making working width of 12 cm and 14 cm, respectively. Six blades were fitted on the rotor unit. Depth of operation was fixed at 6 cm. For 12 cm and 14 cm cutting blade width, at average operational speed of 1.23-1.3 km h^{-1}, field capacity of weeder was found 0.025 to 0.026 ha h^{-1}. Weed control efficiency was found in range of 60 to 70%.

Fig. 2.9. Self propelled single row wet land weeder

Field performance of modified two row self propelled wet land weeder

Two row self propelled weeder having 5.5 HP. petrol start kerosene driven engine was tested in Pooja variety of rice sown with tractor drawn nine row seed drill in row spacing of 20 cm during *kharif,* 2016. Weeder was fitted with modified cylindrical hallow floating depth control wheel at rear to reduce sinkage of wheel in wet soil and cage wheel having 11cm wide pad strips with wheel base of 62 cm . Wheel base was so selected to prevent any stamping of crop plant due to wheel. It was tested using 6 cm, 9 cm, and 12 cm wide L type blades. Rotational speed given to blades was 325 rpm. During field testing, field capacity of weeder was found in range of 0.060 to 0.068 ha h^{-1}. For 6, 9 and 12 cm cutting blade width, weed control efficiency was found 37, 52, and 67% with plant damage 0, 2.5%, and 35.1%, respectively.

Studies on operational efficiency of rice weeding implements

Field evaluation of different type of weeding equipments/methods for cultivation of direct seeded rice (cv. Pooja) was carried out during *kharif,* 2016. Sowing of seed was done with 9 row tractor drawn seed drill. Different type of weeders/weeding methods used were traditional method, finger weeder, cono-weeder, NRRI two row self propelled weeder, Kalinga shakti power weeder and chemical weeding. Study revealed that highest field capacity was observed in NRRI two row self propelled weeder (0.06 ha h^{-1}) followed by Kalinga shakti power weeder (0.04 ha h^{-1}). Total man-h required for weed control was least for chemical weeding (330.5 man-h ha^{-1}) fallowed by NRRI two row self propelled weeder (344.8 man-h ha^{-1}). Least energy of weeding was observed for NRRI two row self propelled weeder (611 MJ ha^{-1}) (Table 2.7). No significant difference in yield of rice was observed among different treatments.

Table 2.7. Effect of weeding implements/methods on productivity, energy and cost of weeding in rice cultivation

S.No.	Implements/ methods	Field capacity (ha h^{-1})	Labor required for operation of implements (Man-h ha^{-1})	Total man-hr required for weeding	Total cost of weeding (Rs ha^{-1})	Energy (MJ ha^{-1})	Yield (t ha^{-1})
1	Traditional	-	-	910.0	23888.0	1428.7	3.54
2	Finger weeder	0.0020	493.0	723.0	21340.0	1351.9	3.32
3	Cono weeder	0.0039	254.0	554.0	15995.0	1035.0	3.43
4	NRRI two row power weeder	0.0675	14.8	344.8	11779.3	611.2	3.42
5	Kalinga shakti power weeder	0.0462	21.6	471.6	14864.5	1770.6	3.54
6	Chemical weeding	-	30.5	330.5	10374.0	568.8	3.33

Study the operational efficiency of wet land seeders

Field evaluation of different type of NRRI developed wet land seeders for sowing sprouted seed of Naveen variety of rice on puddle field was carried out during *rabi* 2016. Different type of seeders used were eight row power operated cylindrical, conical and cup type drum seeder, four row conical manual drum seeder, six row manual cylindrical drum seeder and two row manual cup type seeder. Study revealed that power operated cylindrical (5.73 h ha^{-1}), conical (6.02 h ha^{-1}) and cup type drum seeder (5.65 h ha^{-1}) required almost three times less time as compare to manual operated six row drum seeder (16.66 h ha^{-1}), four times less time as compare to manual operated conical drum seeder (20.16 h ha^{-1}) and seven times less time as compare to two row manual cup type seeder (45.5 h ha^{-1}). Average energy required for sowing with manual operated seeder found to be six time less as compared to power operated seeders. It was 393.0 MJ ha^{-1}, 405.6 MJ ha^{-1}, 386.1 MJ ha^{-1} for eight row power operated cup type drum seeder, conical drum seeder and cylindrical drum seeder and 43.0 MJ ha^{-1}, 47.9 MJ ha^{-1}a and 108 MJ ha^{-1}a for six row manual cylindrical drum seeder, four row conical manual drum seeder and two row manual cup type seeder respectively. Cost of sprouted seed sowing was least for six row manual cylindrical drum seeder (Rs. 768 ha^{-1}) and highest for two row manual cup type seeder (Rs. 1613 ha^{-1}) (Table 2.8). No significant difference in yield of rice was observed among different sowing machines treatments.

Development and evaluation of self-propelled eight row dry direct paddy seeder

A light weight self-propelled eight row paddy seeder with 2.97 KW diesel engine was developed with cup type (10 mm cup size) metering unit and eight cups in one unit. Shovel type furrow opener with adjustable depth were developed and connected with metering unit through seed delivery tube. To give forward motion to the seeder, pneumatic wheel of 60 cm diameter and 13 cm width with lugs was fitted in front. Two rear wheels having diameter 40 cm and width 11 cm with lugs were fitted behind the float enabling ground clearance up to 35 cm. The test was done for Naveen variety of paddy. Effective width of seeder was 140 cm and seed fall of 3 to 4 seeds per hill was observed. Field evaluation results shows that at working speed of 1.4 km h^{-1}, field capacity, field efficiency and fuel consumption of the self-propelled dry direct seeder was 0.18 ha h^{-1}, 84 per cent and 7.1 ha^{-1}, respectively and seed rate was found 30 kg ha^{-1}.

Table 2.8. Field performance of NRRI developed wet land seeders

S. No.	Wet land seeders /methods	Field capacity (ha h^{-1})	Speed of operation (Km h^{-1})	Machine-hr/ha for sowing	Operational efficiency of machine	Cost (Rs ha^{-1})	Energy (MJ ha^{-1})	Grain yield (t ha^{-1})
1	Eight row cup type power seeder	0.1770	1.65	5.65	67.0	1310	393.0	4.100
2	Eight row conical drum type power seeder	0.1659	1.40	6.027	74.0	1398	405.6	4.525
3	Eight row cylindrical drum power seeder	0.1743	1.60	5.730	68.0	1329	386.1	4.500
4	Six row cylindrical manual drum seeder	0.060	0.85	16.66	58.8	768	43.0	4.150
5	Four row conical manual drum seeder	0.0496	0.95	20.16	65.2	834	47.9	4.250
6	Two row cup type manual drum seeder	0.022	0.72	45.450	76.4	1613	108.0	3.800
7	Manual line sowing	0.0096	-	103.89	-	3247	163.1	4.675

Development of four row power operated transplanter using mat type seedling of rice

A four row power operated rice transplanter was developed to transplant mat type seedling at row to row spacing of 24 cm and hill to hill spacing of 15 cm. Power taken from 2.9 KW diesel engine through bevel gear to cam shaft to operate oscillating mechanism and finger units system of transplanter. Through field testing the forward speed of machine was observed to be 1.4 km h^{-1} with a working distance of 240 mm of the oscillating mechanism, whereas, the field capacity of machine was observed 0.1 ha h^{-1}.

Resource Conservation technologies for sustainable rice production

Nutrient (N, P and K) balance under different resource conservation technologies in transplanted and direct seeded rice

Nutrient (N, P, and K) managements are strongly linked to energy and food production, but excess nutrient causes environmental pollution. Balances of N, P, and K were calculated for six (6) resource conservation technologies (Fig. 2.10) along with conventional control under direct seeded and transplanted conditions in a rice-green gram system taking into consideration the inputs through inorganic fertilizer, green manure, leguminous fixation, non-leguminous fixation, crop residues, rain and irrigation water and outputs through crop uptake and losses through leaching, volatilization and denitrification. Inorganic fertilizer was the dominant source of N, P and K inputs in all the resource conservation treatments and the removals was mostly by crops harvesting in both dry and wet seasons. There were positive balances of N for direct seeded and for transplanted rice. Highest N balance under direct seeded could achieved under Green manuring (GM)+customized leaf colour chart (CLCC)-N (T_6) and it was 37.6% more than conventional (T_1) practice, whereas N balance was highest under residue retention (T_2) and it account 42.7% more than T_1 under transplanted condition. Similarly, there were also positive balances of P, for direct seeded and for transplanted rice. Highest P balance under DSR was found under both GM+CLCC-N (T_6) and brown manuring (BM) (T_2) and it was 11.5% more than T_1, whereas under transplanted condition P balance was highest under residue incorporation (T_2) and it account 14.5% more than T_1. K balance under DSR ranged from 7.2 to 30.7 kg ha^{-1} and the highest balance was recorded under zero tillage (T_5), whereas under transplanted condition it was ranged from 0.5 to 44.5 kg ha^{-1} and the highest value was found under T_2.

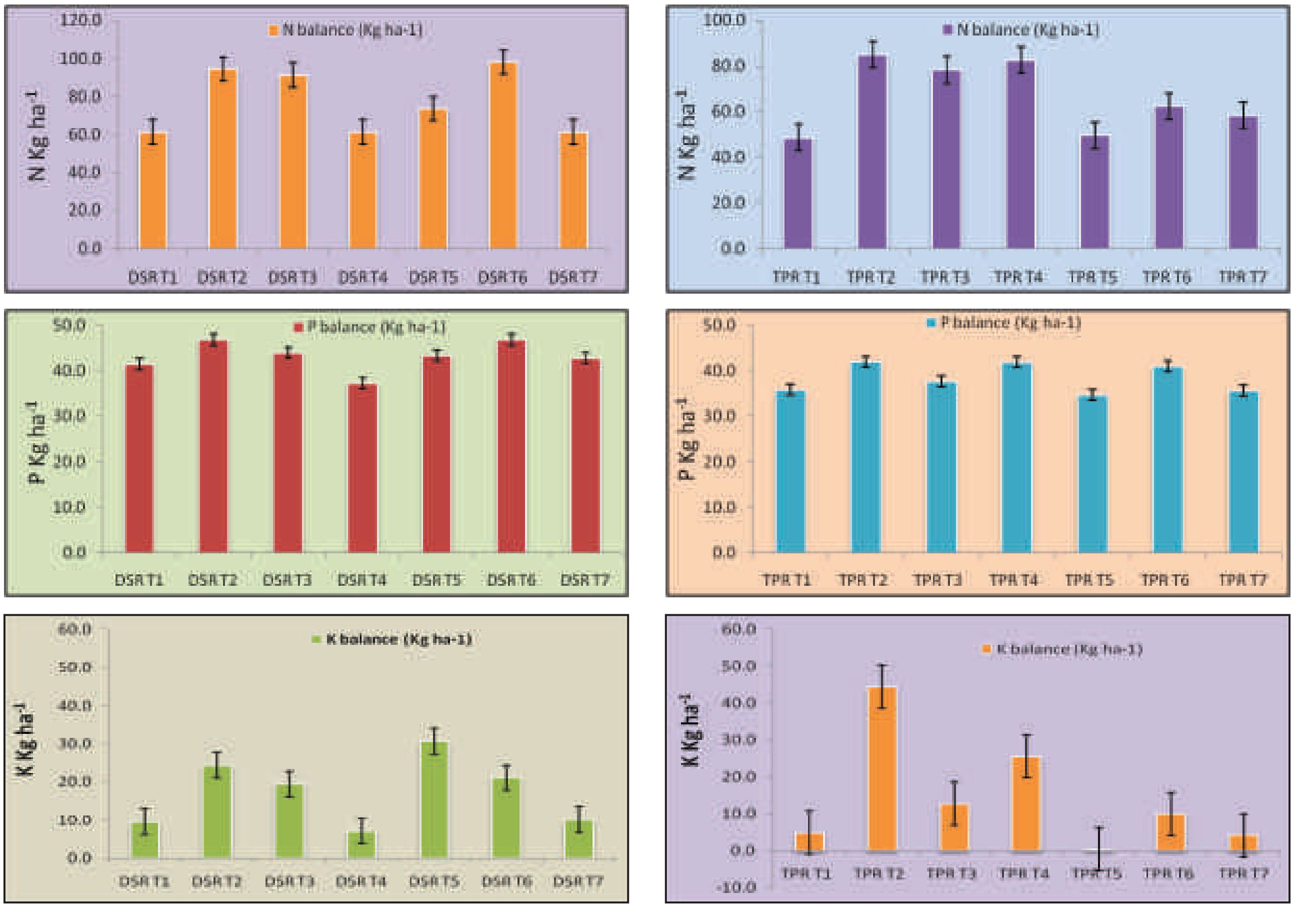


Fig. 2.10. Nitrogen, P and K balances under different resource conservation technologies in transplanted and direct seeded rice

Sustainability, Carbon sequestration and ecosystem functioning for rice-based system under organic nutrient management

The sole application of mineral fertilizers could not maintain SOC stock. Combination of rice straw + green manure could be adoptable soil amendment option to sequester the soil organic C, yield sustainability and minimizing GHG emission. An experiment was conducted in *kharif* season 2016 in rice (cv. Ketakijoha and Padmini)-groundnut (cv. Smruti) cropping system under long-term organically managed field to evaluate 'sustainability, C sequestration and ecosystem functioning for rice-based system under organic nutrient management'. Altogether eight organically supplemented treatments were imposed for rice: T_1-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, and in the subsequent *kharif* season for groundnut: rhizobium treated/non-treated seeds have been sown with a residual treatment effect of previous season crop (Fig. 2.11). Organic nutrient management responded well by both rice varieties in terms of yield (Fig. 2.11) while, FYM application either sole or in combination proved beneficial for both grain and straw yields, however, both the varieties were at par. It had positive effect on flourescein diacetate hydrolysis activity in soil under both rice varieties, but not on soil dehydrogenase activity.

Ratooning behavior of different rice varieties under different management practices

In areas where adequate water is available after the main crop season, rice ratooning could be practiced as an alternative to double cropping. It is suited to areas where mono-cropping is practiced and no crop other than rice could be grown under the climate and moisture condition. Cultural practices and condition

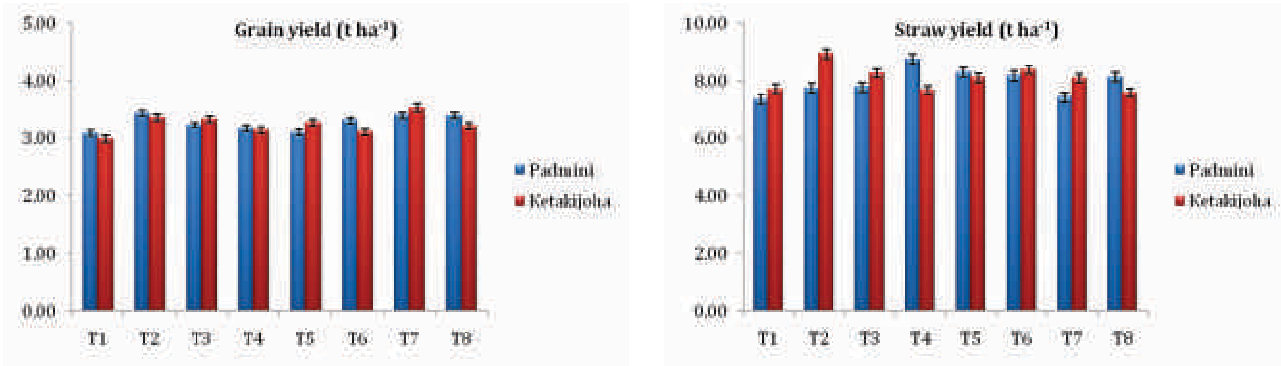


Fig. 2.11. Effect of organic nutrient management on rice yield

of the main crop at harvest impact the growth and development of the ratoon crops. Therefore, response of 10 different rice varieties were studied under three dates of transplanting (1st week of July, 3rd week of July and 1st week of August) in a field experiment with three replications. Results of the study suggested that ratoon crop took almost half time to mature as of main crop. Plant height of main and ratoon crop varied among date of transplanting and varieties; mature plant height of ratoon crop was 50-60% lower than the main crop. Among the tested varieties maximum fertile panicles were recorded in Rajalaxmi and Ajay in both main and ratoon crop. Panicle number decreased in ratoon crop of all the cultivars; maximum decrease was observed in Sahbhagidhan. Delayed planting reduced the grains per panicle and grain filling percentage in both main and ratoon crop. Ratoon crop contributed to the grain yield ranging from 17-47% to the main crop yield, total yield was highest in Rajalaxmi i.e. around 9.4 t ha^{-1} (Table 2.9). Ratoon crop contributed around 1-2 t ha^{-1} grain yield in less than 50% time taken by the main crop. Among the different cultivars, highest ratoon and main crop yield was obtained in hybrids, whereas, maximum ratoon yield after hybrids was obtained in Savitri which was around 46% of the main crop. Timely planting of main crop resulted in higher yield both main and ratoon crop; yield of main and ratoon crop was increased upto 18.1 and 47.8% over late planting (August), respectively.

Weed management under zero tillage transplanted rice

Performance of zero tillage transplanted rice was studied under different herbicide treatments. Three treatments namely, bispyribac sodium @ 30 g a.i. ha^{-1} followed by fenoxaprop-p-ethyl @ 50 g a.i. ha^{-1}; fenoxaprop-p-ethyl @ 50 g a.i. ha^{-1} + ethoxysulfuron @ 20 g a.i. ha^{-1}; and cyhalofop butyl@ 50 g a.i. ha^{-1} were tested along with weed free and weedy check. Most predominant weed were *Echinochloa colona* and *Fimbristyli smiliacea*. Application of bispyribac sodium followed by fenoxaprop-p-ethyl was found to be most effective in controlling the weeds as reflected weed biomass. In Cyhalofop butyl treated plots, there was high infestation of *Echinochloa colona* and severe infestation of *Fimbristylis miliacea* which could not be suppressed by crop growth at 60 DAT (Fig. 2.12). Weed contol efficiency (WCE) at 60 DAT was recorded highest with sequential application of bispyribac and fenoxaprop-p-ethyl (73% for all weeds and 92% for grassy weeds) followed by application of herbicide mixture (fenoxaprop-p-ethyl + Ethoxysulfuron) (64% for all weeds). Cyhalofop butyl recorded only 38% WCE owing to very poor control of *Fimbristylis miliacea* (12% WCE for sedges) (Fig 2.13). Sequential application of bispyribac and fenoxaprop-p-ethyl recorded highest yield (4.28 t ha^{-1}) and cyhalofop butyl recorded the lowest yield (3.38 t ha^{-1}) among the herbicide treatments.

Table 2.9 Effect of planting time and varieties on grain yield of main and ratoon crop of rice

	Grain yield (t ha^{-1})			
	Main crop (MC)	Ratoon crop (RC)	% of MC	Total (MC+RC)
Varieties (V)				
Gayatri	5.91	2.35	39.8	8.26
Pooja	5.72	2.15	37.6	7.87
Swarna-*sub1*	5.11	1.94	38.0	7.05
Sahbhagidhan	4.18	0.74	17.7	4.92
Naveen	4.77	1.48	31.0	6.25
Savitri	5.42	2.52	46.5	7.94
Sarla	5.23	1.98	37.9	7.21
Swarna	5.19	1.81	34.9	7.00
Ajay	6.26	2.74	43.8	9.00
Rajalaxmi	6.49	2.91	44.8	9.40
$LSD_{P=0.05}$	0.72	0.29	-	0.85
Planting time (T)				
1st wk of July	5.87	2.44	41.6	8.31
3rd wk of July	5.45	2.09	38.3	7.54
1st wk of August	4.97	1.65	33.2	6.62
$LSD_{P=0.05}$	0.37	0.16	-	0.97
$LSD_{P=0.05}$ (VxT)	0.87	0.34	-	1.02

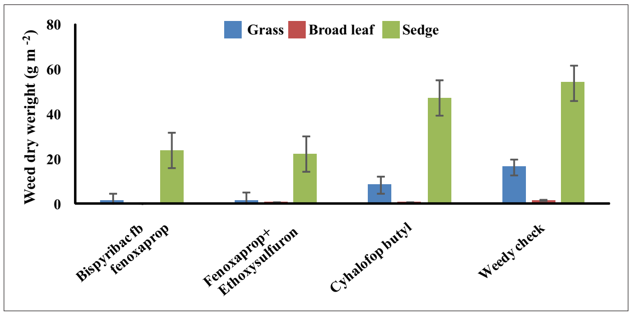


Fig. 2.12. Weed dry matter (g m^{-2}) under herbicide treatmentsat 60 DAT

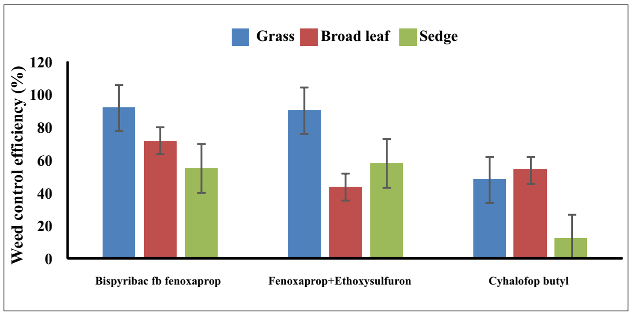


Fig. 2.13. Weed control efficiency of herbicides at 60 DAT

Diversified rice based farming systems for livelihood improvement of small and marginal farmers

Development of rice based farming systems for upland ecologies

Diversified farming system experiment was laid out for the rainfed upland at KVK Santhapur (30 kms from NRRI), with seven treatments and three replications. Three short duration rice varieties *viz*., Satyabhama, CR Dhan 205 and Sahbhagidhan along with sesame (cv. Prachi), pegionpea (cv. NTL 30), urd bean (cv. Nab biri) and okra (cv. Dream girl) were grown during the *kharif,* 2016. Rice variety Satyabhama yielded 2.63 t ha^{-1}, CR Dhan 205 yielded 2.54 t ha^{-1} while Sahbhagidhan yielded 2.77 t ha^{-1}. Due to the paucity of rainfall the yield of non rice crop were affected badly. Sesame, pegionpea, urdbean, and hybrid okra yielded 0.21, 0.53, 0.24 and 7.5 t ha^{-1}, respectively. The net return per hectare was highest with okra (Rs 40,000/-) followed by pegionpea (Rs. 27400/-) and Sahbhagidhan (Rs 11,287/-). Okra recorded 1.14 B:C ratio, the highest being with pegionpea (1.83) followed by urdbean (1.40).

Rice Fish Interaction studies under agronomic management

A field experiment was conducted to evaluate the performance of rice integrated with fish and the duck over rice alone. Results revealed that the treatment with rice-fish-duck gave 15.7% higher yield over rice alone with effective weed control and less incidence of pest.

Development and evaluation of rice based integrated farming systems for coastal saline soils with farmers participatory mode

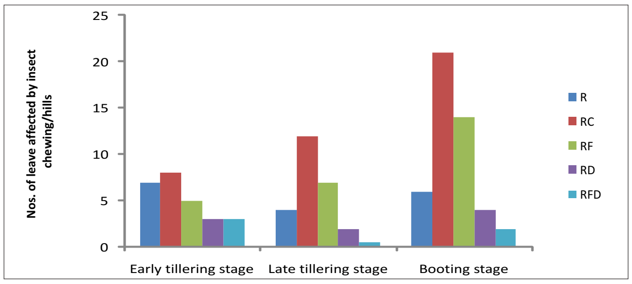
Rice based integrated farming system was developed and validated at Gadakujanga, Jagatsinghpur. Farmer (Sri Kunjo Mullick) converted his 4 acres of land into rice-fish with dyke system. Before shaping of the land the rice field usually remain submerged (upto 50 cm deep) during kharif season with the tidal waves and back water from river. Only option with the farmer was to take the rice crop during the dry season with extra early rice variety with very low productivity. The farmer dug the pond (1 acre) at the edge of his rice field (3 acres) with the initial investment of Rs 52,000/-. Farming system components were rice, fish, ducks, poultry, vegetables and horticultural crops. The farmer realized a net return of Rs. 1,50000 $year^{-1}$ from his farm from improved high yielding varieties with improve package of practices recommended by NRRI, fish (Indian Major Carp) and vegetables during the first year itself.

Improvement in Rice-fish-horticultural, livestock and agro-forestry based integrated farming system model (RFLAIFS)

Adoption of rice –rice system in the RFLAIFS resulted significant increase in rice equivalent yields (REY, 27.72 t ha^{-1}) as compared to the conventional rice mono-cropping (RMC) (7.3 t ha^{-1}). The gross water productivity recorded in the integrated system was higher (1.16 kg m^{-3} of water) in comparison to the conventional rice farming (0.304 kg m^{-3} of water). The net water productivity was Rs. 10.52 m^{-3} of water in integrated farming system as compared to the conventional rice mono-cropping (Rs. 4.25 m^{-3}). The out-put value to the cost of cultivation ratio (OV-CC) was 2.86 in RFLAIFS and 1.57 in Rice Mono Cropping (RMC).

The bio-efficiency evaluation of fish and duck in weed control in rice ecology indicated significant decrease in weed density and biomass in 60 DAT (days after transplanting) and 100 DAT in RFD treated groups. Higher percentage of weed control efficiency (WCE%) was recorded in RFD treatments as compared to rice-duck (RD), rice-fish (RF) and rice mono-cropping (RMC). The weed species richness (Simpson's index D) was decreased significantly ($P < 0.05$) in RFD (0.88) as compared to the control R (0.92), however, Shannon-Wiener diversity indices decreased significantly ($P < 0.05$) in RD (0.83) and RFD (0.76) in comparison to R (0.94), while, the Pielou community evenness indices enhanced significantly ($P < 0.05$) in RD (1.41) and RFD (1.46) against R (1.03) in 60 DAT. At 100 DAT, Simpson index in RFD (0.77, $P < 0.05$) and Shannon-Wiener diversity index in RD (0.69) and RFD (0.48) decreased and Pielou community evenness indices increased in RFD (2.34) as compared to respective control. The results indicated that the species composition of weed community was greatly improved, and the infestation of former dominant weed species was reduced markedly. The findings suggesting that fish and duck can be used as biological weed control agent for rice based integrated farming system, avoiding the application of herbicides for controlling weeds.

Evaluation of bio-control efficacy of fish and ducks in the rice based integrated farming system (rabi season) indicated the numbers rice plant leaf rolled by the rolling insect pests/hills was significantly higher in late tillering and booting stages of rice as compared to the early tillering phases in control treatments (R). The introduction of fishes (RF) was maximum effective during the early tillering stages of rice, however, in rice-duck (RD) and rice-fish-duck (RFD) treated groups indicated significant ($P< 0.001$) reduction in the rolling pest incidence and lower the leaf rolling of the rice plants/hills. Further, the numbers of rice plant leaf affected by the insect chewing/hills was significantly reduced in the integrated system of RF, RD, RDF. This result indicated that insect pest of Brown plant hopper (Nephotettix nigropictus), Zig zag leaf hopper (Recilia dorsalis), rice leaf roller (Cnaphalcrocis medinalis), stem boarer (Scirpophaga incertulas, Chilo suppressalis) can be biologically controlled under the rice-fish –duck integrated farming, and application of pesticides can be avoided (Figs. 2.14 and 2.15).



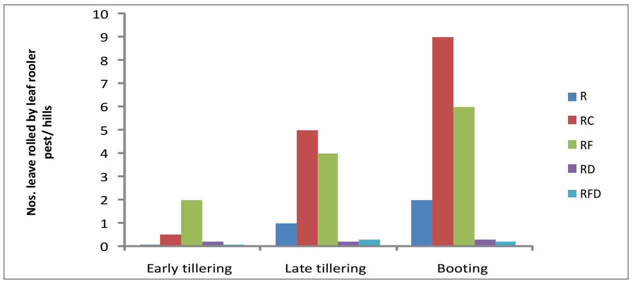


Fig 2.14 and 2.15. Bio-control of leaf roller and leaf chewing insect pests in rice-fish –duck integrated farming system. (R- conventional rice, RC – rice control, RF- rice-fish, RD- rice-duck, RFD- rice-fish-duck).

Management of rice weeds by integrated approaches

Impacts of weed competition on the critical period of weed control in direct-sown rice

The experimental factors consisted of a quantitative series of both the increasing duration of weed interference and the length of the weed free period and two spacing (15 and 20 cm rows). Timing of weed removal was based on the number of days after transplanting. To determine the beginning of the critical period of weed control (CPWC), the first component, increasing length of weed-free period, was established by maintaining weed-free condition for 15, 30, 45 and 60 days after sowing (referred to as weed-free plots) before allowing subsequent emerging weeds to compete for the remainder of the growing season. To evaluate the end of the critical period of the CPWC, the second component, increasing duration of weed interference, was established by allowing the weeds to compete with the rice for 15, 30, 45 and 60 days after sowing (referred to as weedy plots) after which, plots were maintained weed-free until harvest. In addition, season long weedy check and weed-free check were included as control. The results revealed that the critical period of weed-crop competition increased in 20cm spaced crop. The critical period for weed-crop competition under 5% yield loss at the 15 cm and 20 cm were 8-63 and 14–68 days after sowing, respectively. At the 10% yield loss level, the estimated critical period for rice at the 15 cm and 20 cm spacing were 16-47 and 23–53 days after sowing, respectively (Fig. 2.16).

Study on weed spectrum and efficacy of sequential application of low dose herbicides for broad spectrum weed control in wet direct-sown rice

A field experiment was conducted during *kharif*, 2016 to study the weed spectrum and efficacy of sequential application of low dose herbicides for broad spectrum weed control in wet direct-sown rice with cv. Naveen. The treatments included flucetosulfuron-fb-bispyribac sodium (25 and 25 g ha^{-1} applied at 7 and 25 days after sowing, DAS), cyhalofop butyl-fb-ethoxysulfuron (100 and 15 g ha^{-1} applied at 10 and 21 DAS), bispyribac sodium-fb-fenoxaprop-p-ethyl (25 and 60 g ha^{-1} applied at 8 and 30 DAS), flucetosulfuron-fb-ethoxysulfuron (25 and 15 g ha^{-1} applied at 7 and 21 DAS), bispyribac sodium-fb-ethoxysulfuron (25 and 15 g ha^{-1} applied at 8 and 30 DAS), cyhalofop butyl-fb-penoxsulam (100 and 22 g ha^{-1} applied at 10 and 21 DAS) with recommended herbicides of bispyribac sodium (30 g ha^{-1}) and azimsulfuron (35 g ha^{-1}); weed free and weedy check. Altogether ten treatments were evaluated in

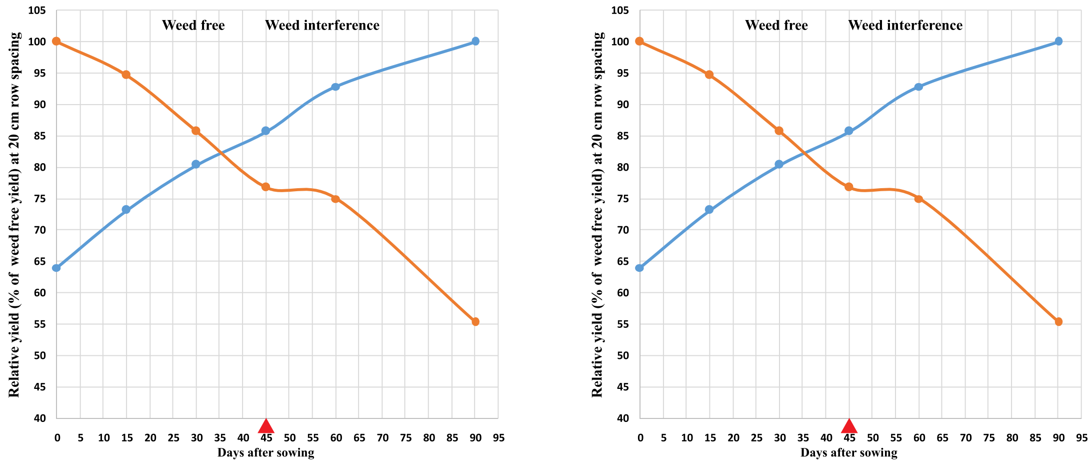


Fig. 2.16. Influence of weed interference on relative yield of DSR sown at 15 and 20 cm row spacing

randomized complete block design with three replications. Experimental results revealed that there was significant control of complex weed flora in bispyribac sodium-fb-ethoxysulfuron and cyhalofop butyl-fb-ethoxysulfuron treated plots with WCE of 89.3% and 87.6%, respectively. The highest yield (5.47 t ha^{-1}) was recorded in weed free check. Among the herbicide treated plots, the grain yield was at par in bispyribac sodium-fb-ethoxysulfuron (5.25 t ha^{-1}) and cyhalofop butyl-fb-ethoxysulfuron (4.99 t ha^{-1}) treated plots.

Study on weed spectrum and efficacy of low dose herbicide mixtures for broad spectrum weed control in transplanted rice

A field experiment was conducted during the wet season, 2016 to study the weed spectrum and efficacy of low dose herbicide mixtures for broad spectrum weed control in transplanted rice with cv. Naveen. Total nine treatments including six herbicide mixtures *viz.,* bispyribac sodium + ethoxysulfuron (25 + 15 g ha^{-1}), fenoxaprop-p-ethyl + ethoxysulfuron (50+15 g ha^{-1}), cyhalofop butyl + ethoxysulfuron (100 +15 g ha^{-1}), bispyribac sodium + azimsulfuron (25+22 g ha^{-1}) and penoxsulam + cyhalofop butyl (120 g ha^{-1}) were compared with two recommended herbicide *viz.,* bensulfuron methyl + pretilachlor (70+700 g ha^{-1}) and azimsulfuron (35 g ha^{-1}) along with weed free and weedy check. The experiment was laid out in randomized complete block design with three replications. Experimental results revealed that there was excellent control of complex weed flora in fenoxaprop-p-ethyl + ethoxysulfuron (50+15 g ha^{-1}) and bispyribac sodium + azimsulfuron (25+22 g ha^{-1}) treated plots applied at 15 days after transplanting (DAT) with weed control efficiency (WCE) of 89.1% and 87.9%, respectively. Among the herbicide treated plots, the highest yield was achieved in fenoxaprop-p-ethyl + ethoxysulfuron (50+15 g ha^{-1}) treatment (5.61 t ha^{-1}) and it was at par with weed free check (5.79 t ha^{-1}). There was 16% yield advantage in this treatment plots over recommended herbicide mixtures of bensulfuron methyl + pretilachlor. The yield reduction due to weed competition in weedy plots was more than 44%.

Effect of herbicides on *Arbuscular mycorrhizal* association in rice

The study was carried out to evaluate the effect of newly standardized herbicide/ herbicide mixtures on *Arbuscular Mycorrhizal* (AM) symbiosis in rice under controlled condition. The treatments comprised single and double the recommended dose of herbicides *viz.,* bispyribacsodium, flucetosulferon, ethoxysulferon, fenoxprop-p-ethyl, penoxulam and herbicide mixtures *viz.,* fenoxprop-p-ethyl + ethoxysulferon and cyhaloforbutyl + penoxulam along with and without AM fungi. After 45 days of treatment imposition, the plant growth parameters, microbial biomass carbon, fluorescein diacetate, dehydrogenase, acid and alkaline phosphatase activity, AM fungi root colonization and sporulation were assessed from each treatment. The results revealed that none of the herbicide molecules or herbicide mixtures had harmful effect on AMF colonization and other microbial properties, which indicated that the above mentioned herbicides would be safe to AM fungal association in rice (Table 2.10).

Table 2.10. Effect of different herbicides with AM fungi on MBC and soil enzymatic activities (45DAS)

Treatment	MBC ($\mu g\ g^{-1}$ soil h^{-1})		FDA ($\mu g\ g^{-1}$ soil h^{-1})		DHA (μg TPF g^{-1} soil h^{-1})		Acid Phos (μg p-nitrophenol released g^{-1} soil h^{-1})		Alka. Phos (μg p-nitrophenol released g^{-1} soil h^{-1})	
	1^n	2^n	1^n	2^n	1^n	2^n	1^n	2^n	1^n	2^n
T_1 (Bispyribacsodium)	560.2	580.2	28.9	30.2	19.6	21.0	38.4	42.3	33.4	40.5
T_2 (Flucetosulferon)	520.6	535.4	31.2	30.5	20.2	22.5	35.2	41.5	33.8	35.8
T_3 (Ethoxysulferon)	545.0	530.0	34.5	33.5	19.8	22.0	41.0	43.0	33.1	34.2
T_4 (Fenoxprop -p-ethyl)	555.8	540.2	33.8	35.4	20.5	19.8	36.8	39.4	34.1	35.1
T_5 (Penoxulam)	540.5	560.5	35.1	36.8	22.1	22.5	40.2	40.8	35.2	34.7
T_6 (Fenoxprop -p-ethyl + Ethoxysulferon)	554.5	535.0	30.8	35.8	19.4	19.5	36.4	39.5	33.4	35.8
T_7 (Cyhaloforbutyl + Penoxulam)	530.8	550.5	29.9	34.8	20.5	20.4	35.8	40.2	33.8	34.0
T_8 (Control)	420.0	420.0	22.8	22.8	15.5	15.5	31.2	31.2	24.6	24.6
T_9 AMF alone	568.4	568.4	35.6	35.6	21.8	21.8	40.6	40.6	35.4	35.4
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

MBC: Microbial biomass carbon; FDA: Fluorescein Diacetate; DHA: Dehydrogenase; Acid Phos: Acid Phosphatase Activity and Alka phos: Alkaline Phosphatase Activity

Bioprospecting and use of microbial resources for soil, pest and residue management

Developing efficient ligno-cellulolytic microbial consortium for rice straw decomposition

The main aim of this experiment was to isolate the rapid decomposing lignocellulolytic microbes for decomposition of paddy straw. In total 59 microbial isolates comprising 23 bacteria, 20 fungi and 16 actinobacteria were isolated from paddy straw and composting pit. Out of 59 isolates, nine isolates were selected based on their ability to produce cellulase, xylanase and laccase activities. The selected nine isolates were evaluated for their ability to decompose the rice straw under microcosm experiment. The results indicated that actinobacterial isolates (DA10, DA13 and DA9) were found to be 72.7-81.6% higher degradation of cellulose as compared to uninoculated control after one month of inoculation, whereas, in case of fungal (DF15, DF7 and DF19) and bacterial isolates (DB12, DB20 and DB23, the efficiency was 66.6-79.0%). The bacteria, fungi and actinobacteria were tentatively identified as *Bacillus* sp., *Aspergillus* sp., *Trichoderma* sp. and *Streptomyces* sp., respectively.

Skermanella sp.: A novel entomopathogenic bacteria for controlling rice leaf folder

An attempt was made to identify some entomopathogenic bacteria to manage rice leaf folder and stem borer. Five entomopathogenic bacteria were isolated from diseased pink stem borer larvae and evaluated for their larvicidal activities against second instars of rice leaf folder and pink stem borer under laboratory condition. And two isolates were selected based on their larvicidal acidities. The selected isolates were identified as *Skermanella* sp. (KX611462) and *Serratia* sp. (KX761232) by 16S rRNA sequencing. The larvicidal activity of these two bacteria was evaluated against second instars of rice leaf folder in potted rice plants (*Oryza sativa var*. TN1) and the results indicated that the *Skermanella* sp. treated rice leaves recorded 100% larval mortality in leaf folder, whereas, *Serratia* sp. treatment showed 79.6-83.3 larval mortality against rice leaf folder. The selected two bacteria were also assessed for their ability to produce protease, chitinase and lipase activities and were found positive for these tests indicated that the cumulative effect of these enzyme activities might have responsible for their larvicidal activities. The present studies indicated that *Skermanella* sp. and *Serratia* sp. have strong insecticidal activities against rice leaf folder.

Influence of high and low nitrogen responsive rice cultivars on functional soil microbial community

A micro-plot field experiment was set up at the institute to evaluate functional microbial dynamics in nitrogen responsive (cv. Ranjeet and Pooja) and less nitrogen responsive cultivars (cv. Sabita) of rice. Rhizosphere and plant samples were collected at flowering stage of rice crop from each cultivar. Population dynamics of different microbes from rhizosphere and plant parts (root, stem and leaves) were analyzed along with various chemical and biological properties of soil. Biolog-based functional soil and root microbial community was assessed in response of N-responsive and low N-responsive cultivars treated with or without fertilizers. Significantly more count of diazotrophs was observed in rhizosphere, root, stem and leaf of N-responsive cultivar Ranjeet treated with fertilizer than low N-responsive cultivar Sabita. Shannon diversity was found non-significant, while, significant in case of McIntosh index. RDA coupled with NMDS and PCA analysis revealed the strong interaction of Av. N, MBC and urease to make varietal significance in soil.

Cyanobiont diversity and their interaction with nutrient profiling in Azolla

Cyanobiont diversity in six species of Azolla (*Azolla microphylla, A. mexicana, A. filiculoides, A. caroliniana, A. pinnata, A. rubra)* was analyzed based on Illumina-Miseq® sequencing technique. Additionally, analysis of biomass and nutrient profiling of Azolla spp. was done and correlated with cyanobiont diversity. Operational taxonomic units (OTUs) data revealed that Nostacaceae family was more abundant in all Azolla spp. and among Nostacaceae, relative abundant of *Cylendrospermopsis was* recorded maximum in most of the Azolla spp. Relative abundance of *Cylendrospermopsis was* found significantly more in *A. pinnata f*ollowed by *A. microphylla, A. mexicana* and *A. caroliniana.* Data on primary productivity of different *Azolla sp*p. recorded significantly ($p<0.05$) higher biomass (6.15 t $ha^{-1}cycle^{-1}$) in *A. pinnata f*ollowed by *A. mexicana* and A. *filiculoides, w*hereas the least biomass was found in *A. caroliniana* (3.49 t ha^{-1} $cycle^{-1)}$. Nutrient profile data indicated that the value of nutrient content in terms of crude protein and total antioxidants was found significantly ($p<0.05$) higher in *A. microphylla* (25.86 and 76.87%, respectively) followed by *A. mexicana.* Biplot analysis based on nutrient profile of six species of Azolla revealed that *A. pinnata* and its cyanobiont sequence (OTUs) was positively correlated with nutrient (NDF) and acid (ADF) detergent fibre which provides information that these factors may play vital role in cyanobiont associations in *A. pinnata* and/or *vice-versa*. However, in case of other species of Azolla, no positive correlation was noticed. Overall, *Cylendrospermopsis w*as found dominant cyanobiont irrespective of Azolla spp. and *A. microphylla ma*y consider as suitable feed for livestock based on nutrient profiling.

Characterization of cellulose degrading microbes from paper mill waste

Cellulose degrading bacteria were enriched from paper mill waste soil by three consecutive inoculations for three months with rice straw and filter paper. From the enrichment culture 11 bacteria were isolated and tested for cellulose degradation using CM cellulose (CMC) as substrate and Congo red indicator. Among them, only three bacteria (PC1-3) (Fig. 2.17) could mineralize CMC (Table 2.11).

These isolates were characterized by cultural, physiological and biochemical characters. The characters are given in Tables 2.12-2.14. The morphological, physiological and biochemical characters of the organisms were variable. Production of wide range cellular structural constituents suggests that they might be suitable for waste decomposition.

Table 2.11. CMC metabolism by the bacteria

Bacteria no.	Growth diameter (cm)	Halo zone (cm)	Activity efficiency (%)
PC1	2.20	3.98	80.91
PC2	1.61	3.01	86.96
PC3	1.74	2.56	47.13

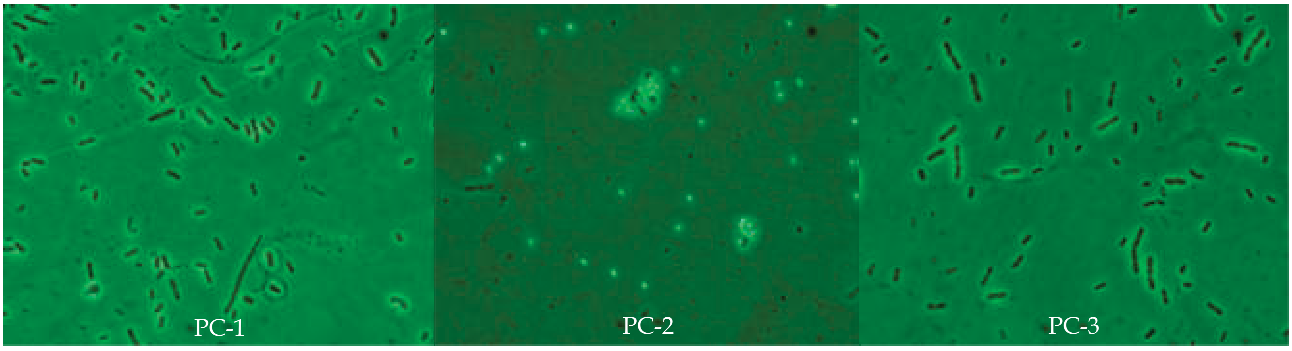


Fig. 2.17. The potent cellulose degrading bacteria

Table 2.12. Morphological and growth characters of the isolates

Isolate No.	Cell shape	Cell size (um)	Motility	Spore shape	pH tolerance	NaCl tolerance (%)	Temp. (°C) tolerance
PC1	Rod	4.01 x 0.98	Non-motile	Rod	5.7-6.8	10	5-45
PC2	Short rod	0.78 x 0.51	Highly motile	Nil	5.5-7.1	2	5-48
PC3	Rod	3.65 x 0.90	Motile	rod	5.0-7.6	10	5-40

Table 2.13. Physiological and biochemical characters of the bacteria

Isolate no.	Catalase	MR	VP	Indole	Citrate	Urease	NO_3 reduction
PC1	+	+	-	-	-	+	+
PC2	-	+	-	-	-	+	+
PC3	+	+	-	-	+w	+	-

Table 2.14. Extracellular enzyme production by the isolates

Isolate no.	Amylase	Pectinase	Caseinase	Gelatinase	Tributyrin hydrolysis	Tween 80 hydrolysis	Cellulase
PC1	+	-	+	+	+	+	+
PC2	+	-	+	+	+	+	+
PC3	+	-	+	+	+	+	+

PROGRAMME : 3

Rice Pests and Diseases-Emerging Problems and Their Management

Introduction

India's rice production target has been projected at 140 million tons by 2025 and also, a drive has been undertaken to double the farmers' income by 2020. In this context, protection technology has a greater role to play as rice crop experiences several biotic stresses which cause considerable yield loss of the crop. So, to combat these biotic stresses, a focused research programme has been undertaken at NRRI. Attempts have been made to address the problem through basic and strategic research on major insect pests and diseases under changing climatic scenario. The present programme has been formulated to solve the emerging pest problems in rice faced by the rice farmers of our country. This programme consists of seven projects out of which five are in the main Institute and one each in regional station of NRRI at Hazaribag and Gerua, respectively. The programme is focused on the study of population dynamics of insect pests and pathogens under changing climatic scenario, search for resistant donors against pest and diseases, IPM components like ecofriendly chemicals, biorational pesticides, biological control agents and IPM modules for the management of emerging rice insect pests and diseases.

Management of rice diseases in different ecologies

Identification of donors for resistance to different diseases

Sheath blight

A total of 1321 genotypes were screened under field condition during *kharif*, 2016 for resistance against sheath blight pathogen, *Rhizoctonia solani* Kuhn. Out of 604 farmer's varieties of Odisha, 31 varieties were moderately resistant (disease score of 1.1-3), whereas 56 varieties showed tolerant reaction (disease score of 3.1-5). In the case of 90 released varieties, 14 were found to be moderately resistant and 16 to be tolerant. Out of a total of 627 entries provided by ICAR-IIRR, Rajendranagar, Hyderabad under All India Co-ordinated Plant Pathology Trials, (NSN1, NHSN and DSN), 40 entries showed moderately resistant reaction while 59 were tolerant.

Bacterial blight

A total of 5000 lines were screened for bacterial blight resistance. The 45 days old plants were clip-inoculated using most virulent isolate of NRRI which is maintained in the net house and laboratory conditions. It was observed that 50 lines consistently showed resistance. Some of them are AC 36797, 35799, 36370, 36362, 35720, 36357, 36253, 35734, 36369, 35719, 35740, 36283, 35714 and 36294.

Brown spot

Out of 573 Assam rice collections screened, only 22 accessions were found to be moderately resistant with 4-5 rating to brown spot. Those are ARC 5846,5918, 5956, 5550, 6017, 6058, 6101, 6110, 6170, 6622, 7080, 7335, 10618, 10670, 10922, 10934, 11206, 11434, 11566, 11641, 11679 and 12006.

False smut

Altogether 158 DSN, 145 NHSN, 371 NSN1 and 100 ARC entries were screened during *Kharif,* 2016 under natural epiphytotic condition against false smut disease. Entries 109 DSN, 127 NHSN, 305 NSN1 and 77 ARC were free from false smut infection. Twenty four NRRI varieties were evaluated against false smut pathogen following the method of Zhang *et.al.* (2006). Eight varieties out of 24, showed resistant to moderate resistant reaction. Ranjit and Luna Suvarna were free from infection, whereas CR Dhan 907, CR Dhan 303, Nua Kalajeera, Ketakijoha, Nua Dhusara, Nua Chinikamini have exhibited moderate resistant against false smut pathogen.

Blast

Among the 1314 germplasm accessions (project on biodiversity sponsored by DRR (ICAR-IIRR) - NBPGR) evaluated for leaf blast resistance at Hazaribagh, 19 accessions (IC 245865, 246277, 246403, 246274, 454167, 121865, 199562, 218270, 245927, 246012, 246228, 246273 and 246659) were highly resistant (SES scores 0, 1, 2).

Table 3.1: Evaluation of some NRRI varieties against false smut disease

Variety	SD	SDS	DI (%)	DIS	CEI	CEIS	DR
CR Dhan 907	1.0	1	2.4	1	1	3	MR
CR Dhan 303	1.8	3	8.8	3	3	3	MR
Nua Kalajeera	1.0	1	3.8	3	2.2	3	MR
Ketakijoha	1.5	3	8.1	3	3	3	MR
Nua Dhusara	1.0	1	3.6	3	2.2	3	MR
Nua Chinikamini	2.0	3	8.6	3	3	3	MR
Ranjit	0.0	0	0.0	0	0	0	HR
Luna Suvarna	0.0	0.0	0.0	0.0	0	0.0	HR

N.B. : SD= smut ball/panicle;SDS=smut ball density score (0-9 scale); DI% = % disease incidence (% infected tiller); DIS = Disease incidence score (0-9 scale); CEI= Comprehensive evaluation index; CEIS=comprehensive evaluation index score (0-9 scale); CEI= (DISx60+SDSx40)/100; DI%= (No. of infected panicle/Total no. of panicle)/100.

Out of 373 accessions evaluated under NSN 1, 18 accessions, namely, IET 24692, 24905, 24934, 24797, 24982, 25113, 25358, 25103, 25618, 25278, 25121, 24983, 24904, 24956, 24331, 24919, 25515 and 25484 were found highly resistant, whereas under NSN 2, 12 accessions (IET 26190, 26351, 25935, 26157, 26302, 26194, 26287, 26365, 26325, 26375, 25138 and 26345) were resistant to leaf blast.

An attempt has been made to find out the resistance by screening and studying the genetic diversity of eighty released rice varieties of National Rice Research Institute (NRRI-RVs) using molecular markers linked to eleven major blast resistance (R) genes *viz., Pib*, *Piz*, *Piz-t*, *Pik*, *Pik-p*, *Pik-h*, *Pita/Pita*-2, *Pi2*, *Pi9*, *Pi1* and *Pi5*. Out of 80 varieties evaluated against leaf blast in uniform blast nursery, 19 varieties were resistant, 21 were moderately resistant and remaining 40 varieties were susceptible. Rice varieties possessing blast resistance genes varied from four to eleven. The gene frequencies of the 11 blast resistance genes ranged from 18.75 to 100%. The cluster analysis based on eleven R genes, grouped the 80 varieties into two major clusters at 53% genetic similarity coefficient. The polymorphism information content value for 12 markers varied from 0 to 0.37 at an average of 0.24. The phenotypic variance of these four markers ranged from 3.5% to 7.7%. Out of 12 markers, only four markers, 195R-1, Pita3, YL155/YL87 and 40N23r corresponded to three broad spectrum *R* genes *viz., Pi9*, *Pita/Pita2* and *Pi5* were found to be significantly associated with the blast disease with explaining phenotypic variance from 3.5% to 7.7%. The population structure analysis and principal coordinate analysis divided the entire 80 varieties into two sub-groups with one admixture. The outcome of this study would help to formulate strategies for improving rice blast resistance worldwide. Further, these resistant varieties would be useful for genetic studies, plant-pathogen interaction, identification of novel *R* genes, development of new resistant varieties through marker-assisted breeding for improving rice blast resistance in India and worldwide (Fig 3.1).

Bakanae disease of rice

Out of 50 genotypes screened under artificial inoculation method, Brown gora, Geetanjali, FL 478 and TN1 were found with moderate disease infection.

A roving survey was conducted during *kharif,* 2016 in different villages of Cuttack and Jajpur districts of coastal Odisha. Kisannagar and Tangi-choudwar blocks of Cuttack district and Kalinganagar block of Jajpur district were surveyed for this disease incidence and loss estimation. Significant disease incidence in some of the popular rice varieties like Pooja, Naveen, Abhishek, Pratiksha, Swarna, Swarna *sub-1* and hybrid Rajalakshmi was observed. Severe

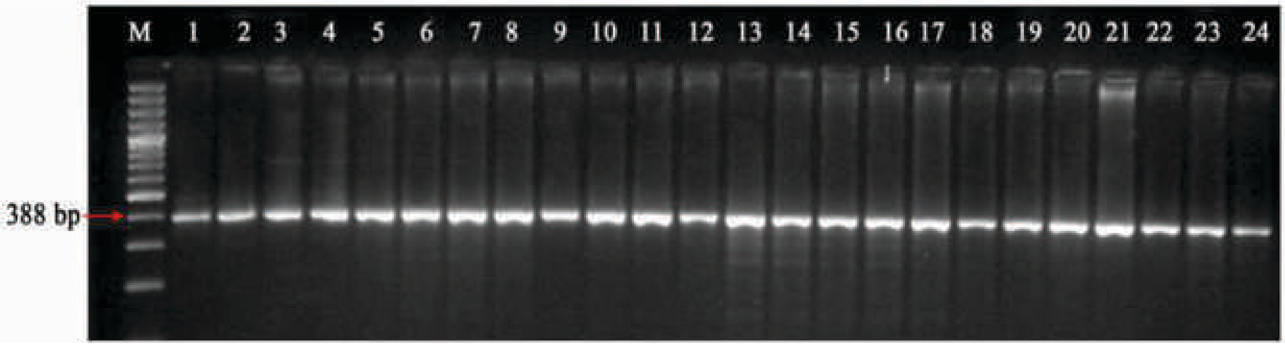
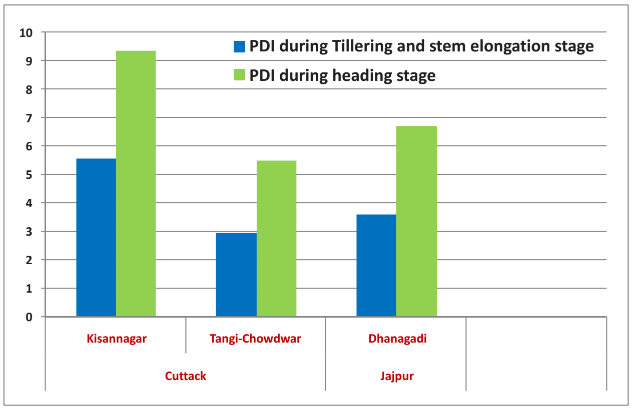


Fig. 3.1. Agarose gel photograph of 22 NRRI-RVs, to know the presence or absence of 388 bp of Pib rice blast resistance gene amplified with SNP marker Pb28.

disease incidence and damage in all these rice varieties was recorded. The maximum disease incidence was noticed from tillering and stem elongation to heading stage. The incidence varied from 1-25.50 per cent in different villages of Cuttack and Jajpur district (Fig 3.2). The maximum disease incidence of 12.50 per cent was recorded in Ratilo village on variety Pooja. Lowest disease incidence was recorded in Gurujunga, Guali villages (1%) during early tillering stage. During late tillering and panicle emergence stage, the disease incidence was highest at Ratilo village of Kisannagar block with 25.50 per cent disease incidence and lowest at Gurujunga and Guali villages of Tangi-chowdwar block with 1 per cent disease incidence. Among the most popular varieties growing in these locations, the maximum disease incidence was recorded on Pooja with a range of 2.5 to 25.50 per cent. The hybrid Rajalaxmi recorded lowest disease incidence of 1-2% (Fig. 3.3).



PDI :Per cent disease infection

Fig. 3.2. Average disease incidence of rice bakanae disaese in two districts of coastal odisha.

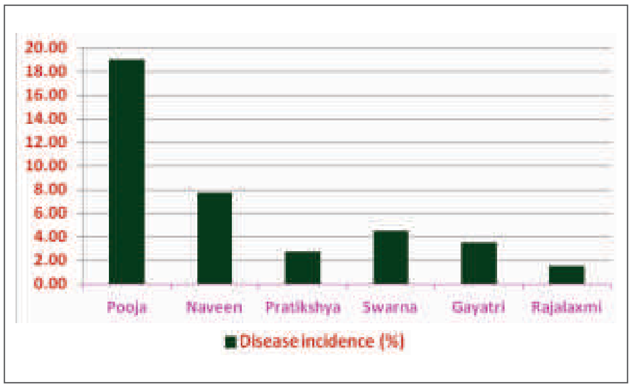


Fig. 3.3. Average disease incidence recorded in popular rice varieties from two districts of coastal odisha.

Yield loss due to False smut

Yield loss of 16 NRRI varieties due to false smut infection was estimated. Except Ranjit and Luna Suvarna (No false smut infection was observed), it was observed that yield loss ranges from 0.12-8.55%. Nua Chinikamini, Nua Kalajira, Luna Sampa and Nua Dhusara were less affected (yield loss 0.12-0.22%) Moderate yield loss (2.75-4.13%) was observed in Varsha, Ajay and Pooja, whereas Tapaswini was most affected varieties (8.55%).

Impact of false smut disease on seed health

Healthy and diseased seeds of 11 varieties were taken separately for studying seedling vigour. Seedling vigor index (SVI) was comparatively low in diseased grain than healthy grain (Fig. 3.4). Reduction of seedling vigor in diseased grain in comparision to healthy grain was 5.2-29.8%. Rudimentary and subnormal growth of the root hairs was observed in the seedlings of infected seeds. Percentage decrease of SVI was ~5 in Ranjit, while in all other varieties it was >12%. Thus it is considered that, Ranjit was least affected and remaining varieties were substantially affected because of false smut infection.

Management of false smut disease of rice

For optimizing fungicide spray (as prophylactic measure) to manage false smut disease, an experiment was conducted where staggered planting of three different varieties (Pooja, Tapaswini and Ajay) was done on 11th August 2016 (early planting), 25th August 2016 (normal planting) and 10th Sept., 2016 (late planting). No incidence was observed in late planting but moderate to high disease incidence was observed in early and normal planting in case of Tapaswini and Ajay. Per cent hill infection (HI), per cent tiller infection (TI) and appearance of average false smut ball number (AFB) were significantly different ($p<0.01$) with respect to planting date. TI was significantly varied with respect to planting date*variety also (Fig. 3.4). Both TI and HI was positively correlated with yield loss (%). Significantly, result of last *Kharif* (2015-16) showed highest tiller infection in late planted crop (3rd Sept.). Two years weather data and experiment data revealed that frequent rainfall during booting to flowering stages, temperature (25-30 °C) and high RH (>90%) induces more false smut disease incidence. Thus management of false smut through prophylactic spray should include weather forecast.

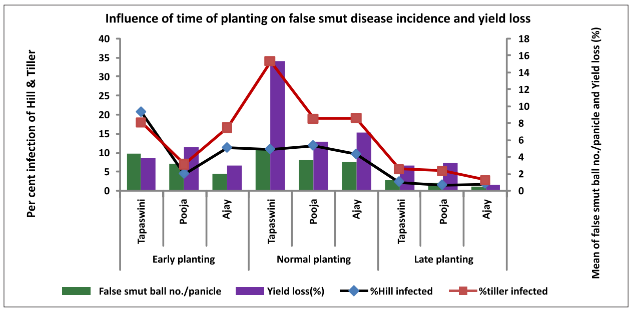


Fig. 3.4. Influence of time of planting on false smut disease incidence

Effect of false smut on quality of grain

A preliminary study of 13 NRRI varieties revealed that amylase content (AC) was significantly high ($p<0.01$) in diseased grain than healthy grain. Other nutritional factors like soluble protein and antioxidant content was significantly low ($p<0.01$), whereas total phenolic content were significantly high ($p<0.01$) in grains of diseased panicles. High AC in diseased grains attributed negative cooking quality and low protein and antioxidant lower the nutritional quality. High phenol content may prove the presence of false smut spore in the grains (Fig. 3.5).

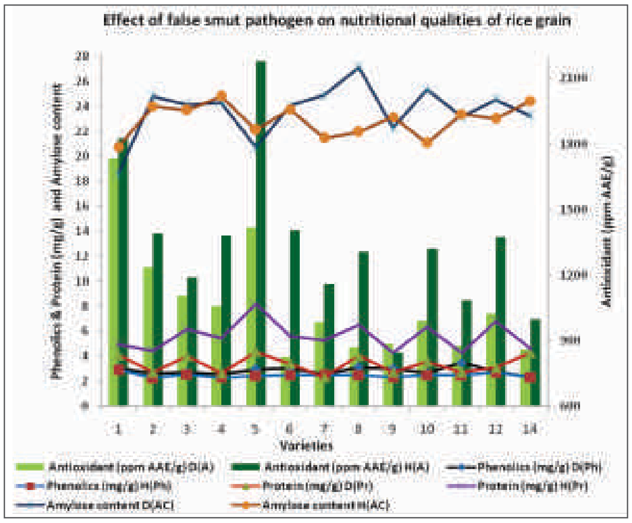


Fig. 3.5. Effect of false smut on nutritional quality parameter of rice grain

Identification and genetic variability of major and emerging diseases of rice

Bacterial blight pathogen (*Xanthomonas oryzae pv oryzae*)

Thirty five isolates of bacterial blight pathogen (*Xanthomonas oryzae pv oryzae*) were grouped according to their pathogenicity and it varied from isolate to isolate. A total of 10 racial structures were present among all the isolates. Similarly the virulence analyses of 28 isolates of *Rhizoctonia solani* revealed that six isolates were hyper virulent.

Isolation and Molecular characterization of sheath rot pathogens.

A total of 15 isolates were obtained from diseased rice sheath portion. Pathogenicity of *Sarocladium oryzae* and *Fusarium* isolates was confirmed and isolate S2 recorded the maximum disease incidence of 79.25%. All the pathogens have been identified based on the morphological characters. Isolates were confirmed at molecular level using universal fungal ITS primers. The sequences have submitted in NCBI gene bank and their accession numbers are MF033164, MF033165, MF033166, MF033167, MF033168, MF033169, MF033170, MF033171, MF033172, MF033173, MF033174, MF033175 and MF033176.

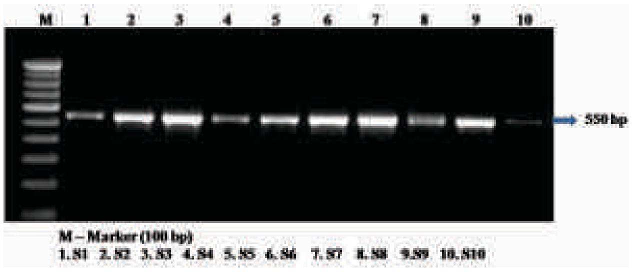


Fig. 3.6. PCR amplification of ITS region of *Sarocladium* isolates

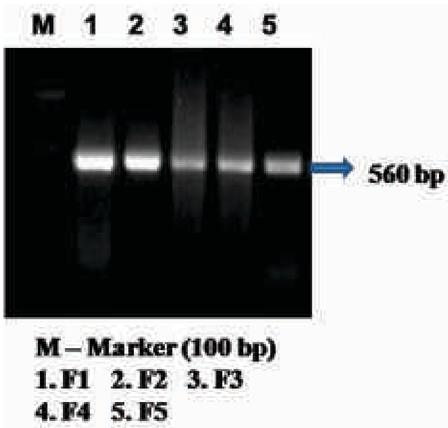


Fig. 3.7. PCR amplification of ITS region of *Fusarium isolates*

Morphological and molecular characterization of rice blast isolates from Odisha and Chhattisgarh

Twenty isolates of *M. oryzae* were collected from Odisha and 52 isolates from Chhattisgarh were morphologically characterized into three groups based on colony colour i.e., greyish blackish, greyish and white, and in two group based on the texture of the colony as smooth and rough (Figure 3.8). The sequence analysis of the Chhattisgarh isolate (CG-2) showed 97% sequence identity with the Indian isolate. The sequence analysis between Chhattisgarh and Odisha isolates showed the maximum similarity of 96% between CG-1 and OD-4 isolates while minimum similarity of 82% was shared between OD-6 and CG-4. In phylogenetic analysis, overall three major genogroups were formed. CG-4 and CG-5 are in different group, whereas all other *M. oryzae* isolates are in one cluster (Fig. 3.8). In phylogenetic analysis with the world isolates, overall two major groups were formed. CG-2 and CG-43 along with, OD-2, KJ522979 (Indian isolate) and KJ766301 (Malaysia isolate) are in one group, whereas other isolate from Kenya, Japan, China are in a separate group (Fig. 3.9). In the mating analysis of *M. oryzae*, we were able to detect only a single mating-type in *M. oryzae* populations from rice growing area of Odisha. This suggests that *M. oryzae* is not sexually reproducing, which can be vital in the population dynamics of this blast pathogen.

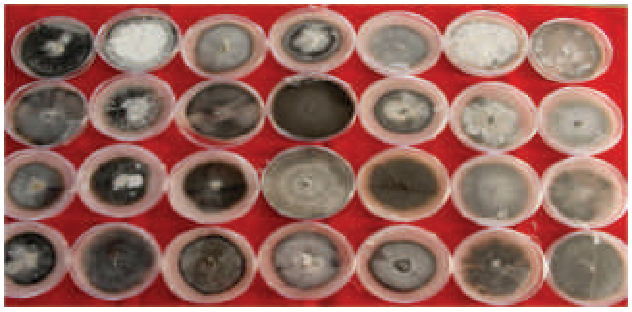


Fig. 3.8. Morphologically different isolates of *M. oryzae* from Chhattisgarh

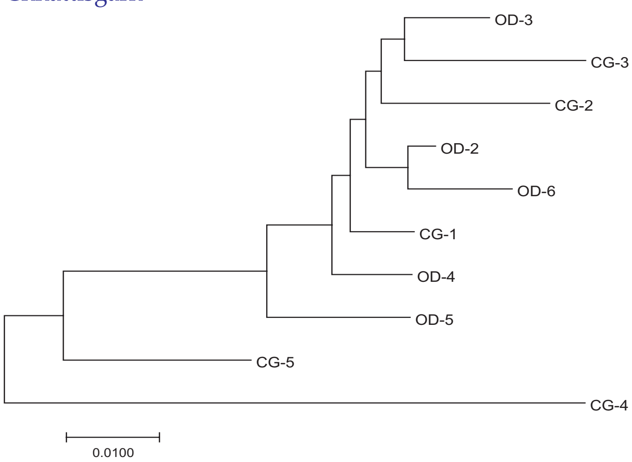


Fig. 3.9. Genetic relationship among *M. oryzae* isolates of Odisha and Chhattisgarh

Bakanae disease (*Fusarium fujikuroi*): Morpho-physiological characterization

The disease is well known to produce various symptoms such as abnormal elongation, seedling death, foot rot, formation of adventitious roots from each node, pale green plants with reduced number of tillers and panicle which are partially filled or chaffy and plants finally dies (Fig. 3.10-3.13). The infected plant samples were collected from surveyed locations to isolate the pathogen. A total of 64 *Fusarium* spp. isolated on PDA from infected plant and seed samples. The isolates were identified based on the keys as described in material and methods. The isolates were further grouped into three categories based on morpho-physiological characters. Group I consist of 39 (60.93%) isolates which were fast growing (> 6 cm) produced white cottony mycelium with smooth margin. These isolates produced pink pigmentation and 80-100 micro conidia (size: 5 x 3.25-8.75 μm) and 10-50 macro conidia (size: 30.25 x 7.00-10 μm). Group II consists of 14 (21.87 %) isolates which were moderately growing (4-5.9 cm) with buff colored mycelium and smooth margin. These isolates produced yellow pigmentation, 60-65 micro conidia (size: 7.25 x 3.25-8.75 μm) and 5-10 macro conidia (size: 28.0 x 7.50-12 μm). Group III consists of 11 (17.18 %) isolates which were slow growing (3-4.9 cm) with white to grey mycelium, smooth margin and purple pigmentation, 40-50 micro conidia (size : 7.50 x 3.75-10 μm) and 5-10 macro conidia (size: 26.25 x 5–8.5 μm) were recorded in these isolates. The chlamydospores were absent in all these isolates.

Fig. 3.10. Foot rot in nurseries

Fig. 3.11. Abnormal elongation of Plants. Var:Pooja

Fig. 3.12. Complete death of the plant

Fig. 3.13. Fusarium fujikuroi

Virulence analysis of *Fusarium* isolates

In order to determine the degree of virulence of different isolates of *Fusarium* spp, the experiment was conducted on susceptible variety Pooja and different symptoms like abnormal elongation, foot rot, stunting and death were recorded. Based on pathogenicity, all the 60 isolates were grouped into three categories: highly virulent, moderately virulent and virulent. Out of 64 isolates, 47 (75.00%) isolates found to be highly virulent, eight (13.33%) were virulent and seven (11.66%) isolates were moderately virulent. There was a significant difference between the isolates in causing the disease.

Chemical control of rice diseases

Bioassay of fungicide against false smut pathogen (*Usilaginoidea virens*)

Two broad spectrum systemic fungicides, *viz.*, Azoxystrobin 25% and Thifluzamide 25% were tested against the *U. virens* culture of native isolate following poisoned food method under laboratory condition. It was observed that both Azoxystrobin 25% and Thifluzamide 25% inhibit the fungal growth nearly 50% at 1 ppm, while inhibit ⩾ 80% at 20 ppm concentration (Table 3.4).

Evaluation of fungicides against sheath blight disease

Field trial was conducted during *kharif* 2016 with susceptible rice variety (Tapaswini) in R.B.D. with four replications for evaluating the efficacy of six fungicides, namely, Tricyclazole 20% + tebuconazole 16%SC at the dosage of 2.0 ml litre^{-1} (T_1) and 2.25 ml litre^{-1} (T_2), Tricyclazole 75%WP @ 0.6 g litre^{-1} (T_3), Tebuconazole 25% @1.5 ml litre^{-1} (T_4), Hexaconazole 5%EC @2.0 ml litre^{-1} (T_5) and Carbendazim 50% WP 1.0 g litre^{-1} (T_6). The rice plants were artificially inoculated with the virulent sheath blight isolate (strain ShBSL4) after 30 days of transplanting. The first spray of the above chemicals in their respective doses was undertaken after 15 days of artificial inoculation and second spray after 10 days of the first spray.

Out of seven treatments, the fungicide Tricyclazole 20% + tebuconazole 16%SC @ 2.25 ml litre^{-1} caused 70% reduction in disease incidence and 77.1% reduction in disease severity over the untreated control (T_7). It was followed by Tricyclazole 20% + tebuconazole 16%SC @ 2.0 ml litre^{-1} and Tebuconazole 25%. Grain and straw yield were the highest i.e, 5.67 t ha^{-1} and 6.95 t ha^{-1}, respectively in Tricyclazole 20% + tebuconazole 16%SC @ 2.25 ml litre^{-1} followed by grain yield of 5.45 t ha^{-1}, straw yield of 6.72 t ha^{-1} in Tricyclazole 20% + tebuconazole 16%SC @ 2.0 ml litre^{-1}; 4.84 t ha^{-1} grain yield as compared to grain yield of 3.36 t ha^{-1} and straw yield of 4.64 t ha^{-1} in untreated control (Table 3.5).

Table 3.4. Sensitivity of fungicide against false smut pathogen *(Usilaginoidea virens)*

Fungicide	Per cent growth inhibition				
	1 ppm	10 ppm	20 ppm	30 ppm	Control
Azoxystrobin 25%	50.4	95.3	100	100	0
Thifluzamide 24%	43.2	74.2	81.4	87.5	0

Table 3.5. Field efficacy of fungicides against sheath blight of rice

Treatments	Dose/lit	Disease Incidence(DI)			Disease Severity(DS)			Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
		% DI after 1st spray	% DI after 2nd spray	% reduction in DI	% DS after 1st spray	% DS after 2nd spray	% reduction in DS		
T_1	2.0 ml	33.8 (35.4)*	28.6 (32.2)	64.0	25.4 (29.8)	19.8 (26.1)	72.3	5.45	6.12
T_2	2.25 ml	28.2 (31.8)	23.8 (29.1)	70.0	22.6 (28.0)	16.4 (23.7)	77.1	5.67	6.95
T_3	0.6 g	57.0 (49.1)	54.2 (47.4)	31.7	57.7 (49.5)	50.6 (45.3)	29.3	4.08	5.21
T_4	1.5 ml	41.7 (40.1)	38.4 (38.2)	51.6	39.8 (39.0)	32.2 (34.8)	55.0	4.84	5.80
T_5	2.0 ml	46.3 (42.8)	43.5 (41.2)	45.2	45.0 (42.1)	41.9 (40.3)	41.5	4.64	5.78
T_6	1.0 g	49.4 (44.6)	46.2 (42.7)	41.8	47.5 (43.5)	42.3 (40.5)	40.9	4.48	5.77
T_7	-	80.0 (63.8)	79.4 (63.3)	-	72.4 (58.5)	71.6 (57.8)	-	3.36	4.64
CD (at 5%)	-	7.60	5.82	-	9.11	4.82	-	1.07	1.34

* Figures in parentheses are the angular transformed values

Efficacy of nano-silver against rice diseases

Indigenous biosynthesized silver nano-partilces (Ag-NPs) mediated by rice plant extracts were tested against brown spot and blast causing fungi. It was effective against brown spot but was not effective against blast in *in-vitro* condition. *Helminthosporium oryzae* (*Bipolaris oryzae*) growth was inhibited to the tune of 42% after 48 hours of inoculation when media was mixed with 10% of silver nanoparticles (Ag-NPs) solution (Fig. 3.14).

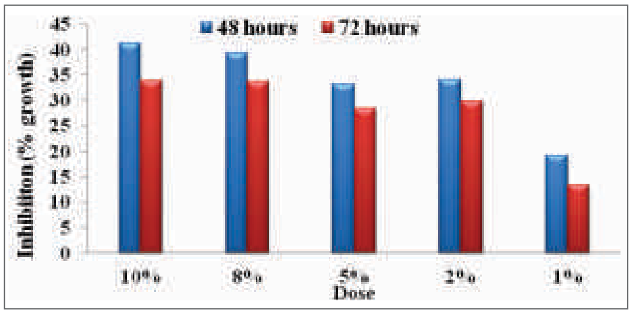


Fig. 3.14. Growth inhibition of Helminthosporium oryzae at different concentration of Ag-NP

Similarly, under *in vivo* condition, Ag-NPs had shown better activity compared to silver nitrate solution. Infection due to sheath blight was 3.4% in 20% of silver nanoparticles spray treatment compared to control which had 13.89% of infection (Fig. 3.15).

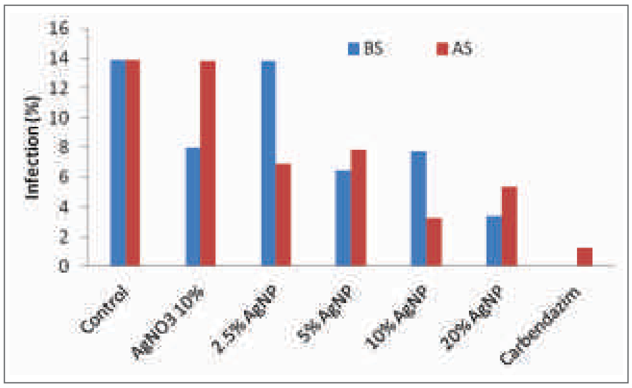


Fig. 3.15. Infection levels of sheath blight pathogen at different concentration of Ag-NP

Bio-control of rice diseases

Seed of the rice variety Naveen was treated with four different *Trichoderma* isolates and data was recorded for their growth promotion activity, seedling vigor and induction of defense in the host. It was observed that all the *Trichoderma* isolates were promoting growth in the seedling (Fig. 3.16) giving better seedling vigour. The defense enzyme expression was higher in all the treated seedlings than that of the absolute control (Table 3.6).

Fig. 3.16. seedlings treated with Trichoderma (T_1, T_5, T_9 and T_{13}) are showing better vigour than the control (T_0)

Table 3.6: Defense enzyme expression of seedlings upon *Trichoderma* treatment.

Trichoderma isolates	Catalase activity of root (in unit/ min/ gm sample)	Catalase activity of shoot (in unit/ min/ gm sample)	Peroxidase activity of root (in unit/ min/ gm sample)	Peroxidase activity of shoot (in unit/ min/ gm sample)	SOD activity of root (in unit/ min/ gm sample)	SOD activity of shoot (in unit/ min/ gm sample)
T_0	4.00^{C}	6.00^{C}	0.53^{C}	0.40^{C}	3.81^{D}	6.14^{D}
T_1	15.67^{A}	21.00^{AB}	1.22^{A}	0.65^{D}	6.99^{C}	9.22^{B}
T_5	15.00^{A}	24.00^{A}	1.58^{A}	1.11^{A}	6.04^{C}	8.79^{C}
T_9	15.67^{A}	18.00^{B}	0.82^{B}	0.62^{B}	7.86^{B}	9.42^{B}
T_{13}	11.00^{B}	16.67^{B}	1.12^{A}	0.73^{AB}	9.54^{A}	11.95^{A}
P-Value	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

Rice Endophyte interaction with pathogens and pests in response to environment

Effect of endophytic *Dendryphiella* isolates FV16 II and FV39II on rice growth at seedling stage

Seeds of Annapurna were treated with @ 10 gm *Dendryphiella* spp. (10^8cfu/g). The seeds were sown in the sterile soil. Twenty days old seedlings were uprooted for their agronomical characteristics. It was observed that the endophytic isolate FV39II were better than that of FV16II. However both the endophytes represented better growth than that of the control i.e not treated with any endophyte (Table 3.7).

Effect of *Dendrphiella* spp. on rice variety Shatabdi grown in soil infested with *Rhizoctonia solani*

Dendryphiella spp. grew well in rice media and also on the sterilized soil containing FYM and other farm waste. Compost & soil were mixed (by volume in 1:1 ratio) and the inoculum raised in one lit. of 'rice media' which was added to 24 kg of compost containing soil. It was incubated for seven days at high humidity before using it for field/net house inoculations. The *Dendryphiella*/pathogen inoculum @ 1 kg of soil (by volume) was applied to each sub plot. Sub-plots in field were inoculated at panicle initiation stage to know the impact of both *Dendryphiella* strains on sheath blight disease of rice and also on the yield attributes of rice like % filled grain, single spikelet weight and yield per plot (YR) in gram of the cultivar Shatabdi (Table 3.8).

Effect of endophytes against rice diseases

The seed treated with *Dendryphiella* showed better survival in sick soil made with *Sclerotium oryzae*, the causal agent of seedling blight than that of control. The infection % was much less in endophyte treated seedlings than that of the control (Fig. 3.19).

Table 3.7. Effect of endophyte treatment on rice seedling

Treatment Name	Dry root weight in gm	Dry shoot weight in gm	Fresh root weight in gm	Fresh Shoot weight in gm	No. of leaves	Root Length in cm	Shoot Length in cm
Control	0.01^C	0.12^C	0.04^C	0.39^C	4.00^C	4.88^C	32.36^C
FV1611	0.01^B	0.18^B	0.06^B	0.43^B	5.00^B	6.52^B	36.99^B
FV3911	0.02^A	0.26^A	0.08^A	0.61^A	5.00^A	8.48^A	41.78^A
CV(%)	1.80	1.78	4.06	0.58	0.00	3.13	1.26

Table 3.8. Effect of *Dendrphiella* spp. on yield attributes of rice variety Shatabdi grown in soil infested with *Rhizoctonia solani*

Treatment Description	Filled grain %	Single spikelet weight(mg)	YR
***Rhizoctonia solani* + *Dendryphiella* sp. FV16**	81.41^{AB}	13.61^B	1114.92^{AB}
***Rhizoctonia solani* + *Dendryphiella* sp.FV39**	80.07^B	13.38^B	1083.40^B
Rhizoctonia solani	75.69^C	12.27^D	947.30^D
***Dendryphiella* sp. FV16**	82.59^A	13.99^A	1159.06^A
***Dendryphiella* sp.FV39**	81.34^{AB}	13.54^B	1105.81^B
Untreated Control	77.07^C	12.78^C	997.85^C
LSD at 1%	1.7082	0.3763	44.924

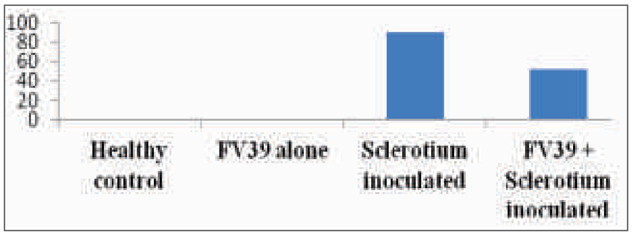


Fig.3.19. Effect of *Dendryphiella* on seedling blight of rice

Fig.3.20. Ustilaginoidea virens growth is suppressed by *Dendryphiella* (FV39)

The *Dendryphiella* spp. suppressed the growth of *Ustilaginoidea virens*, the false smut pathogen in dual culture assay (Fig. 3.20) giving an indication that it may be used for management of false smut.

The cell free culture filtrate (CFCF) of endophytic *Penicillium oryzae* (Gen Bank accession no. KC515385) was tested against sheath blight pathogen *Rhizoctonia solani* and it was observed that the CFCF can reduce the mycelia growth of *R. solani* (Table-3.9).

Table 3.9 Effect of Cell-free Cultural Filtrate of endophyte *Penicillium oryzae* (GenBank accession no. KC515385) on mycelia growth of *Rhizoctonia* species pathogenic to rice

Treatment Name	colony diam. (mm) Day-3	colony diam. (mm) Day-4	Equation describing growth in colony diameter (mm)
Untreated *Rhizoctonia solani* c.o.sheath blight of rice	80.80^{A}	90.00^{A}	y = 64.55ln(x) + 25.64
Rhizoctonia solani c.o.sheath blight of rice treated with CCF of *Penicillium oryzae*	7.60^{C}	11.00^{C}	$y = 2.916e^{0.480x}$
Untreated *Rhizoctonia oryzae sativae* c.o.aggregate sheath spot of rice	28.80^{B}	65.40^{B}	y = 30.68x
Rhizoctonia oryzae sativae c.o. aggregate sheath spot of rice treated with CCF of *Penicillium oryzae*	4.60^{C}	10.60^{C}	y = 7.443x
LSD at 5%	3.0112	3.5558	-

Means followed by same superscript are not statistically significant using Fisher's Least significant Differences

Table 3.8. Expression of defense enzymes under endophyte treatments

Treatment name	APX (unit/min/g of sample)	Rank of Trt	Cat (unit/min/g of sample)	Rank of Trt	GPX (unit/min/g of sample)	Rank of Trt	PPO (Unit/min/g of sample)	Rank of Trt
AC	0.05	3	0.83^{A}	3	0.0009 ^{C}	3	0.02 ^{B}	3
FV-16	0.10	1	0.86^{A}	2	0.00436 ^{B}	2	0.03 ^{A}	1
FV-39	0.10	2	0.14^{A}	1	0.0091 ^{A}	1	0.03 ^{A}	2
CV (%)	21.48		12.04		2.14		7.23	

AC= absolute control, FV-16 & FV-39 are treated with endophytes.

Apx=Ascorbate peroxidase, Cat= Catalase, Gpx= Guaicol peroxidase and PPO= Polyphenol oxidase.

Effect of endophyte treatments on expression of defense enzymes in rice

Then defense enzyme expression namely ascorbate peroxidase, catalase, Guaicol peroxidase, and polyphenol oxidase were studied in two different endophytes treated rice variety Annapurna along with control and it was observed that the endophyte treated plants gave higher expression of defense enzymes than that of control (Table 3.10).

Chlorophyll content was also compared among the treated plants with that of untreated plants and it was observed that the chlorophyll content was much higher in the treated plants than that of control (Table 3.9).

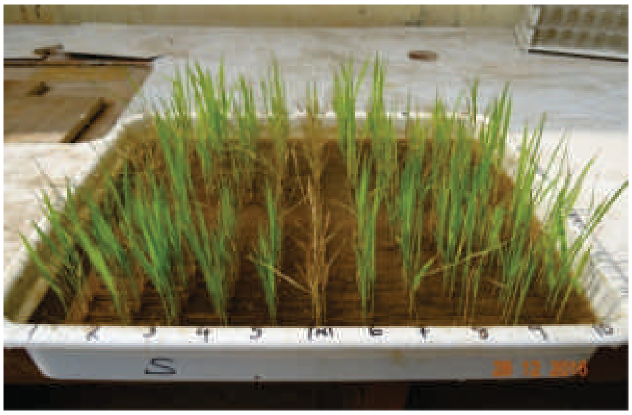
Identification and utilization of host plant resistance in rice against major insect and nematode pests.

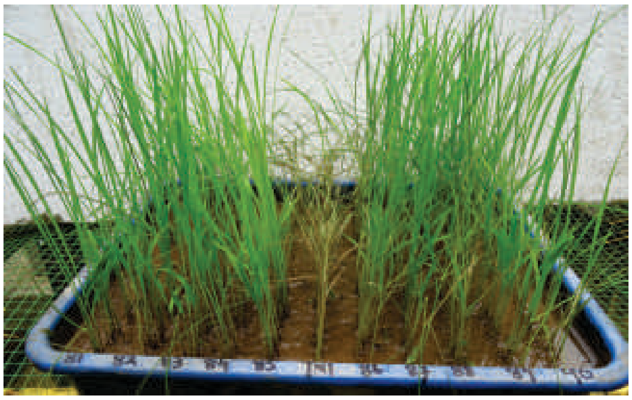
Identification of resistant donors against Brown plant hopper (BPH), *Nilaparvata lugens* Stal

Forty-five accessions derived from wild rice, were screened under net house condition. Three accessions, namely, IR 73382-80-9-3-13-2-2-1-3-B (IR 64 x *O. rufipogon*), IR 75870-8-1-2-B-6-1-1-B (IR 64 x *O. glaberrima*) and IR 77390-6-2-18-2-B (IR 69502-6-SRN-3-UBN-1-B x *O. glaberrima*) were found highly resistant with score 1.

The identified donor IR 75870-8-1-2-B-6-1-1-B was utilized in breeding programme in the background of MTU 1010 and Swarna. Out of 99 lines developed from MTU1010 x IR 75870-8-1-2-B-6-1-1-B, three were highly resistant with score 1, 15 were resistant with score 3 and 16 were moderately resistant with score 5. Selected F_4 plants of 16 lines of IR 113050-B series, i.e., 2, 8, 9, 14, 15, 17, 18, 21, 51, 81, 82, 83, 85, 94, 98, 100, 5 plants of each, were screened again. 15 lines were highly resistant. Out of 100 lines developed in the background of Swarna, three were highly resistant with score 1, 25 were resistant with score 3 and 13 were moderately resistant with score 5.

Out of eighty entries from AICRIP plant hopper screening trial, only one entry RP 2068–18–3–15 was found highly resistant with score 1. MTU 1247 was resistant with score 3 and was comparable with PTB 33. JGL 27020 was moderately resistant with score 5.





MTU 1010 x IR75870-8-1-2-B-6-1-1-B

Fig. 3.19. Screening of rice germplasm against BPH in net house

Table 3.9.Variations in chlorophyll content under endophyte treatements

	Chla		Chlb		Total_chl	
	Chla	Rank of Treatment	Chlb	Rank of Treatment	Total_chl	Rank of Treatment
AC	12.94^{C}	3	4.26^{C}	3	17.15^{C}	3
FV16	18.52^{B}	2	6.04^{B}	2	24.56^{B}	2
FV39	29.64^{A}	1	10.05^{A}	1	40.12^{A}	1
	0.30	.	0.61	.	0.41	.

Out of 200 ARC(Assam Rice Collections) genotypes, four genotypes, ARC 333, 356, 11324 and 11309 were found highly resistant with score 1 and 28 genotypes were moderately resistant.

Host plant resistance to rice Gall midge, *Orseolia oryzae* Wood-Mason

A total of 408 rice genotypes from NBPGR were screened against gall midge of NRRI population. The NBPGR IC 121824, 199557, 199558, 121850A1, 208983, 211156 and Aganni were found highly resistant. All the gall midge known gene differentials having resistant genes 1, 2, 3, 4, 5, 6, 7, 9, 10 and 11 showed susceptible reaction to NRRI gall midge population (Biotype 2) indicating a population change. But however, this will be confirmed through standardized evaluation method of gall midge population monitoring.

Out of 206 Assam Rice accessions (ARC) the ARC 5832, 5985, 6088, 6155, 6551, 6582, 6606, 6609, 6612, 6625 and 6631 were found highly resistant (with SES score '0'). ARC 5833, 5922, 6628 were categorized as resistant (with SES score '1').

Host plant resistance to white-backed plant hopper (WBPH), Sogatella furcifera Horvath

A total of 65 accessions including resistant accessions reported earlier were screened to validate their present status of resistance. Only four accessions, i.e., AC 34222, AC 34264, AC 38468 and AC 42425 were confirmed as resistant with score 1.

Table 3.10. Reaction of known gene differentials against NRRI-gall midge population

Sl. No.	Genotypes	R gene	Score (0 to 9)				
			2012	2013	2014	2015	2016
1	Kavya	GM1	9	7	7	9	9
2	W 1263	GM1	0	0	5	7	9
3	Phalguna	GM2	9	9	7	7	9
4	RP2068-18-3-5	GM3	0	0	7	7	9
5	Abhaya	GM4	0	9	7	9	9
6	ARC 5984	GM5	0	5	3	3	9
7	Dukong I	GM6	9	7	7	9	9
8	RP 2333-156-8	GM7	0	9	7	7	7
9	Madhuru L9	GM9	9	9	5	9	9
10	BG 380-2	GM10	0	0	7	9	9
11	MR 2583	GM11	0	5	7	7	
12	MR 1523	GM11			9	9	9
13	Aganni	GM 8	0	0	0	0	0
14	TN1	none	9	9	9	9	9

Host plant resistance to yellow stem borer (YSB), *Scirpophaga incertulus* Walker

Field screening of 63 breeding lines (CR 1009 x *Oryza brachyantha*), 32 tropical japonica lines, 12 double haploid lines with one hybrid CRHR 32 revealed that two entries *viz*., tropical japonica lines: WC-152; double haploid lines: SS-5 showed zero SES score in the consecutive two years of screening as against the susceptible check TN 1 with damage score of 5. However, during *rabi* 2017, wild derivatives: B-514-32, B–506-2-18 & B-2-12-14 showed damage score of 1 (Fig. 3.20).

Fig. 3.20. Identification of varieties resistant/tolerant to *Sitotroga cerealella* Olivier

Rice grain resistance to *Sitotroga cerealella*

Fifteen rice varieties grains were screened for resistant against the *Sitotroga cerealella* which is an important pest in stored grain of rice. The grains of all test varieties were conditioned in the laboratory for 20 days at the same temperature and relative humidity (28±2ºC and 65±5% RH). Per cent weight loss and adult progeny was used as the parameters to screen out resistant and susceptible varieties against this insect pest. Results indicated that no variety was completely immune to the infestation of this pest. Varieties Ketakijoha, Pyari and Sarala registered lowest moth

Table 3.11. Values of biodiversity indices for culturable bacteria in the imidacloprid treated soil

Treatment	0 day	7 day	15 day	21 day	30 day
Eco-physiological Index (EP)					
CR	0.256±0.054*	0.349±0.035	0.470±0.047	0.365±0.028	0.326±0.033
RD	0.519±0.036	0.260±0.039	0.421±0.040	0.237±0.014	0.415±0.031
2RD	0.443±0.074	0.374±0.027	0.258±0.038	0.381±0.019	0.348±0.038
5RD	0.312±0.051	0.299±0.025	0.278±0.023	0.503±0.080	0.507±0.051
10RD	0.424±0.022	0.352±0.041	0.268±0.028	0.294±0.027	0.446±0.021
Colony Development Index (CD)					
CR	1.830±0.056	1.490±0.089	1.452±0.127	1.730±0.057	1.647±0.110
RD	1.953±0.054	1.858±0.078	1.919±0.131	2.047±0.126	1.733±0.058
2RD	2.272±0.121	1.669±0.091	2.929±0.143	1.744±0.085	2.045±0.101
5RD	1.660±0.125	1.945±0.119	1.884±0.072	1.659±0.073	1.656±0.113
10RD	1.774±0.111	2.318±0.099	2.262±0.0689	1.767±0.067	1.809±0.145

*Data represents mean value ± standard error

Bio-ecology and management of pests under changing climatic scenario.

Occurrence of Yellow Stem borer in *rabi* and *kharif* rice at NRRI during 2016

During *rabi* 2016, yellow stem borer brood emergence started towards 4th week of January (4 SMW) and continued upto 1st week of April (14 SMW) with high brood emergence during 6-8 SMW. This resulted in about 31.24% dead heart formation and complete death of 15.14% hills as compared to 0.24% DH and no dead hills in standing water application of insecticide check chlorantraniliprole with a yield reduction upto 44.15%. During *kharif*, the emergence was towards 1st week of October (40 SMW) with high brood emergence during 42-44 SMW. But since the medium duration variety like Ketkijoha surpassed the PI stage, the brood could not make significant damage or consequent yield loss to the crop. There was a significant positive corelation of minimum temparature and maximum temparature with YSB emergence during *rabi* (Correlation coefficient : 0.890 and 0.795, respectively), whereas rainfall has negative corelation during *kharif* season (-0.456) (Fig. 3.21).

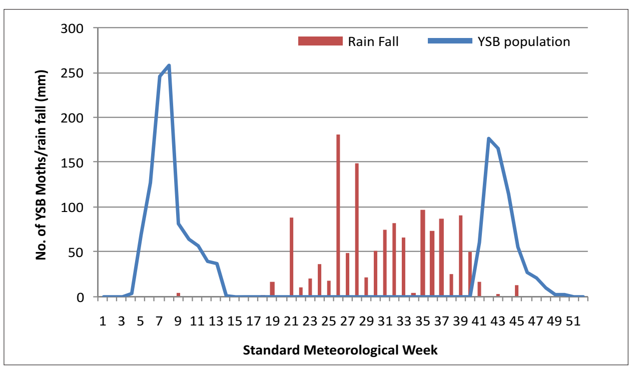


Fig. 3.21. Pheromone trap catch of YSB during 1-52 SMW of the year 2016

Diversity of insect pests and natural enemies in lowland rice ecosystems

The study was conducted during *kharif* 2016 and *rabi* 2017 in semi-deep water and irrigated ecologies, respectively. The collection of insect pests and their natural enemies was mainly done through sweep net in the rice (cv. Lalat, an irrigated variety and Varshadhan, a semi-deep water variety) at fortnight interval till dough stage of rice. In semi deepwater rice ecology, spiders (8.2/ sweep) outnumbered the other predatory groups and were widely distributed throughout the study area. The other major predatory arthropods include damsel fly (6.3/ sweep), lady bird beetle (4.8/ sweep). Among the parasitoids, *Xanthopimpla* sp., *Carcelia* sp., *Stenobracon* sp. *Apanteles flavipes*, *Brachymeria* sp., *Cardiochiles* sp. were the predominant ones which occurred in the study area (Fig 3.22). Although the same trend was observed in the irrigated ecology, the number of was low compared to semi deepwater ecology.

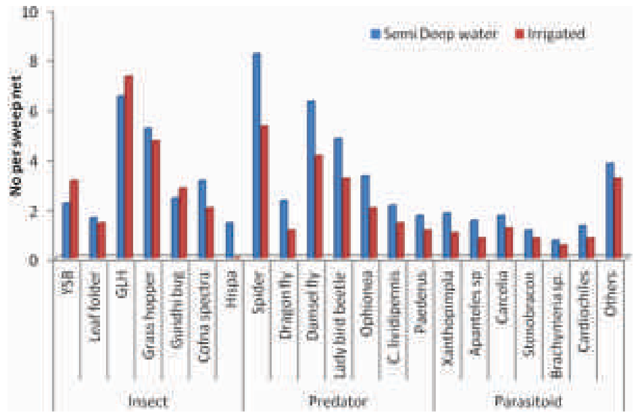


Fig. 3.22. Diversity of rice insect pests and natural enemies in irrigated and semi deep water ecosystem

Effects of insecticides on insect pest-natural enemy community in low land rice ecosystem

Chlorpyriphos 20EC recorded lowest spider population (2.5/sweep) followed by imidacloprid (2.6/ sweep) and thiamethoxam (2.7/ sweep) against water spay (6.7/sweep). Azadirachtin registered spider population of 4.2/sweep followed by Bt (3.9/ sweep) as against water spray (Fig. 3.23).

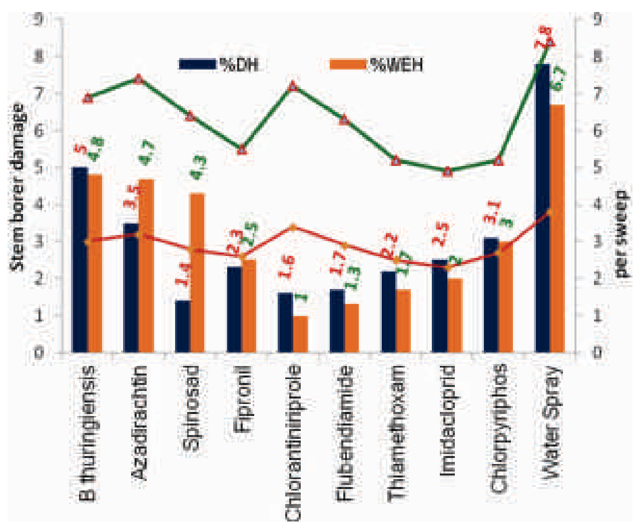


Fig. 3.23. Longterm effect of pesticides on insect pest of rice

Imidacloprid application changes microbial dynamics and enzymes in rice soil

Extensive use of imidacloprid in rice ecosystem may alter dynamics of microorganisms and can change soil biochemical properties. The objective of this study was to assess the effect of imidacloprid on growth and activities of microbes in tropical rice soil ecosystem. Four treatments, namely, recommended dose (at 25 g a.i. ha^{-1}, RD), double the recommended dose (at 50 g a.i. ha^{-1}, 2RD), five times the recommended dose (at 125 g a.i. ha^{-1}, 5RD) and ten times the recommended dose (at 250 g a.i. ha^{-1}, 10RD) along with control were imposed under controlled condition. Dissipation half lives of imidacloprid in soil were 19.25, 20.38, 21.65 and 33.00 days for RD, 2RD, 5RD and 10RD, respectively. In general bacteria, actinomycetes, fungi and phosphate solubilising bacteria population were disturbed due to imidacloprid application. Changes in diversity indices within bacterial community confirmed that imidacloprid application significantly affected distribution of bacteria. Total soil microbial biomass carbon content was reduced on imidacloprid application. Except dehydrogenase and alkaline phosphatase activities, all other soil enzymes namely, β-glycosidase, fluorescien diacetate hydrolase, acid phosphatase and urease responded negatively to imidacloprid application. The extent of negative effect of imidacloprid depends on dose and exposure time. This study concludes imidacloprid application had transient negative effects on soil microbes (Fig. 3.24).

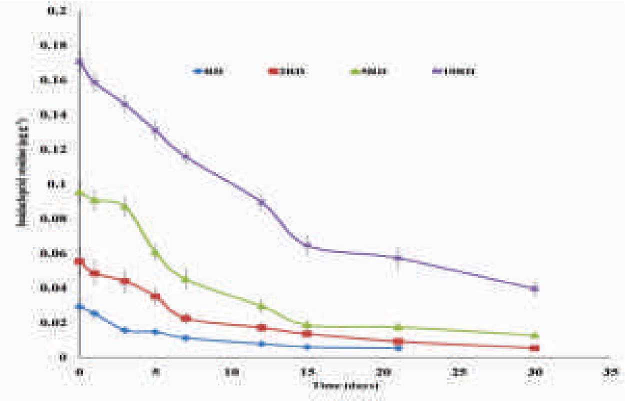


Fig. 3.24. Persistence of imidacloprid in soil under controlled condition (error bars represent the standard deviation of three replications)

Dissipation of chlorantraniliprole in soil under controlled condition

Dissipation of pesticides depends upon the nature of soil, pesticide chemistry, and other environmental factors. Role of soil type and moisture regimes on dissipation of chlorantraniliprole were investigated. Two soils with different characteristics were used and it was found that dissipation was more in ICAR-NRRI soil compared to red soil at field capacity moisture. Higher the moisture content, dissipation was higher. Dissipation of chlorantraniliprole followed first order kinetics. Dissipation half life of chlorantraniliprole was 115.5-138.6 days. Higher organic carbon and pH in presence of moisture play a significant role in degradation behavior of chlorantraniliprole (Fig. 3.25).

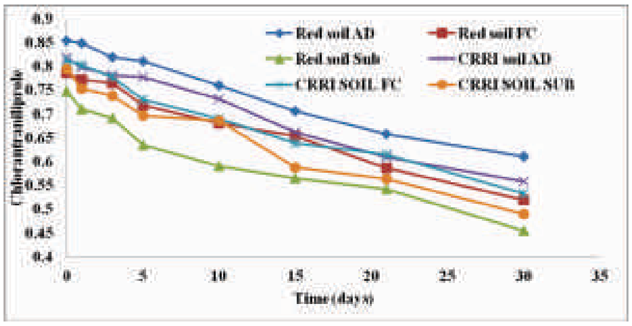


Fig. 3.25. Persistence of chlorantraniliprole in soil under controlled condition

Management of stored grain pests of rice

Evaluation of *Cleistanthus collinus* leaf extracts against rice weevil *Sitophilus oryzae* and red flour beetle *Tribolium castaneum*

Storage is the one of the important postharvest practices that when properly executed, helps in reducing food shortage problems. Storage insect pests inflict both qualitative and quantitative loss to cereals, making them unfit for sowing (loss viability) or for food or feed. Further, it also creates serious problems for food industries and export commodities *via.*, food contamination. Toxicity of *Cleistanthus collinus* (CC) leaf extracted by Soxhlet apparatus in acetone were evaluated against rice weevil, *Sitophilus oryzae* and red flour beetle, *Tribolium castaneum* under laboratory condition. Five concentration (1, 1.5, 2, 2.5 and 4%) with two controls (acetone and water) treatments were used for contact residual toxicity. The insect that survives upon this treatments were transferred to an untreated feeding substrate and the population buildup of subsequent two generation were recorded after 30 (F_1) and 60 days (F_2).

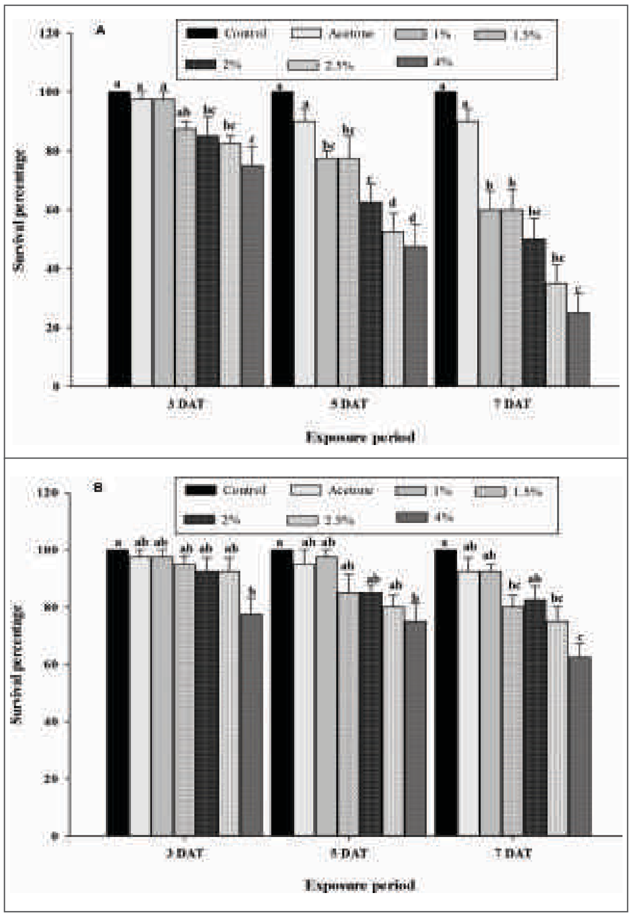


Fig. 3.26. Survival percentage of (A) Sitophilus oryzae and (B) Tribolium castaneum against different concentration of CC residue, acetone and water at different exposure time-interval

In the contact residual toxicity, highest CC concentration (4%) produced 75 % mortality in *S. oryzae* and 62.5 % mortality in *T. castaneum* during seven days of after exposure (Fig. 3.26). Population buildup level in the F_1 generation of both species was affected significantly by all CC treatments and acetone in comparison with control (water) (*S. oryzae*: $F_{6, 18}$ = 31.90; $P < 0.0001$; *T. castaneum*: $F_{6,18}$ = 7.73; $P < 0.001$) (Fig. 27(A). In contrast, the population build up of the following generation (F_2) significantly decreased only in the CC treatments for both the species (*S. oryzae*: $F_{6, 18}$ = 71.91; $P < 0.0001$; *T. castaneum*: $F_{6,18}$ = 98.75; $P < 0.0001$). The F_2 population buildup levels were strongly affected by CC exposure with lowest average (100.75) in *S. oryzae* at 1% CC residue after 60 days versus 233.5 in water control whilst 96 for *T. castaneum* versus 218.5 for water control (Fig. 27(B). To the best of author's knowledge, present study is first step towards assessing the scientific basis for the understanding the effectiveness of CC extracts against rice stored grain pests.

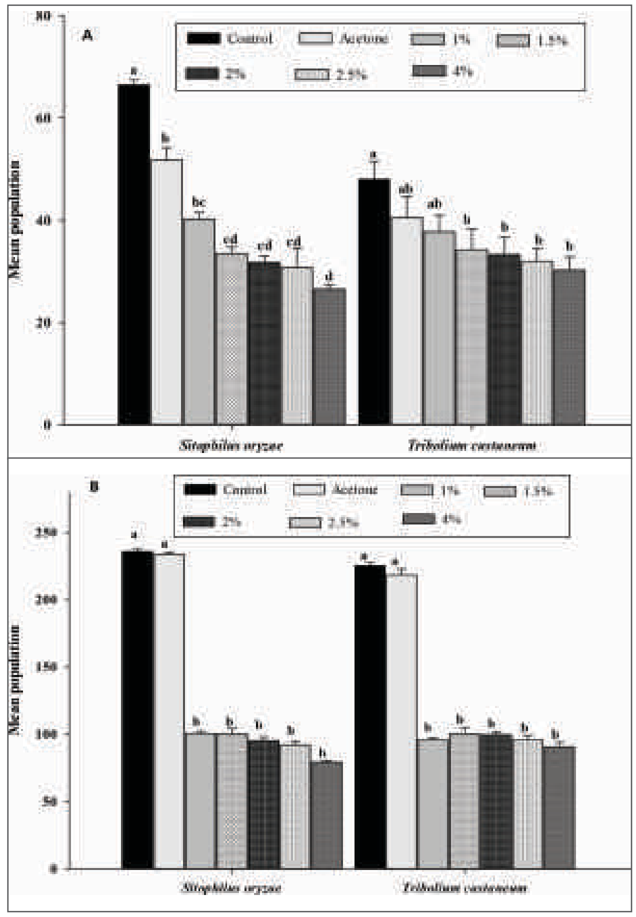


Fig. 3.27. F1 (A) and F2 (B) populations of *Sitophilus oryzae* and *Tribolium castaneum* after 30 days and 60 days of exposure to different concentration of CC residue, acetone and water

Repellency of essential oils against major coleopteran stored grain pests of rice

Stored product insects are perennial problem in storage. The most destructive coleopteran pests of stored rice are *Sitophilus oryzae* (Rice weevil), *Rhyzopertha dominica* (Lesser grain borer), *Tribolium castaneum* (Red flour beetle) and *Oryzaephilus surinamensis* (Saw toothed grain beetle). Research was carried out to test the repellent action of three essential oils i.e., Orange oil, Cinnamon oil and Eucalyptus oil at three different concentrations 1, 2 and 5% prepared in acetone against these pests. Area preference method (Obeng-ofori *et al.*, 1998) was used to assess the repellency of essential oils. Both per cent repellency and Repellency Index (Mazzonetto, 2002) were calculated for each oil and dose to assess potential at one hour after treatment.

Area-preference method

Against *Sitophilus oryzae,* Cinnamon oil @ 5% exhibited significantly higher repellency with PR values of 96.67 (F=10.68), and RI value of 0.03, whereas, Eucalyptus oil @ 5% shown highest repellent action against *Tribolium castaneum* having PR and RI values of 100 (F=1.66), 0.00 and were found significantly superior over rest of the treatments. Different essential oils and concentrations tested against *Rhyzopertha dominica* were found significantly different. Eucalyptus oil @ 5% has shown highest repellency with PR value of 83.33 (F=2.60) and RI value of 0.17. Oils and concentrations tested against *Oryzaephilus surinamensis* did not exhibit significant differences among themselves at all time intervals tested.

The study indicated that these essential oils have potential for development into a natural insecticide/repellent for the control of insects in stored rice if application methods are properly standardized.

Refinement and validation of IPM modules in rice

On-farm validation of IPM module in rainfed shallow land (Location-1)

An area of 10 acres in a compact block was selected in farmer's fields during *kharif*, 2016 involving14 farmers for validation of IPM modules in rainfed shallow low land situation in Bodhpur Village and G.P. in Cuttack district with varieties Swarna and Pooja under need based IPM, schedule based IPM and farmer practice condition. Survey Conducted for the incidence of major rice diseases and insect pests showed stem borer infestation causing dead heart (2.5-5.4%) and white ear head (3.7-5.8%), leaf folder (2.8-5.1%), gundhi bug (5.0-7.5%), during November 2016. Farmers were trained to identify the harmful and beneficial pests in their fields.

In farmer's practice, they used pesticides in whole plot and in a schedule manner, irrespective of disease, pest incidences, at least 4-5 times in a season. Periodical monitoring and recording of disease incidences along with grain/straw yield parameters from the experimented farmer's fields were undertaken in the presence of the participating farmers.

The observations recorded were - variety Swarna with need based IPM practice has significantly higher yield (5.82 t ha^{-1}) as compare to schedule based IPM (4.92 t ha^{-1}) and farmer's practice (3.8 t ha^{-1}). Significantly, higher straw yield of 6.35 t ha^{-1}was obtained from the variety Swarna with need based IPM practice, whereas in case of Swarna schedule based IPM, straw yield of 6.25 t ha^{-1} was obtained and in farmer practice straw yield of 4.7 t ha^{-1} was obtained. Significantly, higher grain yield of 5.65 t ha^{-1}and straw yield of 6.85 t ha^{-1} were obtained from the variety Pooja under need based IPM practice compare to grain yield of 4.62 t ha^{-1}and straw yield of 6.75 t ha^{-1}in case of Pooja under schedule based IPM. In farmer practice the grain yield was 3.32 t ha^{-1}and straw yield was 4.57 t ha^{-1} in Pooja. The dead heart, white ear head, leaf folder damage and gundhibug damage were significantly less and natural enemies population was significantly more in need based IPM practice in both the tested varieties (Table 3.12). Significant reduction in different disease incidences i.e, brown spot, sheath blight, sheath rot, false smut was also observed in need based Swarna and Pooja IPM than schedule based Swarna/Pooja IPM and farmer's practice. (Table 3.13).

On-farm validation of IPM module in rainfed lowland rice ecosystem (Location-2)

On-farm IPM trial on rice (cv. Swarna *sub - 1*) was conducted in rainfed lowland ecosystem in the Pipili block of Puri district in Odisha during *kharif*, 2016. The pest scenario and strategies were evaluated under two regimes *viz*., 1. *Farmers' practice (FP):* (a) Broadcasting of seed (b) Application of carbofuran in the main field after seeing the damage 2. *IPM treatments:* (a) Seed treatment with carbendazim @ 2 g kg^{-1} seed (b) Fixing of pheromone traps @ 8 traps ha^{-1} for monitoring yellow stem borer and routine field survey and (c) Chlorantraniliprole 0.4 G @ 10 kg ha^{-1} applied at 25 DAT (d) Need based application of foliar spray of flubendiamide 480 SC @ 30 g a.i. ha^{-1} and thiomethoxam 25 WG @ 25 g ai ha^{-1} (e) Need based application of fungicide, tricyclazole 75 WP @ 0.6 g litre^{-1} against sheath blight and blast. In case of IPM, 3.0% dead heart (DH), 2.1% white ear head (WEH) due to stem borer, 2.8% leaf folder damaged leaf, gundhi bug (1.6/ sweep), 3.3% sheath blight and 2.1% blast infections were recorded; whereas in case of Farmers practice, 9.2% DH, 5.2 % WEH, 9.4 GLH hill^{-1},

Table 3.12. Effect of IPM module on rice insect pest in shallow rainfed rice ecology during *kharif*, 2016 in village Bodhpur of Cuttack Sadar, Cuttack

S.N.	Treatment	%DH	%WEH	%LF	%Gbug	NE	G-yield	S-yield
1	Swarna IPM need based	2.7 (9.42)d	3.42 (10.66)d	2.55 (9.18)d	5.02 (12.95)d	3.25c	5.82a	6.35b
2	Swarna IPM schedule based	3.1 (10.14)cd	3.7 (11.09)c	2.85 (9.71)b	5.35 (13.37)c	2.45e	4.92b	6.25b
3	Swarna farmer practice	5.0 (12.19)a	5.6 (13.66)a	4.92 (12.82)a	7.32 (15.70)b	5.15a	3.80d	4.7c
4	Pooja IPM need based	3.52 (10.82)c	3.75 (11.16)c	2.57 (9.22)cd	5.15 (13.11)d	3.35 c	5.65a	6.85a
5	Pooja IPM schedule based	4.1 (11.67)b	3.95 (11.46)b	2.8 (9.63)bc	5.4 (13.43)c	2.75d	4.62c	6.75a
6	Pooja farmer practice	5.4 (13.43)a	5.8 (13.93)a	5.05 (12.96)a	7.55 (15.94)a	4.95b	3.32e	4.57c
CD at 5%		0.74	0.26	0.42	0.21	0.22	0.26	0.36

Data in parenthesis are angular transformed values

Table 3.13. Effect of IPM module on rice diseases in shallow rainfed rice ecology during *kharif*, 2016 in village Bodhpur of Cuttack Sadar, Cuttack

Treatments	Brown spot (%)	Sheath blight (%)	Sheath rot (%)	False smut (%)
T_1-Swarna IPM (Need based)	3.96 (11.45)	6.44 (14.67cd)	3.77 (11.14b)	2.82 (9.51d)
T_2-Swarna IPM (Schedule based)	4.80 (12.62)	7.83 (16.21)	4.30 (11.89b)	4.00 (11.38cd)
T_3-Swarna (F.P)	8.52 (16.94)	13.80 (21.79)	6.98 (15.26a)	6.26 (14.39b)
T_4-Pooja IPM(Need based)	2.92 (9.74)	5.22 (13.16)	4.26 (11.77b)	4.12 (11.63bcd)
T_5-Pooja IPM(Schedule based)	4.68 (12.39)	6.56 (14.77)	5.34 (13.31ab)	5.86 (13.98bc)
T_6-Pooja (F.P)	7.94 (16.33)	10.72 (19.07)	7.16 (15.42(a)	9.84 (18.22a)
CD (at 5%)	2.20	2.06	2.77	2.95

Figures in parentheses represent the angular transformed values

3.4 gundhi bug hill^{-1}, 6.4% sheath blight, 8.2% blast were found. In IPM plots, predator population was more (8.8 sweep^{-1}) compared to FP plots (5.7 sweep^{-1}) which includes spider, damselfly, dragon fly, mirid bugs, whereas parasitoid population was 6.5 sweep^{-1} in IPM and 4.3 sweep^{-1} in FP plots (Fig. 3.28 & 3.29).

The grain and straw yields in IPM treatments were 5.8, 9.2 t ha^{-1}, respectively compared to 4.6 and 9.7 t ha^{-1} in FP treatment (Fig. 3.31). Farmers were trained for the identification of insect pests and their natural enemies through use of riceXpert app developed by NRRI to decide the timing of pest management practices (Fig. 3.30).

Fig. 3.28. Blast incidence in Farmers' practice plot

Fig. 3.30. Awareness on the use of riceXpert app among the rice farmers in Arhua, Pipili (Puri) for IPM practices

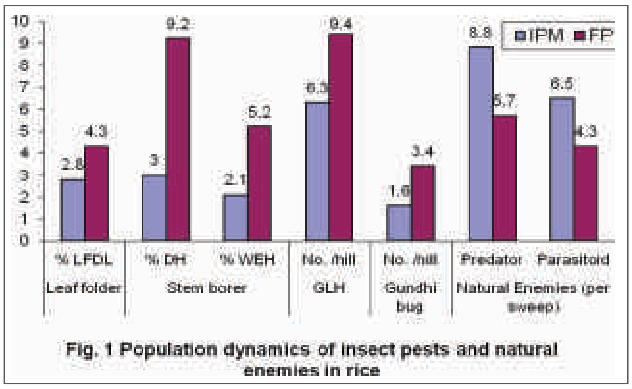


Fig. 3.29. Population dynamics of insect pests and natural enemies in rice

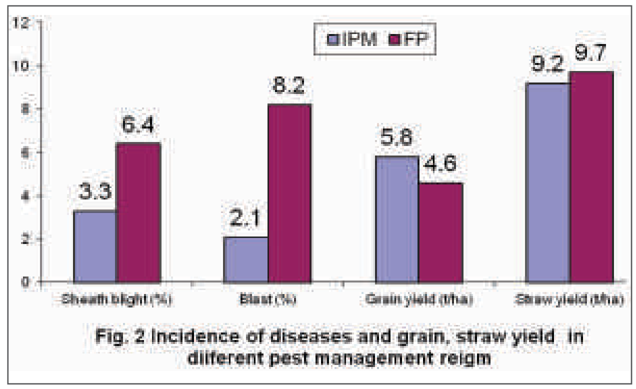


Fig. 3.31. Incidence of diseases and grain, straw yield in different pest management reigm

On-farm validation of IPM package in favourable lowland ecology (Location-3)

In favourable lowland ecosystem of cuttack district (Block-Mahanga, Village-Baianpur), IPM package was validated in 30 acres of rice field with rice variety Pooja. The IPM treatments included proper monitoring of pests which was given major emphasis. Seed treatment with carbendazim prior to sowing and fixing of pheromone trap after 30 days of transplanting (DAT) was scheduled-based treatments. Weekly recording of trapped YSB moths till harvesting indicated the time of protection measures in proper area (3-5 moths day^{-1}). Thirty day old seedlings were tranlplanted during last week of July. The crop suffered infestation from swarming caterpillar at nursery, caseworm and leaf folder infestation at 45 DAT, sheath blight at PI stage and YSB, BPH, false smut at flowering stage of the crop. Proper pest surveillance reduced the pest incidence rate by taking the management measures at proper time. Neem based application of protection measures were used to get rid of chemical pesticides.

Table 3.14 Occurrence of pests and treatments applied in affected area

Pests	Time of occurrence	Area	Application
Swarming caterpillar	August-1st wk	Nursery-2 Ac	Chlorpyriphos
Case worm	August last wk - September first wk	3 Ac	Neem oil (0.5%)
Leaf folder	September first wk	1.5 Ac	Neem oil (0.5%)
YSB	October-3rd wk	2 Ac	Ferterra 10 kg ha^{-1}
Sheath blight	October-1st wk	0.5 AC	Carbendazim
False smut	October-4th wk	In trace	No treatment

Monitoring through Pheromone trap could reduce pesticide application significantly. Application of selective insecticides like imidacloprid, thiamethoxam, chlorpyrifos etc. at initial stage of insect or disease attack could reduce pesticide application. Application of neem oil for leaf folder and BPH management was found promising and it reduced pesticide application significantly during 2014, 2015 and 2016. Yield was within 5.5 - 6.3 t ha^{-1} with an Av. of 5.90 t ha^{-1} in IPM treatment against 4.04 – 4.8 t ha^{-1} in farmers' practice.

Search for new/effective IPM components

Efficacy of insecticides against rice caseworm

Eight treatments including untreated control were evaluated at their recommended doses under field condition during *kharif*, 2016 against rice caseworm, *Nymphula depunctalis* in variety Ketkijoha. DPX-RAB 55 was more effective in reducing pest infestation followed by thiamethoxam and Spinetoram. Accordingly, yield advantage was 15.5–17.55% in those three treatments over untreated control (Table 3.15).

Testing of some new insecticides against insect pests of rice

Eight treatments including insecticides, fungicide and combinations were evaluated against insect pest and disease of rice during *rabi* and *kharif*, 2016. The treatment, Coragen @ 0.3 ml $litre^{-1}$ + CM75 @ 2 ml $litre^{-1}$ was best combination for higher grain yield (5.7 t ha^{-1}) and was at par with Coragen @ 0.3 ml $litre^{-1}$ + V3 @ 2.5 ml/lit (5.6 t ha^{-1}) during *rabi* season.

During *kharif*, 2016, the same eight pesticides were evaluated and Coragen @ 0.3 ml $litre^{-1}$ + CM75 @ 2 ml $litre^{-1}$ was again found as the best combination for higher grain yield (5.6 t ha^{-1}) and was at par with Coragen @ 0.3 ml $litre^{-1}$ + V3 @ 2.5 ml $litre^{-1}$ (5.46 t ha^{-1}) and Coragen @ 0.3 ml $litre^{-1}$ (5.4 t ha^{-1}). Coragen @ 0.3 ml $litre^{-1}$ along with carbendazim and mancozeb combination @ 2 ml $litre^{-1}$ was very effective in controlling pest and disease and increasing grain yield during both *rabi* and *kharif* in variety TN1.

Biotic stress management in rainfed upland rice ecology

IDM for hybrid rice (PHB 71) under rainfed transplanted conditions (2016)

An experiment for Integrated Disease Management (IDM) of false smut of rice was conducted at CRURRS farm during *kharif*, 2016, involving three components, *viz*., different dates of transplanting (16 July and 26 July, 2017), dosages of fertilizers [F_1= 80:40:40 (NPK), F_2= 100:60:40 (NPK)] and chemical fungicides [C1: Hexaconazole (Contaf 5 EC) @ 2 ml a.i./l, C2: Mancozeb (Indofil) @ 2.5 g a.i./l, C3: Control]. The

Table. 3.15 Effect of insecticides against rice case worm

Sl.No	Insecticides applied at 35 DAT	% Mean tillers infested	Yield (t ha^{-1})	% Yield Advantage
1	Spinetoram	12.9	4.22 a	17.52
2	Dpx-Rab 55	7.62	4.214 a	17.35
3	Flubendiamide (Fame)	46.88	3.780 de	5.26
4	Chlorantraniliprole (Coragen)	26.47	3.979 ab	8.86
5	Hunk(Flu.+Bupro)	45.35	3.664 cd	2.03
6	Thiamethoxam	8.41	4.148 a	15.51
7	Osheen (Dimethoate)	24.17	3.763 bc	4.79
8	Control	62.49	3.591 e	
	CD at 5% level	1.08	0.296	

Table 3.16 Evaluation of pesticides against insect and disease of rice in *kharif* 2016

SL No.	Treatment	Dose	%WEH	%Gbug	%blast	%blight	NE	Yield
1	Coragen	0.3 ml litre^{-1}	2.7 (9.45)	4.7 (12.52)d	2.5 (9.09)c	2.7 (9.45)d	2.2e	5.4ab
2	Token	0.4 ml litre^{-1}	3.1 (10.14)	5.3 (13.30)c	2.96 (9.91)b	3.1 (10.14)c	2.9d	5.0d
3	CM75	2 ml litre^{-1}	4.7 (12.52)	6.7 (15.0)b	1.7 (7.49)f	3.4 (10.62)b	3.96b	4.73e
4	V3	2.5 ml litre^{-1}	4.9 (12.78)	6.7 (15.0)b	3.0 (9.97)b	1.7 (7.48)f	4.04b	4.63e
5	Coragen+CM75	0.3+2 ml litre^{-1}	2.12 (9.69)	4.33 (12.01)e	1.83 (7.77)e	3.06 (10.08)c	2.23e	5.6a
6	Coragen+V3	0.3+2.5 ml litre^{-1}	3.1 (10.14)	4.06 (11.63)f	2.56 (9.21)c	2.16 (8.39)e	3.8bc	5.46ab
7	Token+CM75	0.4+2 ml litre^{-1}	3.6 (10.93)	4.3 (11.96)ef	2.0 (8.12)d	3.2 (10.29)bc	3.83bc	5.30bc
8	Token+V3	0.4+2.5 ml litre^{-1}	3.4 (10.62)e	4.5 (12.24)de	2.46 (9.03)c	2.7 (9.45)d	3.36cd	5.10cd
9	Control	500lit water ha^{-1}	5.43 13.43)a	7.53 (15.92)a	4.66 (12.47)a	4.4 (12.10)a	5.12a	2.70f
CD at 5%			0.17	0.35	0.27	0.59	0.48	0.21

Data in parenthesis are angular transformed values

results indicated that the combination of early transplantation (16th July, 2017), moderate fertilizer dose (NPK: 80:40:40) and preventive sprays with Hexaconazole at booting and flowering stage, was most effective in minimizing false smut infection (% panicle infection) and increase in rice yield. Integration of the three management components revealed that early transplanting (16th July) under high fertilization (100:60:40; N:P:K) and prophylactic spray of Hexaconazole @ 2 ml a.i./l resulted maximum reduction in false smut incidence and highest grain yield.

Comparative efficacy of IPM modules for direct seeded rice (cv. Sahabhagidhan) under favorable uplands

Comparative efficacy of three IPM modules were evaluated for direct seeding under favourable uplands using cv. Sahbhagidhan at CRURRS Farm during *kharif*, 2016 and found that all IPM Modules significantly reduced the weed infestation and disease (brown spot & sheath rot) incidence as compared to control (Framer practice). But IPM Module 1 was most effective in minimizing weed infestation, disease incidence and highest grain yield of Sahbhagidhan. The results also indicated that weed is the major problem in direct seeded rice, particularly if not weeded out at critical stage (Tillering) of rice. Timely application of weedicides (IPM modules 1, 2 & 3), on the other hand, reduced weed competition at critical crop growth stage (maximum tillering) and resulted in higher dry matter production of rice. All the IPM modules led to significant increase in rice dry matter production and grain yield over farmer's practice. On the other hand, combination of pre-emergence (Butachlore application at 2 DAG) and post-emergence (Bispyribac sadium application at 21 DAG) weedicide application (IPM module 1) significantly reduced weed biomass at 25 DAG over single applications of either pre-emergence or post emergence weedicides. Very low incidences of gundhi bug, stem borer and blast were observed.

The details of IPM modules were: Control: No seed treatment + hand weeding (30-40 DAG: done on- 35 DAG) + N application = 20 (basal) : 40 (40 DAE) : 20 (65 DAE); IPM module 1: Seed treatment (MSS) + Pre-emergence weedicide (Butachlore at 2 DAG) application + Post-emergence weedicide application (Bispyribac Na: 21 DAG) + N application = 20 (basal) : 40 (25 DAE) : 10 (45 DAE) : 10 (65 DAE) + need based application of fungicide/insecticides; IPM module 2: Seed treatment (MSS) + Pre-emergence weedicide (Butachlore at 2 DAG) application + Need based hand weeding + N application = 20 (basal) : 40 (25 DAE) : 10 (45 DAE) : 10 (65 DAE) + need based application of fungicide/insecticides and IPM module 3: Seed treatment (MSS) + Post-emergence weedicide application (Bispyribac Na: 21 DAG) + N application = 20 (basal) : 40 (25 DAE) : 10 (45 DAE) : 10 (65 DAE) + need based application of fungicide/insecticides

Updation of IPM for rice leaf blast

A field experiment was conducted at CRURRS farm during 2016 to update the IPM module of rice leaf blast under direct sowing in unfavourable uplands. All treatments significantly reduced the rice blast incidence and corresponding increase in rice yield (cv.Vandana). But T_6 treatment was most effective in minimization of rice blast incidence and disease severity and increase in yield of rice, followed by T_5, which was statistically at par. However, rice equivalence yield of T_5 treatment was significantly higher than T_6 treatment due to additional yield of pigeonpea. The only difference between T_6 (8:1) and T_5 (4:1) is ratio of rice: pigeonpea. The T_5 treatment consists of seed treatment with {MSS with 2% salt solution} + {seed treatment with *Trichoderma* (@ 5 g kg^{-1} seed)} + {pre-emergence weedicide (Pendimethaline) + need based post-emergence weedicide (25-30DAE)} + {nitrogen: 15 + 30 +15} + intercropping with pigeonpea (4:1) + need based application of Tricyclazole + Propiconazole. Intercropping with pigeonpea resulted into reduced leaf blast incidence and increased equivalence yield of rice. The wider space of intercrop (8:1) had favoured the growth of rice crop without any shade effect (of pigeonpea) and prevented the free movement and landing of *Magnaporthe* spores on the nearby rice crop.

The results also indicated that seed treatment with *Trichoderma*, had significantly enhanced seed germination, seedling vigour and minimized leaf blast incidence. The treatments were: T_1: No seed treatment + Late hand weeding (25-30 DAE) + Nitrogen: 15 +30 +15; T_2: Seed treatment (MSS) + Seed treatment with *Trichoderma* + Pre-emergence weedicide (Pendimethaline) + Need based post-emergence weedicide (25-30DAE) + Nitrogen (15 +30 +15) + Need based application of Propiconazole + Tricyclazole; T_3: Seed treatment (MSS) + Seed treatment with *Trichoderma* + Pre-emergence weedicide (Pendimethaline) + Need based post-emergence weedicide (25-30DAE) + Nitrogen (15 +30 +15) + Intercropping with pigeonpea (4:1); T_4: Seed treatment (MSS) + Seed treatment with *Trichoderma* + Pre-emergence weedicide (Pendimethaline) + Need based post-emergence weedicide (25-30DAE) + Nitrogen (15 +30 +15) + Intercropping with pigeonpea (8:1); T_5: T_3 + Need based foliar spray of Tricyclazole + Propiconazole; and T_6: T_4 + Need based foliar spray of Tricyclazole + Propiconazole. However, This experiment will be repeated in the next year for its validation.

Management of major insect-pests and diseases of rice in rainfed flood prone lowlands in Assam

Rice leaf folder (*Cnaphalocrosis medinalis*), stem borers (*Scirpophaga incertulas* and *S. innotata*) and gundhi bug were found to be the major insect pests of *kharif* rice in flood prone areas of Assam. Rice swarming caterpillars (*Spodoptera mauritia*) population rapidly built up during 2nd and 3rd weeks of September in Assam and infested 56,768 ha of winter rice crop. Pupae were 1.68 ±0.15 cm in length, 0.58 ± 0.07 cm in breadth and 0.22±0.06 gm in weight with a pupal period of 8.97±1.01 days.

Moth activity of rice stem borer and leaf folder on

Fig. 3.31. Screening of Rice Blast

Fig. 3.32. Swarming caterpillar

Fig. 3.33. Pupa at the base of rice plant

kharif rice started at the first week of October. Daily catches of rice stem borer in light trap reached its first peak (28.5 nos. of moth/day) on fourth week of October. Use of scirpo-lure in funnel trap @ 20 nos./ha recorded the lowest incidence of dead heart (3.19%) at 45 days after transplanting (DAT) as against 7.71% in control. Rice stem borer infestation in post flood situation was the lowest in crop transplanted in first fortnight of August (3.50% DH) as compared to second fortnight (4.27%) and first fortnight of September (5.04%) crop. Rice crop transplanted in second fortnight of September recorded the highest percentage of leaf folder folded leaves (1.38%) as compared to first fortnight (1.06%) and second fortnight of August (0.82%). Grain yield loss of paddy for each per cent infestation of rice leaf folder on rice variety CR Dhan 909 was 45.67 kg ha^{-1}.

RTD incidence was observed in Bongaigaon, Darrang, Dhemaji, Kamrup, Lakhimpur, Sonitpur and Udalguri districts of Assam on the varieties Bahadur, Ranjit, Swarna, Mahsuri, PAC 837, Lurki and Borsalidhan during *sali/kharif* 2016. Widespread incidence of neck blast disease was observed in Bongaigaon, Barpeta and Darrang of Assam during *rabi* 2015-16. Balimah Putih, IR 20, Pankhari 203, PTB 8, PTB 18, PTB 21, Shuli 2, Utrirajapan and Utri Merah showed resistant reaction against Gerua isolate of *tungro* disease. Gerua isolate of *Xoo* was found to be a virulent one and it showed moderate to high virulence with location specific index of 6.2.

PROGRAMME : 4

Biochemistry and Physiology of Rice in Relation to Grain and Nutritional Quality, Photosynthetic Efficiency, Abiotic Stress Tolerance and Climatic Resilience

The research program of the Division (Program 4. *Biochemistry and physiology of rice in relation to quality, photosynthetic efficiency and abiotic stress tolerance)* consisted of four research projects namely, *Project 4.1: Rice grain and nutritional quality – evaluation, improvement, mechanism and value addition,* Project 4.2 Phenomics of rice for tolerance to multiple abiotic stresses, *Project 4.3: Rice physiology under drought and high temperature stress and* Project 4.4: Improvement of Photosynthetic Efficiency of Rice. The main emphasis on research in biochemistry was to identify rice with high micronutrient (Fe, Zn) content along with high bioavailability. To achieve this objective, mineral content and content of the antinutrient phytic acid (PA) were determined along with a study on the expression of the gene *IPK1* which was found to play key role in PA synthesis. Besides, the in vitro method to determine mineral bioavailability was standardized and used. The *in vitro* glycemic index evaluation procedure was improved and made highly reproducible. One significant finding of the work on pigmented rice was that a very high amount of anthocyanins was lost due to their solubilisation during parboiling/cooking.

In physiological research, several multiple abiotic stress tolerant lines were identified. Using the Chlorophyll Fluorescence Imaging technique, the images of F_o and F_m were found to be useful to distinguish between the tolerant and susceptible cultivars. About 135 genotypes were observed to be highly tolerant to vegetative stage drought with SES score "0" and "1". Under control condition, 20 best genotypes were observed to have higher values for more than one root trait indicating that their tolerance to vegetative stage drought may be based on different root traits. The increase in total chlorophyll content and a decrease in chl a/b ratio under shade gave clear indications of the acclamatory response of rice genotypes to low light environment. Expression levels of NADP-Malic enzyme (ME) in four different species were analysed by Real time PCR. Based on the expression analysis results, the ME gene showed highest expression in *Seitaria italica* plant. RNA from this plant was isolated and converted to c-DNA and Full-Length c-DNA gene of ME was amplified using the PCR.

Rice grain and nutritional quality – evaluation, improvement, mechanism and value addition

Impact of Phytic acid on mineral bioavailability in rice grain

Though essential for plants, phytic acid (PA) is considered as an anti-nutritional factor (ANF) present in cereals and legumes, because it binds the cationic minerals, reducing their bioavailability in both ruminants and non-ruminants. Considering the world-wide deficiencies of iron (Fe) and zinc (Zn), the objective of this study was to find if grain PA content affects the bioavailability of Fe and Zn and to identify varieties that exhibit highest bioavailability of the two minerals with an ultimate aim to improve the bioavailability of these minerals by reducing insoluble mineral–phytate complexes. Out of the seventy rice varieties analyzed for PA content, six were evaluated for Fe and Zn bioavailability from brown and milled rice. An inverse relationship was found between PA content and Fe/Zn bioavailability among different varieties. The brown rice of Bindli, which had the lowest PA (0.82%) showed highest Zn bioavailability (12.51 ppm), while PB267, which had the highest amount of PA (2.62%) showed low bioavailability of Zn (8.94 ppm) and Fe (4.04 ppm). The bioavailability of Zn increased after milling because most of the amount of this mineral is present in endosperm, while bioavailability of Fe decreased, most likely because the major amount of Fe is found in the bran layer (Fig. 4.1 and 4.2).

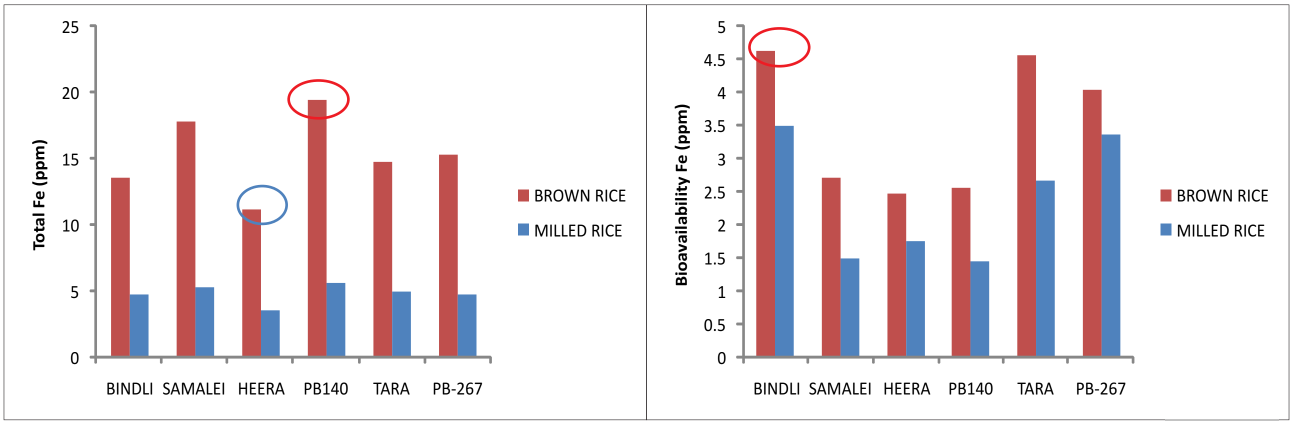


Fig. 4.1. Total Fe content and its bioavailability in brown and milled rice of six cultivars with contrasting PA content

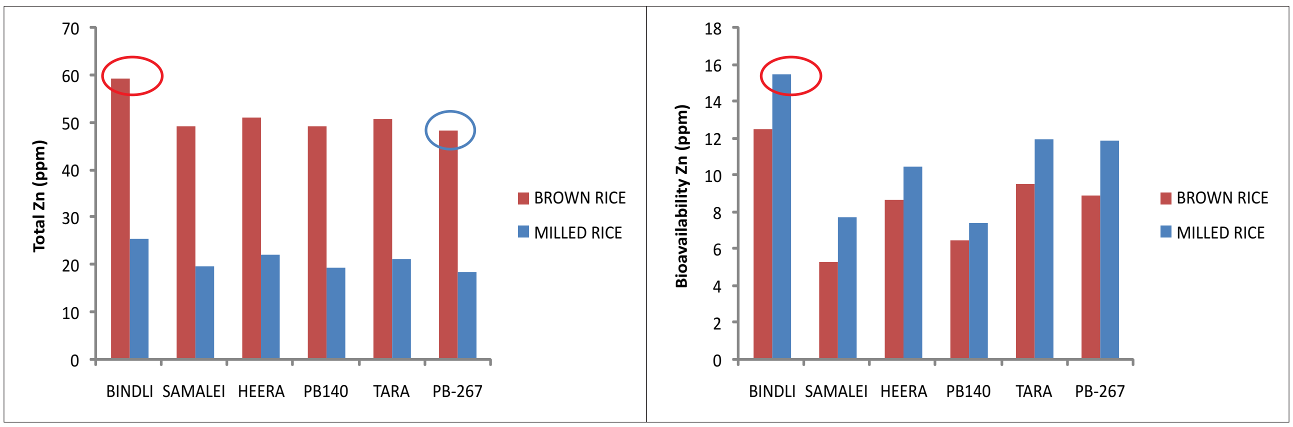


Fig. 4.2. Total Zn content and its bioavailability in brown and milled rice of six cultivars with contrasting PA content

Expression pattern of *IPKI* (Inositol phosphate kinase I) gene at different stages of grain development

The enzyme *IPKI* plays a key role in the last step of PA biosynthesis. The rice *IPKI* gene (Os04g0661200) is highly expressed in developing rice grain and activation or suppression of this gene may result in alteration of PA biosynthesis and change in total phosphorus content in rice seeds. Keeping in view the importance of *IPKI* in PA biosynthesis, expression analysis was done in developing grains of three rice cultivars (Bindli, Heera and PB267) having different levels of PA in grains. The results are shown in Fig. 4.3. Lower level expression of *IPKI* transcripts was detected at the initial and final stages of grain development in all the three cultivars suggesting that the process of synthesis and accumulation of PA occurs during the mid-stage of grain filling. There was several fold increase (13.67 x in Bindli, 16.52 x in Heera and 32.82 times in PB 267) in the expression level of *IPKI* in the middle stage in the three genotype. Among the three granules, PB267 showed highest expression of *IPKI* at the mid-stage of grain filling, which was positively correlated with their phytate content. The finding strongly supports the important role of *IPKI* in PA biosynthesis.

Development of an improved *in vitro* method for determination of Glycemic index

Glycemic index (GI) of a food is an indicator of its ability to raise the blood sugar level after it is consumed. People eating rice and leading a sedentary lifestyle are more likely to suffer from obesity, type-II diabetes and colon diseases in long terms, especially in Asian countries. The GI of rice is known to be relatively high compared to other starchy foods. So, the information on GI value of rice varieties may help to choose the right ones for reducing the risk of such life style related diseases. The GI can be measured by *in vitro* method or by studying the response of human volunteers after they are fed a given quantity of the test food. However, the *in vivo* method depends on management of human volunteers and is vulnerable

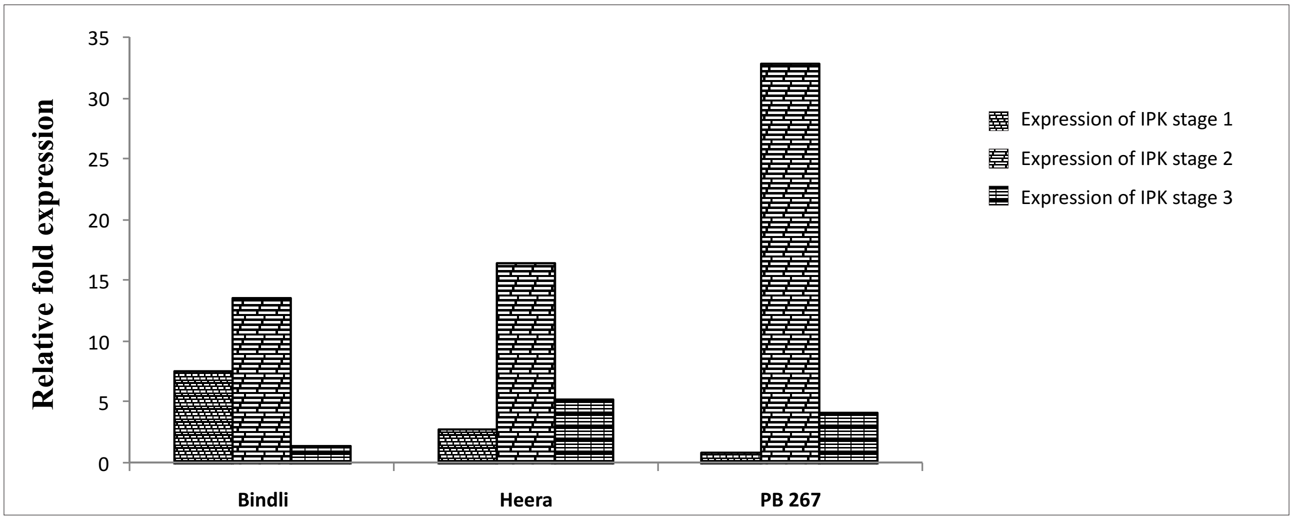


Fig. 4.3. Expression pattern of IPKI gene at different stages of grain development in three rice genotypes. The expression level was determined by qRT-PCR [Expression relative to the leaves at the grain developmental stages (2, 7 and 14 DAA)]. B-tubulin was used as the internal control

to myriads of external as well as internal influences resulting in lack of precision and poor reproducibility of the results in most cases. Hence, there is need of a simple *in vitro* method that could mimic the *in vivo* environment. We improved the *in vitro* method of Goni *et al*., 1997. The method is not only inexpensive, but also simple, rapid and reliable. In this method, the cooked rice is digested with pepsin and alpha amylase and the digest is transferred into a dialysis membrane, which mimics the small intestinal conditions. Thus, the small molecular weight soluble compounds are transported through the membrane wall by simple diffusion process obviating the need of α-amylase inactivation. The maltose resulting from starch digestion permeates through the membrane and is released into the ambient buffer, an aliquot of which is treated with amyloglucosidase hydrolyzing it into glucose units. Conventionally, the anthrone reagent is used for glucose estimation, which uses corrosive chemicals and also has poor reproducibility. In contrast, GOPOD reagent used by us gives more reproducible results with high degree of precision. The method measures the Hydrolysis index (HI), which is converted to GI with the formula:

GI = 39.71 + 0.549HI (Goni, I.; Garcia-Alonso, A.; Saura-Calixto, F. 1997. A starch hydrolysis procedure to estimate glycemic index. Nutr. Res. (N.Y.) 17,: 427-437).

Looking to the fact that the estimation of the GI of foods is a routine activity for the carbohydrate rich foods, the availability of a simple, rapid and precise estimation method would be useful. In this study, the GI was estimated in rice cultivars grown in different ecologies where large variation in the value of GI

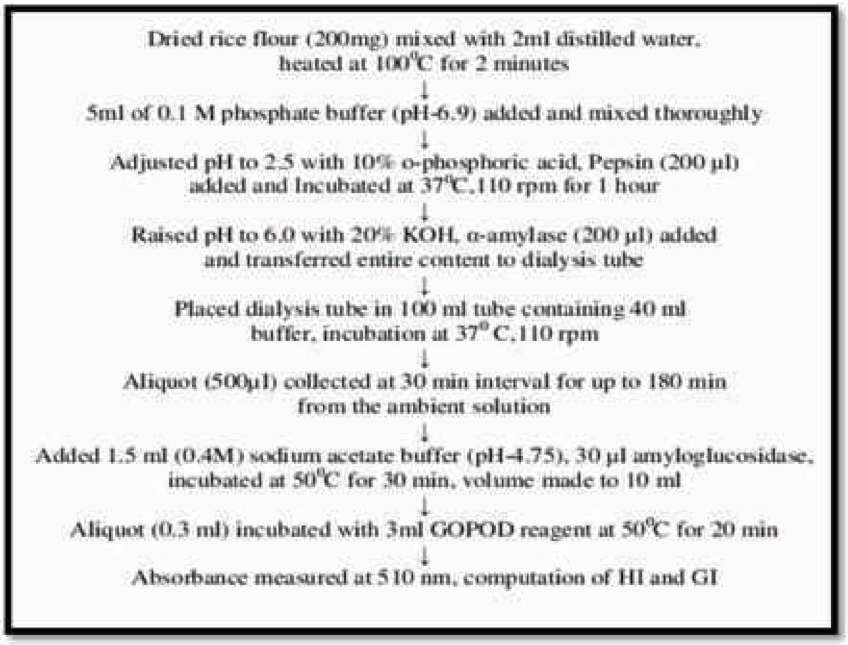


Fig. 4.4. The protocol for the *in vitro* GI estimation

(60.07-70.36) was observed. Among the genotypes studied, Mahsuri (irrigated rice) showed lowest GI (60.07), while the highest value for GI (70.36) was found in Abhishek (upland rice). The modified flow chart for determining the GI is given in the Fig. 4.4. The data obtained using this method are reported in Table 4.1.

Table 4.1. Hydrolysis index and GI of 24 rice genotypes from different ecology

VARIETY	HI	GI
Swarna	38.41±1.45	60.79±0.80
Mahsuri	37.08±0.28	60.07±0.15
Luna Sankhi	46.46±0.39	65.22±0.20
Luna Barial	55.48±0.55	70.17±0.30
CR Dhan201	50.94±1.75	67.68±0.96
Abhishek	55.82±2.36	70.36±1.29
Sarala	44.11±2.54	63.93±1.39
Pooja	50.71±2.21	67.55±1.21
CR Dhan 907	39.58±1.56	61.44±0.85
Maudamani	51.51±0.72	67.99±0.39
Vandana	42.82±0.99	63.21±0.54
Tapaswini	41.32±1.70	62.40±0.93
Rajlaxmi	41.03±3.19	62.24±1.75
Nalbora	50.56±2.39	67.47±1.31
Nua Kalajeera	48.36±1.14	66.26±0.62
Pyari	43.38±0.79	63.53±0.43
Heera	53.93±1.31	69.32±0.72
CR Dhan 310	49.69±2.94	66.99±1.61
Naveen	48.65±1.53	66.42±0.84
Kalobhat	46.90±1.01	65.46±0.55
Ajay	43.38±2.25	63.53±1.23
O. nivara	48.94±1.12	66.58±0.61
O. brachyantha	53.06±2.15	68.84±1.18
NE-1	51.16±2.72	67.86±1.49

Characterization of pigmented rice for anthocyanin and gamma-oryzanol content

Fifty pigmented rice genotypes were evaluated for anthocyanin and gamma-oryzanol content. The purple grain type Kalobhat (204 mg/100g) was found to be the richest in anthocyanin pigments followed by Mamihunger (183 mg/100g), Chakhao (85 mg/100g), Manipuriblack (64 mg/100g) and Kalabiroin (72 mg/100g), whereas Mamihunger (100 mg/100g), Chakhao (92 mg/100g) and Kalobhat (90 mg/100g) were obviously the rich sources of gamma-oryzanol.

The effect of processing of rice on anthocyanin and gamma-oryzanol content was also studied in Chakhao, Mamihunger and Mornodoiga (Fig. 4.5). Highest reduction in anthocyanin and gamma-oryzanol content (97 and 88%, respectively) was observed after parboiling and open-pan cooking of the parboiled rice, whereas only 2-3% reduction in anthocyanins and 70% reduction in gamma-oryzanol content was observed in popped and puffed rice (Fig. 4.6). This clearly suggests that a very high amount of anthocyanin pigments is lost due to their solubilisation during parboiling/cooking.

Fig. 4.5. Pigmented rice and their end use products as prepared in the laboratory.

Physico-chemical and cooking characteristics of pigmented rice

Twenty pigmented rice genotypes were evaluated for grain quality and cooking characteristics. The results (Table 4.2) indicated that they exhibited low head rice recovery (HRR) in general with the lowest HRR found in Annapurna. Medium and long slender grain types were observed in most of the pigmented rice. The

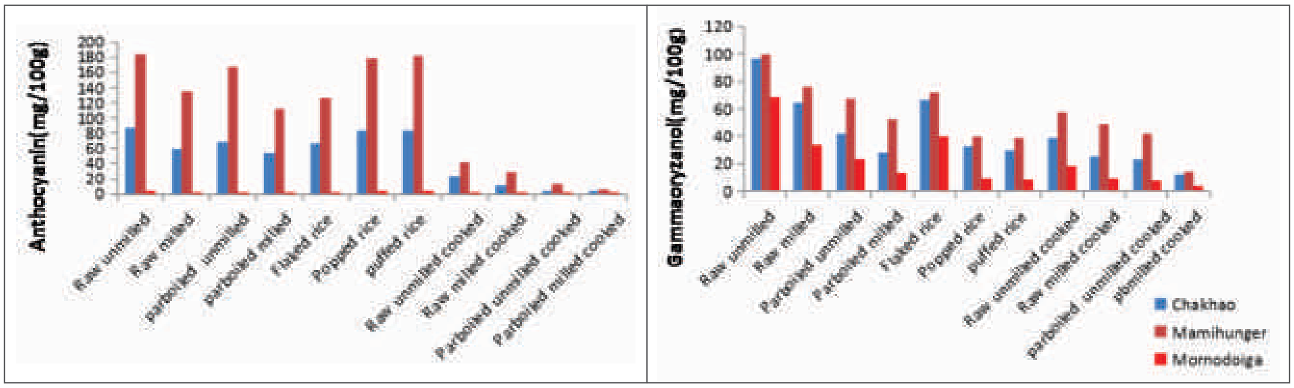


Fig.4.6. Effect of processing on anthocyanin and gamma-oryzanol content of pigmented rice

purple grain types had low amylose content which include Chakhao (12.7%), Mamihunger (19.2%) and Manipuri black (9.52%); these were found to be rich in antioxidant compounds and were of hard to intermediate gel consistency type: Mamihunger (35.8mm), Chakhao (55.2mm), Manipuri black (54.6mm). The consumer preference is for intermediate and soft GC rice, hence, emphasis needs to be given on improving the grain quality traits, particularly the GC value of antioxidant rich pigmented rice to enhance their acceptability.

Phenomics of rice for tolerance to multiple abiotic stresses

Identification of multiple abiotic stress tolerant rice genotypes: *Evaluation under complete submergence with saline water*

The experiment was conducted with 199 rice germplasm including checks in which survival percentage varied greatly among the tested rice genotypes under the combined effect of salinity and submergence. Five distinct groups were made based on survival percentage. Group I, consisted of 91 genotypes, considered as highly susceptible with 0-20% survival; Group II, consisted of 26 genotypes, considered as susceptible with >20 to 40% survival; Group III, consisted of 43 genotypes, considered as moderately tolerant with >40 to 60% survival; Group IV, consisted of 20 genotypes considered as tolerant with >60 to 80% survival and Group V, consisted of 19 genotypes, termed as highly tolerant with >80% survival. Some of the promising genotypes are IC 145357, IC 459362, IC 451469, IC 450292, IC 449848, IC 580261, AC-43409, AC 43365, AC 43391, AC 43351 and FR13A.

Standardization of chlorophyll fluorescence imaging technique for phenotyping under combined stresses of stagnant flooding and salinity

The experiment was conducted under stagnant flooding with salt-stress with six genotypes *viz.*, Varshadhan (susceptible), Rashpanjor (tolerant), IC 459733, IC 115617, AC 43353 and AC 39460. Several 'Chlorophyll a' fluorescence parameters were obtained using the Imaging PAM. These parameters were F_o (dark minimal fluorescence yield when theoretically all the reaction centers were open), F_m (dark maximal fluorescence yield when theoretically all the reaction centers were closed), F_o' (light minimal fluorescence yield when theoretically maximum reaction centers were open baring a few), F_m' (light maximal fluorescence yield when theoretically maximum reaction centres were closed barring a few), $F_v/F_m = (F_m-F_o)/F_m$ (maximal PS II quantum yield). Among them, F_v/F_m i.e. maximum photosystem quantum yield was most insensitive to stress. The F_v/F_m was unable to distinguish the tolerant and susceptible genotypes under stressed condition. The ETR and difference between coefficient of photochemical quenching (qP-qL) was found highly suitable in distinguishing between tolerant and susceptible cultivars (Fig. 4.7 and 4.8). Among the six cultivars IC 459733, IC 115617 and AC 39460 were found to be more tolerant as compared to Rashpanjor.

Assessing chlorophyll fluorescence imaging techniques using contrasting genotypes

Chlorophyll Fluorescence Imaging technique emerged as a powerful tool to distinguish very easily and convincingly, between tolerant and susceptible

Table 4.2. Physico-chemical and cooking properties of some pigmented rice

Treatment Name	Hulling (%)	Milling (%)	HRR (%)	Length (mm)	l/b	Amylose content AC (%)	Gel consistency (mm)	Alkali spreading value (ASV)	Kernel length after cooking KLAC (mm)	Volume expansion ratio (VER)	Water uptake WU (ml/100g)
Annapurna	78.00	63.00	21.00	5.09	2.17	17.01	33.12	3.00	120.00	3.75	120.00
Assambiroin	74.50	61.50	55.00	6.24	3.14	17.34	35.70	3.89	332.50	3.75	332.50
Balam	75.33	65.00	57.00	6.79	4.22	21.25	71.00	2.89	140.33	3.75	140.33
Chakhao	74.50	50.50	48.50	6.27	4.48	12.70	55.16	4.89	135.00	3.75	135.00
Gandhibiroin	75.00	62.00	58.60	6.46	4.00	17.55	75.00	7.11	190.00	3.75	190.00
Harirana	76.00	65.00	57.83	5.07	1.94	25.36	38.95	3.00	172.50	4.00	172.50
Harishankar	75.50	61.00	52.00	5.65	2.23	24.46	39.56	3.00	255.00	3.75	255.00
Hida Vanga	77.17	63.00	55.50	5.62	2.23	24.85	38.52	3.00	152.50	3.75	152.50
Jool	74.00	64.50	61.00	5.26	2.84	25.31	65.00	2.89	102.50	3.75	102.50
Khaibadal-1	77.00	66.50	55.50	5.42	3.28	25.62	57.50	2.89	100.00	4.25	100.00
Lalbora	78.00	62.00	41.00	5.48	2.18	22.24	26.63	2.89	145.00	5.00	145.00
Mamihunger	78.00	65.00	48.50	6.16	4.18	19.18	35.75	4.11	105.00	4.00	105.00
Manipuriblack	75.00	62.00	45.00	5.73	3.41	9.52	54.60	6.11	195.00	3.75	195.00
Mornodoiga	75.00	62.50	35.50	5.42	3.13	21.91	65.00	2.89	82.50	3.75	82.50
Mugai	77.50	65.50	58.50	5.29	3.47	23.88	42.91	5.11	105.00	3.75	105.00
Nalbora	76.50	63.00	51.00	6.24	4.02	17.64	31.75	7.11	330.00	4.00	330.00
PB140	74.50	61.00	36.50	6.09	3.71	22.07	43.00	2.89	75.00	3.75	75.00
RPHP112	77.00	62.00	42.00	4.94	2.87	19.75	30.50	2.89	102.50	3.75	102.50
Saathi	79.67	68.50	52.00	4.98	2.91	23.93	28.50	2.89	100.00	3.75	100.00
Setka 36	76.00	64.00	50.00	4.99	2.10	24.38	35.86	2.89	145.00	3.75	145.00
CD at 5%	1.2	1.5	1.9	0.03	0.1	8.2	20.1	0.1	3.1	0.4	3.1

genotypes under stressful environment, which are otherwise difficult to differentiate with naked eye or using simpler tools such as recording leaf character using SPAD meter or F_v/F_m. Several images were obtained for F_o, F_m and F_v/F_m (Fig. 4.9). The colour of the images changed with values of each parameter. The images taken in a particular light intensity signified the physiological condition of the leaf in response to light intensity. Though, the distinction by F_v/F_m was not apparent among the tolerant and susceptible types, the images of F_o and F_m were useful to distinguish between the tolerant and susceptible cultivars. Besides, it is also possible to give a grade of tolerance within tolerant cultivars by visualizing the images. Rashpanjor is a tolerant cultivar, yet the tolerance level of Rashpanjor was comparatively inferior to that of IC 459733 and IC 115617.

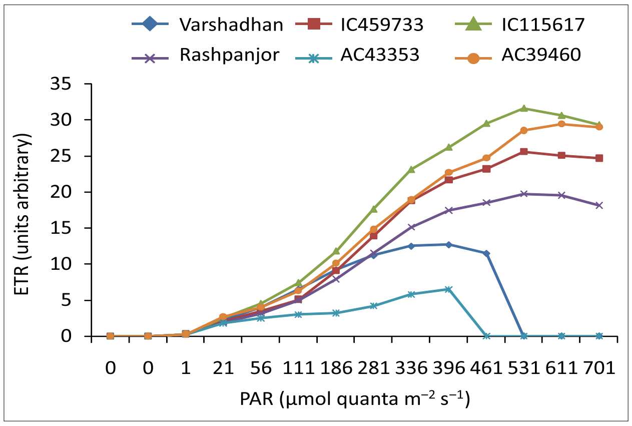


Fig. 4.7. Changes in ETR with changing PAR

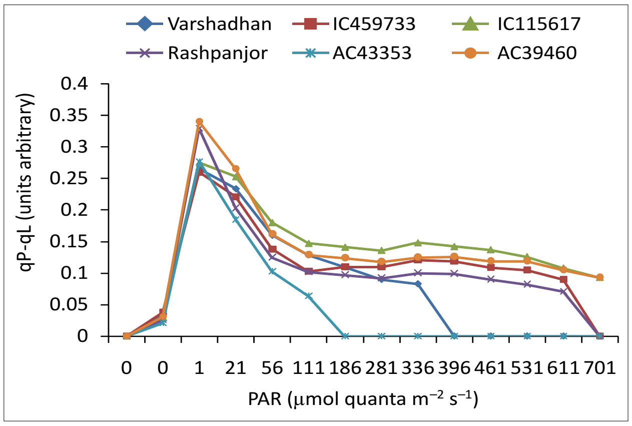
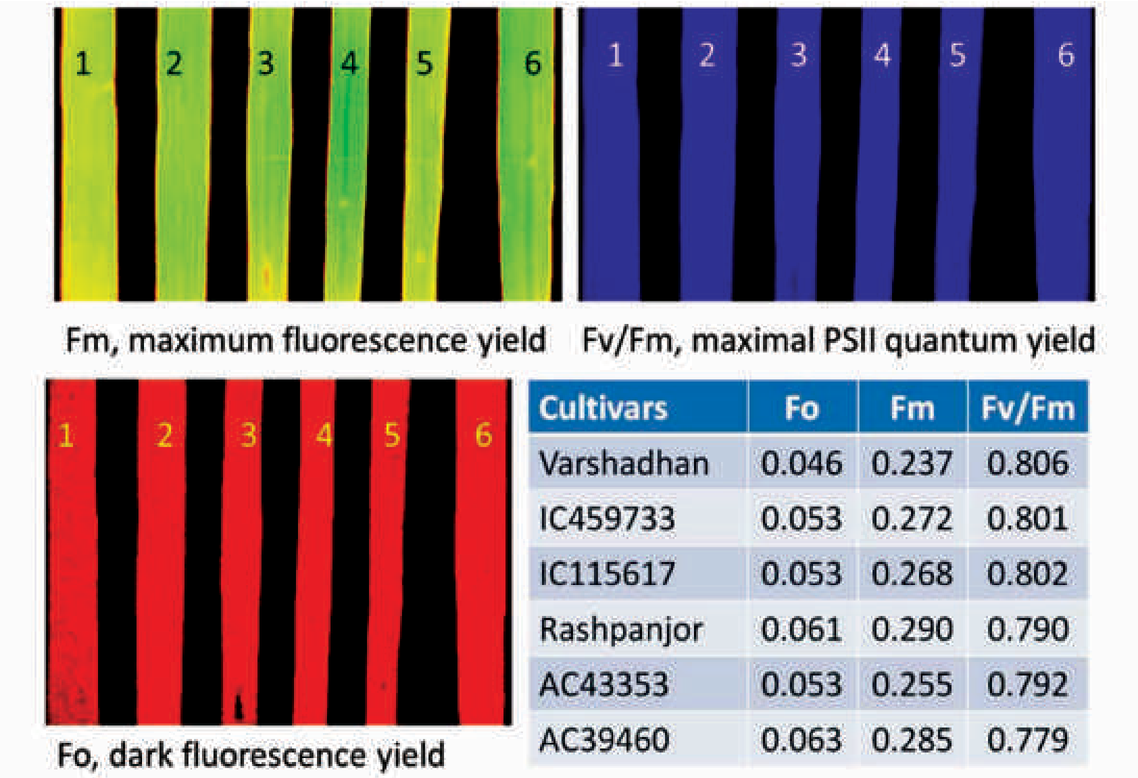


Fig. 4.8. Changes in photochemical quenching with changing PAR



Cultivars	Fo	Fm	Fv/Fm
Varshadhan	0.046	0.237	0.806
IC459733	0.053	0.272	0.801
IC115617	0.053	0.268	0.802
Rashpanjor	0.061	0.290	0.790
AC43353	0.053	0.255	0.792
AC39460	0.063	0.285	0.779

Fig.4.9. Effective photosystem II quantum yield can rightly distinguish between tolerant and susceptible cultivars

Rice physiology under drought and high temperature stress

Screening of rice genotypes for vegetative stage drought tolerance and drought tolerance under rainfed upland condition

Two hundred ninety selected genotypes were screened in an augmented design for vegetative stage drought tolerance under field condition for confirmation. Thirty days old seedlings were exposed to moisture stress and during the period of stress, soil moisture content was 6.24 to 10.22%, soil metric potential was -50 to -68 kPa below 30 cm soil depth and water table depth was below 85 cm. Out of 290 genotypes, 135 genotypes were observed to be highly tolerant with SES score “0” and “1”, 51 were tolerant (SES '3'), 39 were moderately tolerant (SES '5'), 45 were susceptible (SES '7') and 18 were found to be highly susceptible (Fig. 4.10).

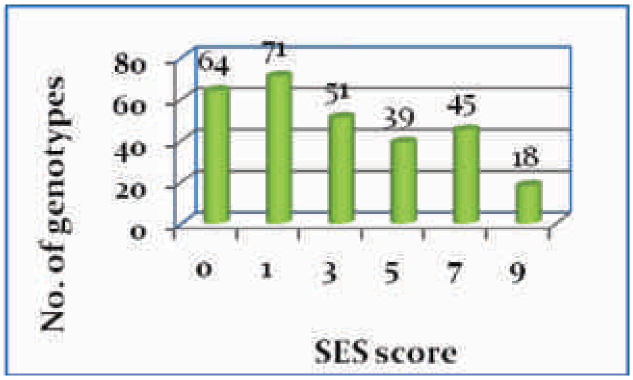


Fig. 4.10. Performance of genotypes under vegetative stage

In another trial, seventy five early rice genotypes were screened for vegetative stage drought tolerance under rainfed upland condition at Hazaribagh station during wet season. The entries were exposed to severe moisture stress one month after seeding because of no rain and rainless period continued for 23 days. Leaf drying score was recorded on 24th day following standard evaluation system (SES, 0-9 scale). Distribution of genotypes based on average drought tolerance score (averaged over 2 reps) is presented in the figure (Fig. 4.11).

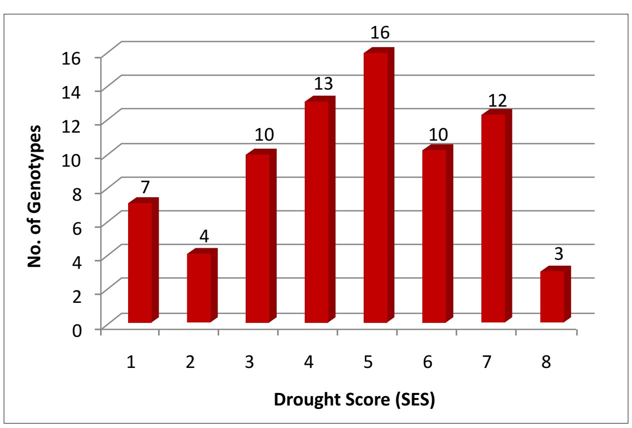


Fig. 4.11. Distribution of rice genotypes based on drought reaction score

About 28% (21 nos.) of the genotypes found to have good drought tolerance with score 1 to 3. Majority of the genotypes (51 nos.) were having moderate tolerance for vegetative stage drought. Only three genotypes IR 20, IC 516599 and IC 516358 showed highly susceptible drought reaction.

Characterization of root traits of identified drought tolerant lines

One hundred and ninety drought tolerant lines were grown in Hoagland solution with pH adjusted at 5.7 in regular basis. Stress was induced by applying 10% PEG-6000 to 30 days old seedlings (Fig. 4.12). Root morphological traits: root length, shoot length, root dry wt., shoot dry wt., root to shoot ratio and specific root length (SRL) were assessed. Under control condition 20 best genotypes observed to have higher values for more than one root trait which indicates that their tolerance to vegetative stage drought may be based on different root traits. In hierarchical clustering analysis, under both control and osmotic stress conditions, genotypes were divided into three groups.

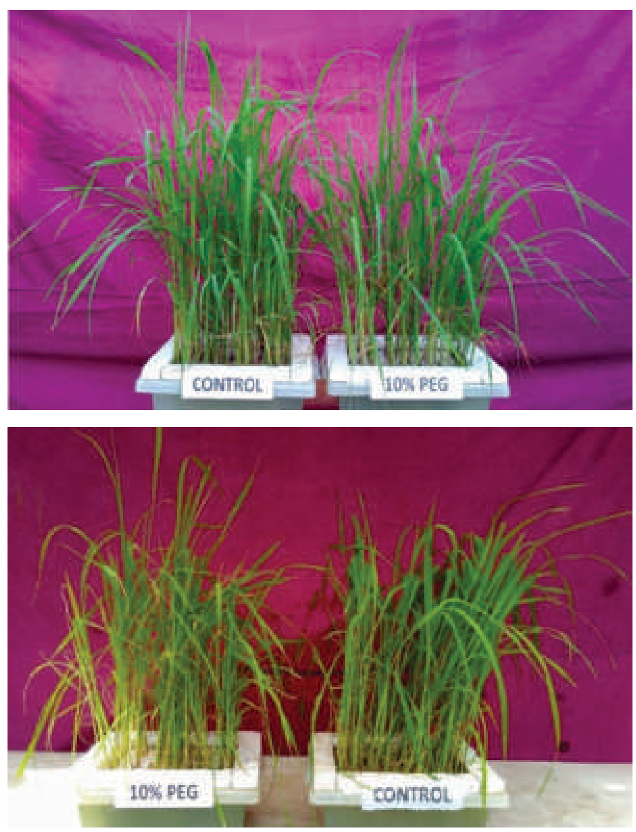


Fig.4.12. Rice seedlings under control condition and before and 3 days after PEG treatment

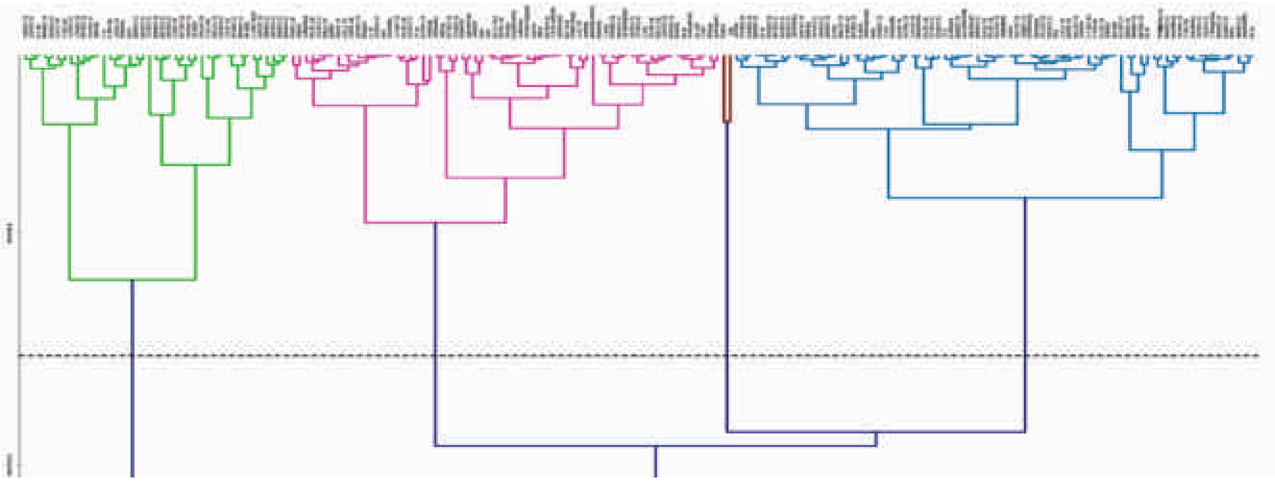


Fig.4.13. Agglomerative hierarchical clustering of 190 rice genotypes based on seven root traits under osmotic stress condition

In stress condition, group I consisted of 66 genotypes which are most promising among all the tested genotypes having high values for six traits SL, MRL, RDW, SDW, RDW/SDW and low values for SRL. However, among these, AC 26685 had higher values for five root traits *viz.*, RDW, SDW, SRL, RDW/SDW, MRL/SL ratio and AC 35679 and EC 205334 had higher values for four traits which indicates that these traits are essential for drought tolerance (Fig. 4.13 and Fig. 4.14).

Segregation analysis of RILs (F_8) derived from IR 20 x Mahulata by using STMS markers:

A total of 350, F_8 RILs derived from IR 20 (susceptible parent) and Mahulata (tolerant parent) were evaluated for drought tolerance at vegetative stage along with parental lines. Polymorphic survey for gene identification was performed between two parents (IR 20 and Mahulata) using molecular markers. A total of 1010 STMS (sequence tagged microsatellite site) markers were used for polymorphic survey. Out of these 108 (10.7%) markers were found polymorphic (Fig. 4.15).

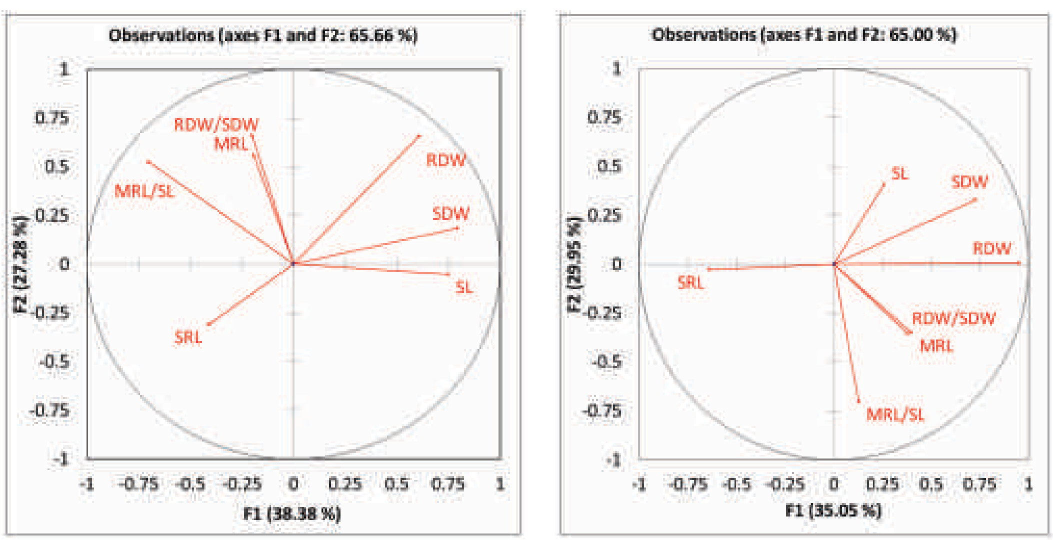


Fig.4.14. Multiple Factorial Analysis using all the phenotypic variables: maximum root length (MRL), shoot length (SL), shoot dry weight (SDW), root dry wt. (RDW), root to shoot dry wt. ratio, maximum root length to shoot length ratio (MRL/SL) and specific root length (SRL) under control (A) and osmotic stress condition (B)

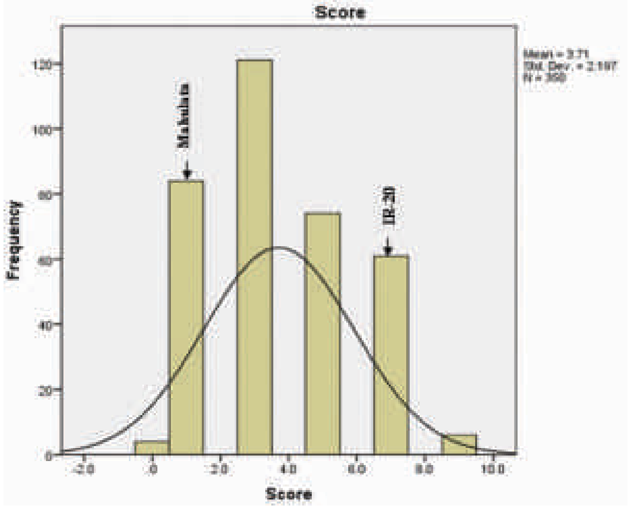


Fig. 4.15. Distribution of RILs derived from IR-20 and Mahulata for drought tolerance at vegetative stage

Effect of high temperature on grain yield and carbohydrate accumulation in contrasting genotypes

Seven rice varieties (N 22, Ratna, Annapurna, Satabdi, IR 72, Lalat, Naveen) were grown in the field condition in staggered manner (four dates of sowing *viz.*, S_1, S_2, S_3, S_4) sown in 10 days interval during dry season 2016 to get high temperature during flowering time in late sown condition. During flowering time of all sowing dates max temp ranged from 34.5°C to 42.3°C and min temp ranged from 23.0°C to 28.2°C. Grain yield was reduced under high temperature stress (S_4) and it was reduced by 43.7 to 47.9% in susceptible variety Naveen and Satabdi, while reduction was minimal (6.9 to 18.3%) in tolerant varieties Annapurna and N 22. Similar trend was observed for grain filling pattern, it was reduced by 10% in tolerant varieties, Annapurna and N 22, while the reduction was 24.2 to 26.2 % in susceptible variety Naveen and Satabdi (Table 4.3).

Total sugar content was estimated in flag leaf and in panicles. Accumulation of total sugar in the panicles of heat tolerant variety N 22 was much more pronounced than the heat susceptible variety, Naveen. In Satabdi and Naveen, the carbohydrate concentration in grains was significantly lowered suggesting the impaired carbohydrate mobilization process existing in susceptible varieties (Fig. 4.16).

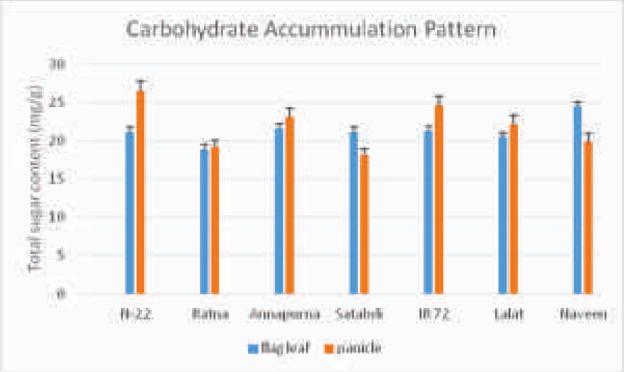


Fig. 4.16. Carbohydrate accumulation pattern in flag leaves and panicles of tolerant and susceptible varieties

Table 4.3. Effect of high temperature on grain yield and grain filling percentage of rice varieties sown in four different dates

	Grain Yield (t ha^{-1})					Grain Filling %				
	S_1	S_2	S_3	S_4	% REDN	S_1	S_2	S_3	S_4	% REDN
RATNA	3.66	3.17	2.60	2.19	40.09	78.36	62.45	61.92	61.01	22.14
N 22	2.79	2.63	2.44	2.28	18.27	90.19	89.23	87.04	81.42	9.71
ANNAPURNA	3.54	3.54	3.49	3.29	6.95	84.08	81.52	76.86	76.29	9.26
LALAT	4.70	3.60	3.05	2.74	41.65	81.53	76.83	68.27	56.27	30.98
SATABDI	3.36	2.73	2.43	1.75	47.90	81.79	77.30	67.31	60.30	26.28
NAVEEN	3.89	3.50	2.64	2.19	43.71	78.65	70.80	65.04	59.57	24.26
IR 72	4.64	3.93	2.77	2.99	35.53	78.41	65.98	65.12	64.33	17.96
MEAN	3.79	3.30	2.77	2.49	33.44	81.86	74.87	70.22	65.60	20.08
CD 5%	T- 0.35	V- 0.46	V X T - 0.92							

Improvement of Photosynthetic Efficiency of Rice

Photosynthetic and chlorophyll accumulation efficiency of some elite genotypes of rice

The photosynthesis of the rice genotypes grown under low light environment (50% of full sunlight) was affected due to reduced Photosynthetic Photon Flux Density (PPFD). The PPFD recorded diurnally is presented in Fig. 4.17. Maximum photosynthesis was recorded in Pantdhan-102 and GAR-13 followed by Rajendradhan-102 and Himalaya-L under normal light and the same trend was observed under reduced light environment. The stomatal conductance and the transpiration rate also showed similar trend. The photosynthetic water use efficiency did not show any definite trend under normal or reduced light environment (Table 4.4). The photosynthesis of shade leaves was saturated at low irradiance in contrast to sun leaves. Since shade leaves usually have a lower photosynthetic capacity on the leaf area than the sun leaves, the shade leaves exposed to high PPFDs can readily acquire excess energy. Furthermore, thermal energy dissipation and quantum yield of Photosystem-II (PS-II) were non-significant in the shade leaves and they typically correlate with electron transport rate (ETR) (Fig. 4.18) and CO_2 assimilation rate. Plant plasticity is an important aspect of photosynthesis and light acclimation. Chlorophyll content and Chl a/b ratio are two of the light acclimation variables, the former increases when shading is imposed on rice genotypes, while the latter decreases. In the present study, the increase in total chlorophyll content and decrease in chl a/b ratio under shade are clear indications of the acclamatory response of rice genotypes to low light environment (Fig. 4.19 and 4.20).

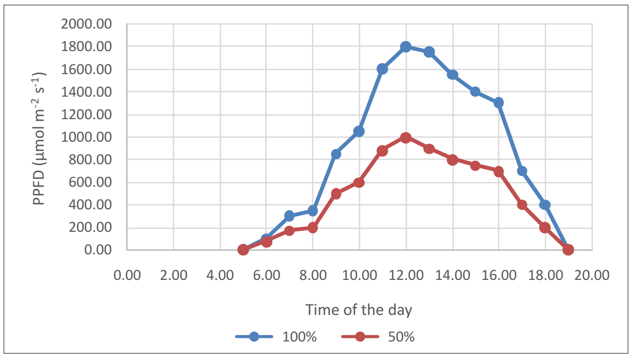


Fig.4.17. Diurnal changes of PPFDs under two levels of light environment

Table.4.4. photosynthesis and related parameters in rice genotypes as influenced by low light stress

Rice Genotypes	Photosynthetic rate (µmol/m²/sec)		Stomatal conductance (mol H_2O/m²/sec)		Transpiration (mol H_2O/m²/sec)		Photosynthetic WUE (µmol/m²/sec) /mol H_2O/m²/sec	
	NL	LL	NL	LL	NL	LL	NL	LL
CR-DHAN-401	22.209	12.459	1.089	0.284	16.976	5.666	1.308	2.199
SATYABHAMA	20.808	12.847	0.680	0.282	12.426	5.586	1.675	2.300
ABHYA	23.446	16.217	0.436	0.264	13.137	10.458	1.785	1.551
RAJENDRADHAN-102	24.147	16.469	0.395	0.269	14.917	9.162	1.619	1.797
PANTDHAN-102	25.063	17.332	0.767	0.468	18.763	13.601	1.336	1.274
HIMALAYA-L	24.096	15.989	0.530	0.326	15.667	10.181	1.538	1.570
ASHA-M05	23.808	15.847	1.289	0.384	15.281	9.734	1.558	1.628
MEGHASA-1	22.799	17.319	0.562	0.397	8.595	6.589	2.652	2.628
IMP-SABARMATI	22.799	15.319	0.495	0.372	7.545	5.532	3.022	2.769
GAR-13	25.603	18.679	0.683	0.401	15.174	10.891	1.687	1.715
SD (±)	1.328	1.836	0.275	0.066	3.347	2.622	0.535	0.475

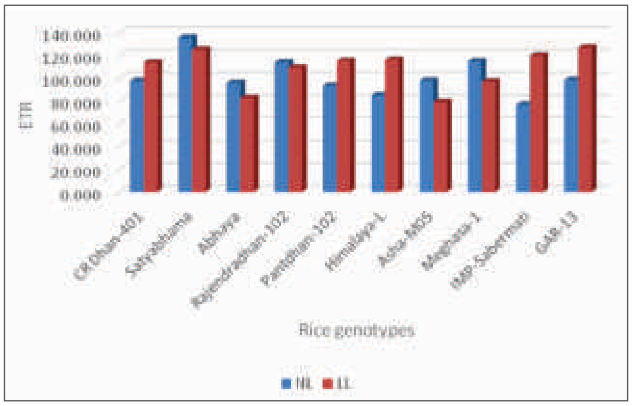


Fig.4.18. Electron Transport Rate (ETR) in rice genotypes as influenced by Low light environment

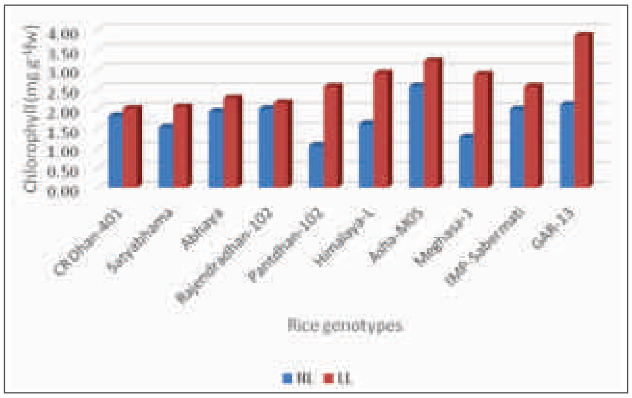


Fig.4.19. Accumulation of total chlorophyll in rice genotypes as affected by low light environment

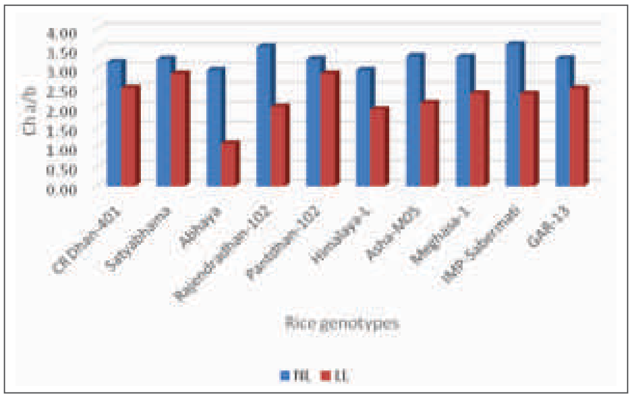


Fig.4.20. Chlorophyll a/b ratio in rice genotypes as influenced by low light environment

Cloning and transformation of C4 photosynthetic maize NADP- Malic Enzyme (ME) into *indica* rice

Expression levels of NADP-Malic enzyme (ME) in four different species were analysed by Real time PCR using equal amount of c-DNA with different expression primers. Data obtained from the RT-result for *Sorghum bicolour* (Sb), *Zea mays* (Zm) and *Setaria italica* (Si) were normalized using Actin as reference gene and the data for *Oryza sativa* (Os) was normalized using β-tubulin gene as reference. Highest expression level of PPDK and ME was found in *Seitaria italica* plant (Fig. 4.21).

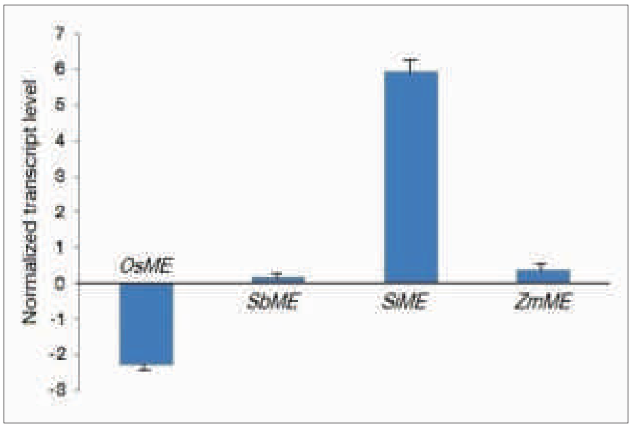


Fig.4.21. Expression level of NADP-Malic enzyme (ME) in four different species of *poaceae*

Based on the expression analysis results, the ME gene showed highest expression in *Seitaria italica* plant. RNA from this plant was isolated and converted to c-DNA and Full-Length c-DNA gene of ME was amplified using the PCR (Fig. 4.22).

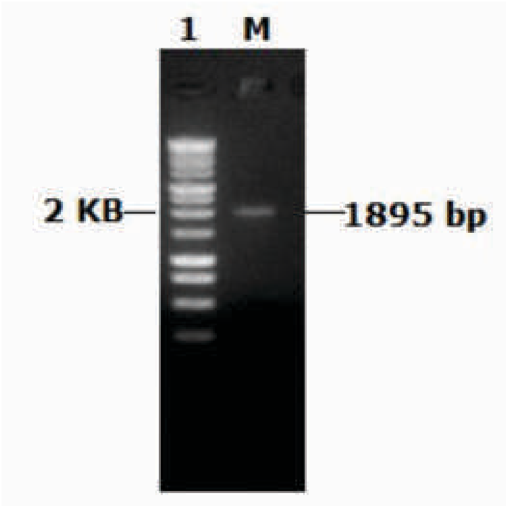


Fig.4.22. NADP-Malic enzyme (ME) Gene

The amplified gene was cloned in the PTZ-57 vector and the confirmation of cloning was done by restriction enzyme digestion (Fig. 4.23) and the cloned ME gene in pTZ and blue white screening was done by the expression of Lacz (Fig. 4.24).

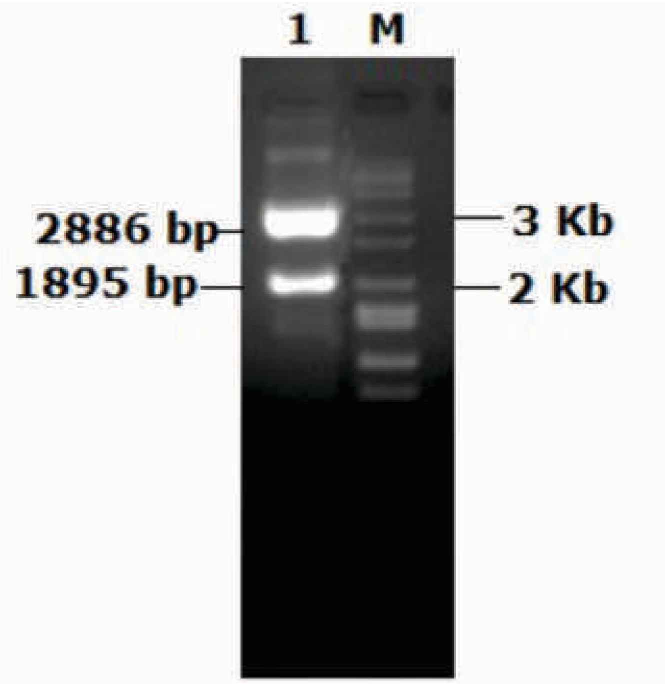


Fig.4.23. Digestion Of ME gene with SalI and XbaI restriction Enzyme

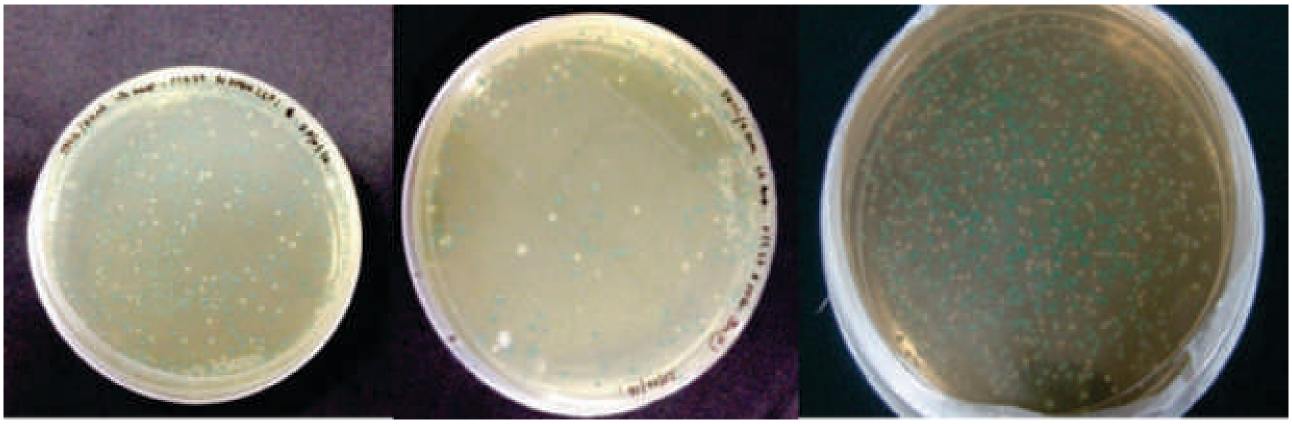


Fig.4.24. Blue white colony of the cloned ME gene


SWARNA Sub-1

PROGRAMME : 5

Socio-economic Research and Extension for Rice in Development

The socio-economic research deals with behavioural issues of rice growers in relation to adoption of different rice production technologies, adoption constraints, training needs, impact of the rice technologies on the income, employment and changes in cropping pattern etc. They also deals with policy variables those are needed to increase rice productivity and income of farmers. In this context, three research projects has been undertaken under Programme-5.

The first project deals with development of model villages through demonstration of different crop varieties, livestock management etc., designing and testing gender sensitive approaches in rice farming, feedback from rice growers on different development schemes being in operation, problems faced by rice farmers and demonstration of rice varieties. Under the second project, a business plan was developed for a Farmers Producer Organization located in Cuttack district. The spread of NRRI varieties and constraints in availability of inputs were also studied in different blocks of Cuttack district. The third project assess the spread of NRRI developed varieties in six states *viz.,* Assam, Haryana, Karnataka, Kerala, Punjab and Tamil Nadu and the Union Territory of Puducherry. It was also assessed from all the five years (2012-13 to 2016-17) data analysis that NRRI varieties are grown to the extent of 2.83 million ha in 14 states of India. The cost of cultivation data of 15 states were updated upto the year 2013-14 and analysis of input data like fertilizer, manure and pesticides over the period of 34 years. The trend in land rent was also studied for different states. ARIMA models were fitted to rice production data of Uttar Pradesh to find out the best model, which predicts the future rice production of that state.

Socio-economic approaches, mechanism and transfer of technologies for sustainable rice production

Development of Model Village, Evaluation of Interventions and Recommendations

Development of rice-based model village (Gurujanga and Guali) was taken up in a rainfed cluster of Tangi-Chodwar block of Cuttack district for dissemination of production technologies through method as well as result demonstrations, trainings, etc. During 2016-17, seed of seven rice varieties i.e., Reeta, Sahabhagi Dhan, Chakka Aakhi, CR Dhan-202, Naveen, CR Dhan-300 and CR Dhan-701 have been supplied for conducting demonstrations in total area of 2 ha covering 18 farmers. Farmers and farmwomen were also given advisory services to grow vegetables for commercial and kitchen garden purposes and seeds of bitter gourd, capsicum, bean, coriander, pumpkin, broccoli were distributed during *kharif* and *rabi*.

Interventions in livestock production and management were taken up like earlier years under convergence mode with the involvement of SMS, KVK, Veterinary Assistant Surgeon (Tangi-Choudwar) and Mobile Veterinary Unit, Department of Animal Husbandry, Government of Odisha for providing optimal health and improvement in livestock production. The Mobile Veterinary unit kept regular surveillance of the region and provided necessary services like deworming, vaccination and treatment as and when required. One Animal Health Camp was conducted at the village in association with Veterinary Assistant Surgeon, where animals were treated and dewormed along with suitable advice for better health management. For creating awareness about fodder production for livestock, 10 fodder kits were provided to the farmers along with the training on feed management as well as clean milk production. An assessment was made and it was observed that the convergence actions resulted in gender sensitization involving of farmwomen and sensitization of famers to visit veterinarian for livestock related problems. A demonstration on health management in goats (N=30) was also taken up and protein supplement were distributed among goat owners and the programme boosted their confidence due to improvement in production and reproduction traits as revealed during a focus group discussion.

As part of the Swachhta Pakhwada, a 'Village Awareness-cum-Cleaning Drive' was organized on

25th October 2016 at Gurujanga village of Tangi-Chowdhar block of Cuttack district. Dr. H. Pathak, Director along with Heads of Divisions, Scientists and other staff participated in a rally to generate awareness about the necessity of keeping the surroundings clean among the villagers, who also participated with enormous interest with slogans and invocation. Director in his address to the villagers elucidated the necessity of cleanliness of self, family and village. On this occasion, Director distributed fodder seeds to the farmers and farmwomen.

'Village Awareness-cum-Cleaning Drive' at Gurujanga Village

Distribution of fodder seeds to the farmers

Director addressing the gathering at Gurujanga Village

Designing and Testing of Gender Sensitive Approaches in Rice Farming

Under this activity, socioeconomic, technological and institutional interventions were continued and evaluated in Sankilo village of Cuttack district. During *kharif*-2016, five NRRI varieties *viz.*, Sachala, CR Dhan-310, CR Dhan-303, CR Dhan-304 and Maudamani were demonstrated as per pre-*kharif* plan meeting in ½ - 1 acre area with the participation of forty farmwomen in Sankilo village. Crop cutting data showed that CR Dhan-303 and CR Dhan-304 performed extremely well with average grain yield of 6.68 t ha^{-1} and 6.44 t ha^{-1}, respectively. The high protein rice variety CR Dhan-310 has performed well with an average grain yield of 6.3 t ha^{-1} followed by Maudamani (6.22 t ha^{-1}) and Sachala (5.9 t ha^{-1}).

Bio-fertilizers like Azotobacter liquid @ 250 ml ha^{-1} and Mycorrhyza @ 1 kg/800 m^2 were distributed to selected farmwomen for vegetable farming. All the forty farmwomen (100%) adopted 'seed treatment with Carbendazim', 'line transplanting' and 'application of recommended dose of fertilizers' and perceived these technologies as very good. All the practicing women perceived both 4-row manual as well as 8-row power-operated transplanter as moderate performers.

The adopted women farmers have attended a training programme on 'Integrated Weed Management' on 9 September, 2016 and one adopted farmwoman received the 'IARI Innovative Farmer' award during Krishi Unnati Mela held at IARI, New Delhi during 15-17 March 2017.

Smt. Rukmini Nayak, adopted farm-women, receiving Best Innovative Farmer award during 'Krishi Unnati Mela–2017' at IARI, New Delhi

Adopted farm-woman receiving Best Farmer award from Hon'ble Minister of Agriculture & Farmers' Welfare during 'Akshay Tritiya–2016' at NRRI, Cuttack

Returns from rice cultivation

Before inception of the project, the beneficiary farmwomen were cultivating many local varieties with less yield along with few improved rice varieties. However after initiation of the project, they have been cultivating only improved rice varieties. Table 5.1 presents the growth in yield (average of all the varieties) as well as operational expenses over the pre-project period (2011-12). It indicates that average yield increased by 42% during the period. Though, operational expenses per unit area increased by 18%, gross returns and net returns over operational expenses increased by 41% and 76%, respectively.

The decomposition analysis was used to estimate the contribution of sources to the difference in returns from rice cultivation between the two periods with respect to the beneficiary farms. The decomposition analysis indicated that the effect of 'technology' contributed mostly which accounted for 27% difference out of total estimated difference in gross returns of 38.21% (Table 5.2). This implies that even without changing the level of resource use, the returns could have been increased by about 27%, if all of them participated in the demonstrations.

The total contribution of differences in the levels of input use to the gap were positive to the extent of 11%, which indicate that gross returns could be increased

Table 5.1. Input-output analysis of rice cultivation (per ha) during pre-project period and 2016-17

Particulars	2011-12	2016-17	Mean difference	t Stat
Yield (q/ha)	35.5	50.38	14.88 (42%)	3.95*
Operational expenses (Rs./ha)	25,575	30,280	4705 (18%)	9.85*
Gross returns (Rs./ha)	42,273	59,593	17,320 (41%)	8.71*
Net returns (Rs./ha)	166,98	29,313	12,615 (76%)	6.22*

*Mean differences were significant at 1% level

Table 5.2. Decomposition of difference in gross returns between the two periods (N=40)

Sources of difference in gross returns	% contribution
Difference due to technical change	27.21
Difference due to input use efficiency	11.00
Total estimated difference in gross returns	38.21
Total observed difference in gross returns	40.97

by 11%, if the per ha input use increased to the same level as during present period. There was a slight discrepancy between the observed and the estimated differences in gross returns between the two periods which was attributed to the random error term and the variables that could not be included in the model.

Household income and its' determinants

An analysis was done to assess the sources of income of the beneficiary household *viz.,* crop cultivation, livestock, labour wages and non-farm sector and the result is presented in Table 5.3. It was observed that crop cultivation including horticultural crops and vegetables contributed about 59% of the household income followed by livestock (15%), non-farm sources (14%) and labour wages (12%).

It was opined by the respondents that the acquired knowledge, skill and demonstrated technologies have been used and adopted for cultivation of rice as well as other crops and enterprises. Cultivation of vegetable and pulses boosted and other activities like animal husbandry have also been intensified, which resulted in increasing annual income of the households. Further, to understand the dispersion in income a multiple regression analysis was carried out to identify the factors that might influences the variation. The results indicated that level of education, family size and extent of irrigated land influenced significantly towards accrual of income from crops and other enterprises (Table 5.4). A variable was added indicating the beneficiary farmers who have joined later period of the project interventions, though found positive coefficients but not significant.

Table 5.3. Sources of household income

Sources	Mean income (rupees in thousand)	Proportion (%)	Standard deviation	Minimum (rupees in thousand)	Maximum (rupees in thousand)
Crops and horticulture	24.85	58.57	36.18	4.58	198.41
Livestock	6.41	15.11	7.10	1.00	10.07
Wage labour	5.17	12.18	2.52	1.98	9.77
Non-farm income	5.97	14.14	5.09	1.59	35.77
Total	42.39	100			

Table 5.4. Determinants of household income

Variables	*Coefficients*	*Standard Error*	*t Stat*
Age	-0.10	0.59	-0.16
Education	2.87*	1.47	1.95
Family size	7.95**	2.45	3.25
Irrigated land	26.74**	5.56	4.81
Standard animal unit	-2.15	2.70	-0.80
Participation from beginning of the project	5.81	11.49	0.51
Intercept	-37.94	28.56	-1. 23
Multiple R	0.75		
R Square	0.56		
Observations	40		

*Significant at 10% level; ** Significant at 1% level

Perceptions of beneficiary women on the appropriateness of recommended/ demonstrated varieties and technologies

It was utmost necessary to assess the perceptions of the beneficiaries at the end of the execution of gender sensitive approaches with regards to the appropriateness of recommended/demonstrated varieties and technologies to their farming systems. Respondents were asked to compare the demonstrated rice varieties to earlier grown improved/local varieties in combination with recommended technologies on the attributes like yield, pest resistance, profitability, weed tolerance, labour requirement, etc. They were asked to rate the recommended varieties on a five-point Likert scale as: much lower, lower, equal, higher or much higher in different attributes than earlier grown varieties. Table 5.5 presents the analysis of the data which shows that majority of the respondents had positive perceptions with regards to comparative advantage of recommended/demonstrated rice varieties over earlier grown varieties in terms of yield, resistance to pest/diseases, tolerance to weeds, cooking qualities and marketability. For instance, 60% of the respondents rated demonstrated rice varieties higher and another 36% rated as much higher in yield than the earlier grown varieties, while only 4% of respondents felt that there was no comparative yield difference between them. In the same vein, 82%, 55%, 70% and 86% of respondents expressed the opinion that the demonstrated varieties exhibited comparative advantage over the earlier grown varieties in terms of cooking quality, tolerance to weeds, storage quality and marketability, respectively.

Demonstration of rice variety Swarna *sub-1* in the gender project village

Adopted women farmers doing crop cutting in Sankilo village

Table 5.5. Distribution of respondents according to their perceptions on attributes of demonstrated rice varieties

	Much lower	Lower	Equal	Higher	Much higher	Rank*
Yield advantage	0.00	0.00	3.81	60.00	36.19	I
Cooking qualities	4.76	0.00	13.33	51.43	30.48	III
Resistance to pests/diseases	0.00	5.71	43.81	40.95	9.52	VI
Tolerance to weeds	0.00	4.76	40.00	47.62	7.62	V
Labour requirement	0.00	8.57	61.90	24.76	4.76	VIII
Storage quality	0.00	3.81	25.71	57.14	13.33	IV
Drought Resistance	0.00	5.71	52.38	36.19	5.71	VII
Marketability	0.00	1.90	12.38	60.95	24.76	II

*Rank prepared based on % of respondents rated higher & much higher for a particular attributes

In order to identify the attributes which actually influence for liking of particular technologies/ methods demonstrated and/or adopted by the beneficiary farmwomen, they were asked to express their ratings through same Likert scale and the findings are presented in Table 5.6. It is observed from the data that majority of the respondents, over 94%, perceived that the demonstrated technologies were helpful to reap better yield and more than 90% of them perceived that they easily received the information about the methods and usages. However, a sizeable number of respondents, i.e. about 26 to 34% were not affirmative that the technologies are easy to use and save materials input/ labour.

Demonstration of NRRI Rice Varieties

The newly released rice varieties of NRRI were transplanted for on-station demonstration during *kharif* and *rabi* (2016-17). The main objective of this demonstration was to showcase the performance of varieties to different groups of visitors. The yield and other yield attributes were recorded.

During *rabi* 2016-17, 24 rice varieties of different duration were demonstrated *viz.,* Rajalaxmi, Ajay, CR Dhan 304, CR Dhan 701, CR Dhan 303, CR Dhan 305, CR Dhan 306, Satyakrishna, Binadhan 8, Phalguni, Naveen, CR Dhan 201, CR Dhan 204, Binadhan 10, Lunasankhi, Pyari, CR Dhan 203, CR Dhan 205, Sahabhagidhan, Hazaridhan, Satabdi, Satyabhama, CR Dhan 202 and CR Dhan 101. Among the demonstrated varieties Rajalaxmi recorded highest yield (7.3 t ha^{-1}) and CR Dhan 101 recorded lowest yield i.e. 3.5 t ha^{-1}.

During *kharif* 2016-17, 24 different rice varieties were demonstrated *viz.,* Rajalaxmi, Ajay, CR Dhan 701, Reeta, CR Dhan 304, CR Dhan 305, CR Dhan 303, Sumit, Maudamani, Chakaakhi, CR Dhan 306, CR Dhan 505, CR Dhan 500, CR Dhan 300, CR Dhan 501, Lunasuvarna, Pyari, Satyabhama, CR Dhan 206, CR Dhan 205, CR Dhan 202, CR Dhan 204, CR Dhan 203 and Lunabarial. During *kharif* 2016 also Rajalaxmi recorded highest yield (7.1 t ha^{-1}) followed by Ajay (6.9 t ha^{-1}). Lowest yield was recorded from the varieties Lunabarial and CR Dhan 203 (4.3 t ha^{-1} each).

Feedback on Rice Production Technologies (RPTs) as Perceived by Different Stakeholders

During 2012-17, feedback on various aspects of rice, like suitability of varieties, performance of various production technologies (RPTs) and government sponsored programmes/schemes and related issues were collected randomly from 1100 rice farmers covering fifteen states namely, Odisha, Bihar, Jharkhand, Assam, West Bengal, Meghalaya, Madhya Pradesh, Chhattisgarh, Andhra Pradesh, Tamil Nadu, Gujarat, Maharashtra, Punjab, Uttar Pradesh and Delhi using a structured interview schedule. However, data with regard to the awareness, perception on performance of various government schemes/ programmes and major problems faced in rice farming were collected from 740 farmers and analyzed in a five-point continuum scale (1-5 score) and ranked as per the Weighted Cumulative Score (WCS) as well as Weighted Unit Score (WUS) obtained from the practicing farmers (Table 5.7).

It can be seen from the table that about 69%, 54%, 45%, and 35% farmers were not aware about the recent programmes like National Food Security Mission (NFSM), Soil Health Card (SHC), Pradhan Mantri Fasal Bima Yojana (PMFBY) and Bringing Green Revolution to Eastern Indian (BGREI) programmes,

Table 5.6. Distribution of respondents according to the perceptions on attributes of various technologies

Attributes of Technologies	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Yield advantage	0	0.00	5.88	58.82	35.29
Access to information on how to use	0	2.35	9.41	74.12	14.12
Easiness to obtain the technology	0	7.06	29.41	45.88	17.65
Easiness to use the technology	0	4.71	25.88	57.65	11.76
Saving of material inputs	0	1.18	34.12	54.12	10.59
Labour saving	0	7.06	25.88	55.29	11.76

Table 5.7. Awareness of farmers about major Government programmes and schemes (N=740)

Major Schemes/ Programmes	Not Aware		Aware, but Not Experienced		Aware and Experienced	
	Frequency	%	Frequency	%	Frequency	%
1. PMFBY	334	45.1	399	53.9	7	1.0
2. Soil Health Card	397	53.6	277	37.4	66	8.9
3. NFSM	509	68.8	172	23.2	59	8.0
4. ATMA	61	8.2	29	3.9	650	87.8
5. BGREI	256	34.6	159	21.5	325	43.9
6. MSP	35	4.7	69	9.3	636	85.9
7. KVK	89	12.0	106	14.3	545	73.6
8. Seed sale though Govt. outlets	84	11.4	115	15.5	541	73.1

respectively. While, 54% and 37% farmers were aware about PMFBY and SHC programmes, very few of the 740 respondents had experienced these two newly launched programmes. On the other hand, 88%, 86% and 74% farmers were both aware as well as experienced the relatively older programmes like Agricultural Technology Management Agency (ATMA), Minimum Support Price (MSP) and Krishi Vigyan Kendra (KVK), respectively.

Regarding the perception about the performance of various government schemes among the aware and experienced farmers mentioned at table 5.8, the schemes namely, BGREI (with WUS-4.65), ATMA (WUS-4.42) and NFSM (WUS-4.34) have been well appreciated by the beneficiary farmer stakeholders, followed by the relatively older programmes like Seed sale through Government outlets (WUS-4.17) and KVK (WUS-4.05).

From the analysis on major problems (twelve) encountered by the farmers, it can be seen from the table 5.9 that unavailability of quality seeds in time (WUS-4.27), unavailability of labour during peak cropping season (WUS-4.05), crop damage due to drought (WUS-3.64), distress sale of paddy below MSP (WUS-3.64) and lack of irrigation facility (WUS-3.63) were the major problems faced by the farmers in rice farming.

Characterization of Resources and Innovations to aid Rice Research and Develop Extension Models

Development of Business Models of NRRI technologies for entrepreneurship development at community level

During the year 2016-17, a Farmer Producer Organization (FPO) was formed and registered in Mahanga block of Cuttack district in the name of Mahanga Agro Producer 4S4R Pvt Ltd under the Company Act. The major business of the FPO is paddy seed production and processing at local level. Hence, a business plan on Paddy Seed Production through FPO was prepared. The total cost of the project was estimated to be Rs. 31.95 lakhs (Table 5.10). As per profitability projections, it was observed that a small profit to the extent of Rs.0.68 lakhs occurred at the end of first year. However, during second year Break-Even Point (BEP) was achieved (Table 5.11 and Fig 5.1). The profit in the first year was less because it is beginning of the seed production cycle starting from breeder seed to foundation seed. During the first year, only 32,000 kg of foundation seed was produced having sales realization (Gross returns) of Rs. 8.96 lakhs. However, in the second year the sales realization is projected to be Rs. 97.13 lakhs due to

Table 5.8. Perception about the performance of major Government programmes and schemes among the beneficiary farmers (N=740)

Major Schemes/ Programmes	No. of beneficiary farmers	No. of farmers rating the Performance (5/ 4/ 3/ 2/ 1)					WCS	WUS	Rank
		Very Good	Good	Average	Poor	Very Poor			
BGREI	650	504	91	31	24	0	3025	4.65	I
ATMA	159	103	29	17	10	0	702	4.42	II
NFSM	59	36	11	8	4	0	256	4.34	III
Seed sale though Govt. outlets	541	328	81	45	71	16	2257	4.17	IV
KVK	545	276	146	59	41	23	2207	4.05	V
Soil Health Card	77	3	42	21	0	0	246	3.73	VI
MSP	636	123	233	56	148	71	2102	3.31	VII
PMFBY	7	0	2	5	0	0	23	3.29	VIII

(WCS: Weighted Cumulative Score; WUS: Weighted Unit Score)

additional production of 2755.2 quintals of certified seed. Second year onwards, the FPO is supposed to maintain this level of sales realization. The cumulative discounted (at the rate of 10%) gross return is shown in Fig 5.1 against cumulative discounted cost of seed production over the first five years.

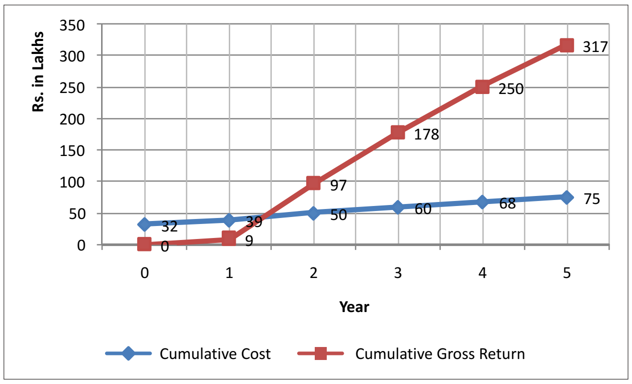


Fig. 5.1. BEP (Break-Even Point) of Paddy Seed Production through FPO

Develop pilot model for characterisation of resources and innovations for rice development in eastern region

Data were collected from Cuttack district to verify the earlier results on characterization of resources and innovations. The results showed that Pooja covered nearly 28% of total area under rice (Fig. 5.2) followed by Swarna *sub1* (14%). It was also found that the input supply such as seed, fertilizer and pesticide were easily available to majority of the farmers, while 50% farmers reported that it is difficult to get labour during the peak season (Fig. 5.3). Further, data was collected at block level from Cuttack district on coverage of NRRI HYVs in 2016-17, which was close to predicted coverage (Fig 5.4). However, in some of the blocks namely, Kantapara, Banki, Baramba, Banki-Damapada and Tigiria, the difference was found to be large between observed and predicted data.

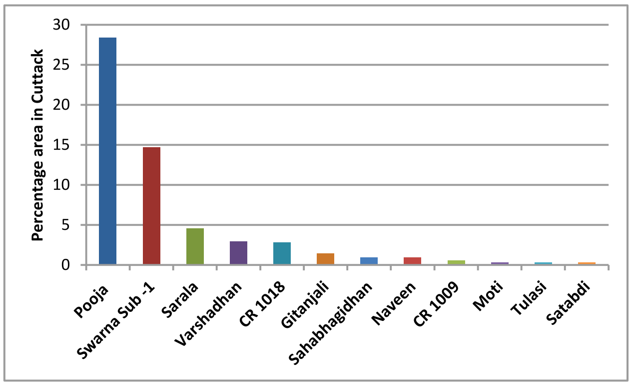


Fig. 5.2. Area under NRRI Varieties in Cuttack district

Table 5.9. Problems in rice production as perceived by the farmer stakeholders (N=740)

S. No.	Problems in Rice production	Severity of the Problem (5/ 4/ 3/ 2/ 1)					WCS	WUS	Rank
		Very severe	Severe	Moderate	Mild	Very mild			
1	Unavailability of quality seeds in time	448	152	69	32	39	3158	4.27	I
2	Unavailability of labour during peak cropping season	339	192	152	20	37	2996	4.05	II
3	Crop damage due to drought and/or water scarcity	263	183	91	174	29	2697	3.64	III
4	Distress sale of paddy below MSP	304	198	51	40	147	2692	3.64	IV
5	Lack of irrigation facility	234	199	156	103	48	2688	3.63	V
6	Erratic rainfall pattern in rainfed areas	241	191	88	135	85	2588	3.50	VI
7	Infestation of diseases and pests	191	180	168	162	39	2542	3.44	VII
8	Poor farmers-officers interactions	217	120	216	134	53	2534	3.42	VIII
9	High costs of farm inputs	178	151	140	173	98	2358	3.19	IX
10	Crop damage due to flood and submergence after heavy rainfall	198	127	164	115	136	2356	3.18	X
11	Unavailability of sufficient pesticides and fertilizers	143	135	199	171	92	2286	3.09	XI
12	Unavailability of sufficient numbers of farm implements/ machineries	159	98	201	193	89	2265	3.06	XII

(WCS: Weighted Cumulative Score; WUS: Weighted Unit Score)

Table 5.10. Cost of the Project on Paddy Seed Production through FPO

S. No.	Particulars	Value (in thousand rupees)
1	Land and Building	1206.00
2	Machineries/Equipment	983.11
3	Miscellanous Fixed Assets	63.00
4	Preoperative and Preliminary Expenses	600.07
5	Working Capital (First Year)	292.62
6	Contingencies	50.00
	TOTAL	**3194.80**

Table 5.11. Discounted Profitability Projections during First Five Years of Paddy Seed Production through FPO

S. No.	Particulars	1st Year	2nd Year	3rd Year	4th Year	5th Year
A	**Cost of Production**	**Value (in thousand rupees)**				
	i. Working Capital	292.62	807.34	733.93	667.2	606.56
	a. Raw materials (bags Only)	88.62	559.15	508.31	462.10	420.09
	b. Utilities	40.00	36.36	33.06	30.05	27.32
	c. Salaries/wages	123.00	111.82	101.65	92.41	84.01
	d. Repairs and maintenance	0.00	9.09	8.26	7.51	6.83
	e. Marketing expenses	10.00	9.09	8.26	7.51	6.83
	f. Administrative expenses	2.00	1.82	1.65	1.50	1.37
	g. Interest on Working Capital	29.00	80.01	72.74	66.12	60.11
	ii. Interest on Fixed Capital	319.71	253.92	193.77	138.75	88.40
	iii. Rent	60.00	54.55	49.59	45.08	40.98
	iv. Depreciation	155.41	126.25	102.84	83.97	68.70
	Total	**827.74**	**1242.05**	**1080.14**	**935.02**	**804.64**
B	Sales realization (Gross Returns)	896.00	8829.67	8026.97	7297.25	6633.86
C	**Profit (B-A)**	**68.26**	**7587.63**	**6946.83**	**6362.23**	**5829.22**

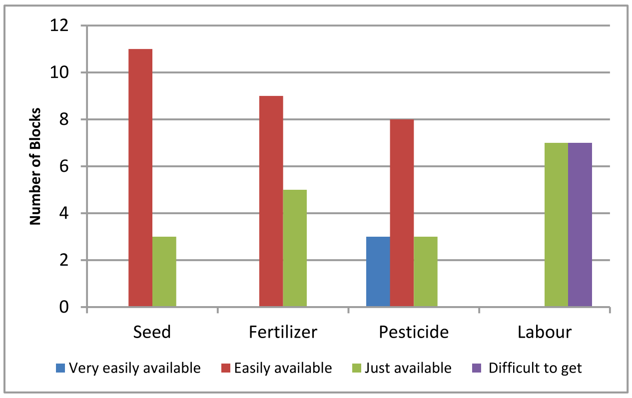


Fig. 5.3. Input availability in Cuttack district

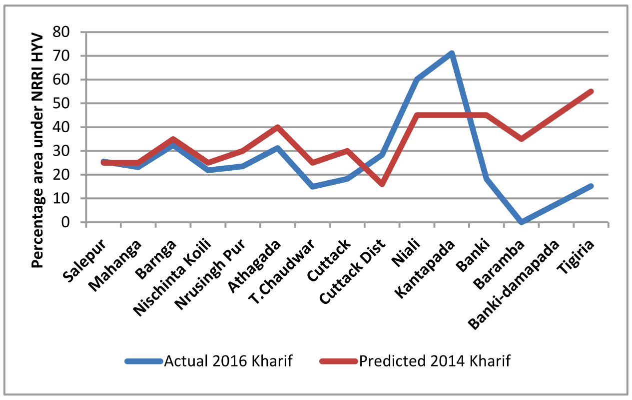


Fig. 5.4. Observed and predicted coverage of NRRI HYV in Cuttack district

Impact analysis and database updation in relation to rice technologies, policy and programmes

Estimation of Area under NRRI Varieties in Different States

The variety wise certified seed distribution and HYV area information for five years were used to estimate the area under different rice varieties in seven states *viz.*, Assam, Haryana, Karnataka, Kerala, Puducherry, Punjab and Tamil Nadu.

Analysis of data revealed that the varieties with more than one lakh ha of area in the state of Assam were Ranjit, Mahsuri and Swarna. The other important varieties of the state were Bahadur, Swarna *sub-1*, IR 64, Luit, Abhisek, and Lachit. NRRI varieties like Abhisek, Naveen, Chandrama and Sahabhagi were grown to the extent of 68,131 ha.

The mega varieties (> 1 lakh ha area) of the state of Haryana were Pusa-1121, Pusa-44, PR-118, HKR-47 and PR-114 and Pusa Basmati-1. The other prominent varieties of the state were CSR-30, PR-113 and HKR-147.

The mega varieties of the state of Karnataka were MTU-1001, BPT-5204, IR 64, and Jyothi. The other important varieties of the state are Jaya, JGL-1798, MTU-1010, Tellahamsa, Uma, BR-2655, Thanu and Abhilash.

The analysis of data for Kerala state revealed that Uma is the only variety covering more than 1 lakh ha area. The other important varieties of the state were Jyothi and Kanchana. NRRI variety CR-1009 was grown to the extent of 5074 ha.

The important varieties of the Union Territory of Puducherry were Improved white ponny, CR-1009, ADT-37, ADT-43 and BPT-5204. It is estimated that CR-1009 was grown to the extent of 3068 ha in the Union Territory

The mega varieties of the state of Punjab were Pusa-44, Pusa-1121, PR-118, HKR-47, HKR-127, PR-114, PR-114, PR-111, PR-113 and PR-116. The other prominent varieties of the state were Pusa Basmati-1, Pusa Basmati-1509, PR-122, Basmati-386, Pusa Basmati-3 and PR-121.

The major rice varieties with larger area coverage (> 1 lakh ha) in the state of Tamil nadu were ADT-45, ADT-43, ADT-39, BPT-5204, ADT-36, CR-1009 and Improved White Ponni. The NRRI variety CR-1009 was grown to the extent of 115,238 ha in the state during Samba season. The other important varieties (area more than 50,000 ha) of the state were ADT-38, ADT-37, Co-43, JGL-1798 and ASD-16.

It was also revealed from the compilation of data of all the states that thirty NRRI varieties are grown to the extent of 2.83 million ha in 14 states of India.

Analysis of Cost of Cultivation Data

Detailed cost of cultivation data of rice for 18 states of India for two years (2012-13 and 2013-14) was digitized and data were analyzed taking the last 34 years data (1980-81 to 2013-14) to find out the trends in fertilizer, manure and pesticide use in different states over years. The trends in land rent over years was also studied as land rent is the second important cost item after human labour expenses in rice cultivation.

On an average, at all India level the fertilizer use in rice crop is computed to be 142 kg ha^{-1} during 2009-13 and the rate has increased over years (Fig. 5.5). The average manure use has decreased from 28 q ha^{-1} during early 1980s to 13 q ha^{-1} during the period 2009-2013 (Fig. 5.6). The expenditure on pesticide use was Rs. 863 per ha at all India level at constant (2013-14) price (Fig. 5.7). The land rent has also increased over years at all India level (Fig. 5.8). It has increased from Rs. 8293 during early 1980s to Rs. 13896 per ha during the period 2009-13.

State wise observation revealed that the fertilizer use was more than 200 kg ha^{-1} in Karnataka, Tamil Nadu, A.P., Punjab and Haryana and between 150 to 200 kg ha^{-1} in the states of Gujarat, U.P. and Kerala (Fig. 5.9). Least fertilizer use was observed in the states of Assam (16 kg ha^{-1}) and HP (24 kg ha^{-1}). The manure use was maximum in Tamil Nadu (33.7 q ha^{-1}) and least in the states of Bihar, Jharkhand, Uttar Pradesh, Himachal Pradesh and Assam (1 to 5 q ha^{-1}) (Fig 5.10). The pesticide expenditure per ha in rice cultivation was maximum in the states of Punjab (Rs. 3340) followed by Haryana (Rs. 2442), Andhra Pradesh (Rs. 2001) and Karnataka (Rs. 1777) at constant prices of 2013-14 (Fig. 5.11). The pesticide use was least in the states of Jharkhand, Bihar, Assam and Odisha. The land rent per ha was maximum in the state of Punjab

(Rs.31,758) at constant prices (2013-14) and less in the states of Jharkhand, Bihar, Himachal Pradesh and Assam (Fig. 5.12).

Fifty three years data (1960-61 to 2012-13) was used for developing model of rice production data of Uttar Pradesh (including Uttarakhand). The data was divided into two parts *viz.*, model estimation and model testing. The data from 1960-61 to 2004-05 was used for model estimation and data from 2005-06 to 2012-13 was used for model testing. The statistics Akaike information criterion (AIC) and Bayesian information criterion (BIC) were used for the model estimation. Twenty five models have been tested and ARIMA (1, 1, 1) was found to be the best fitted model. The parameter estimates of MU, MA1, 1 and AR1, 1 are 198.71, 0.39 and -0.45, respectively. The forecasted rice production of Uttar Pradesh for the year 2020 is 13.7 million tons with the standard error of 3.3 million tones.

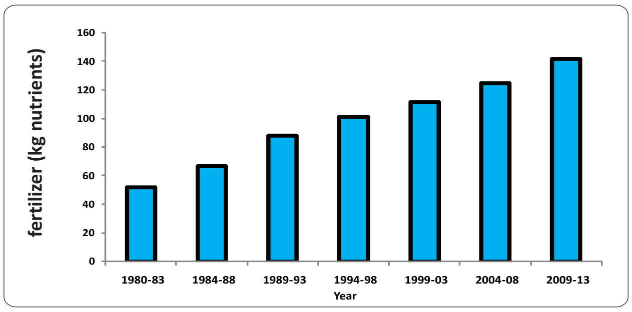


Fig. 5.5. Trends in fertilizer use in rice in India (1980-2013)

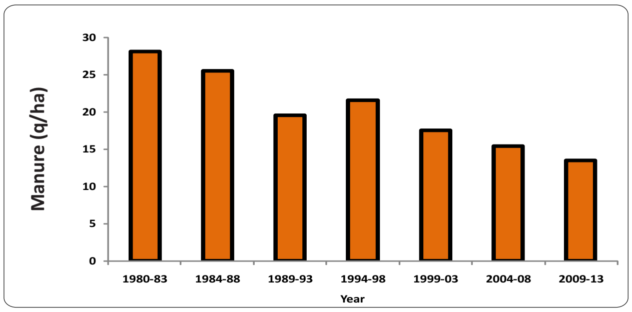


Fig. 5.6. Trends in manure use in rice in India (1980-2013)

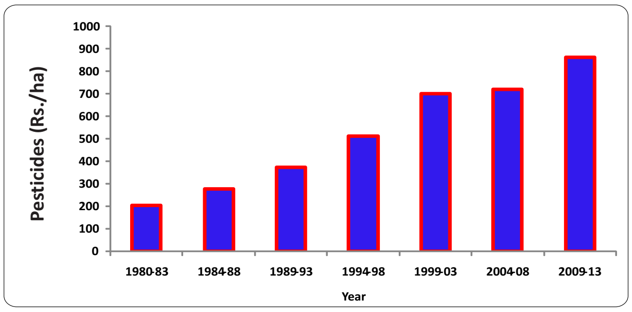


Fig. 5.7. Trends in pesticides use in rice in India (1980-2013)

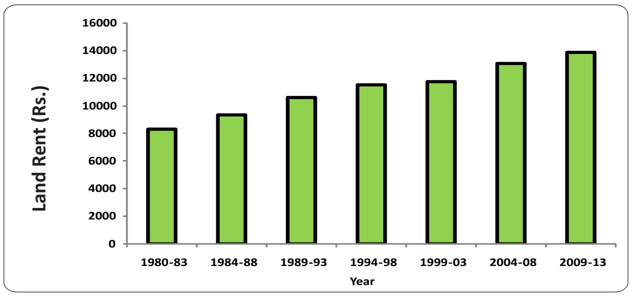


Fig. 5.8. Trends in land rent in rice in India (1980-2013)

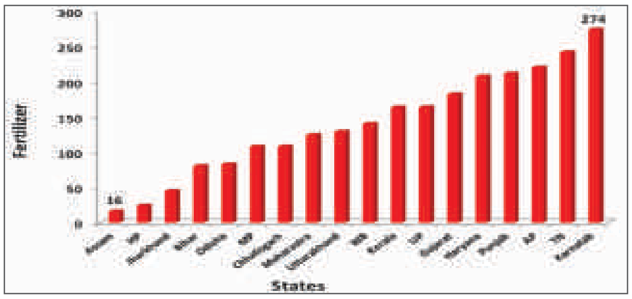


Fig. 5.9. Fertilizer use in different states (kg nutrients/ha) (2010-13)

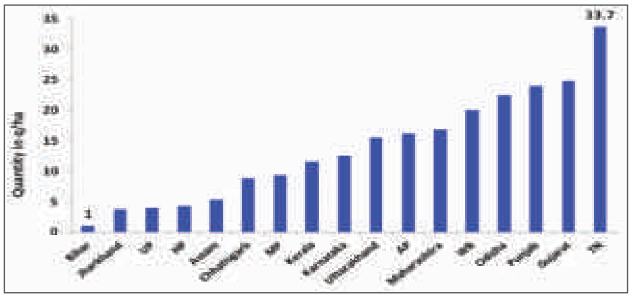


Fig. 5.10. Statewise manure use (q ha^{-1}) in rice cultivation

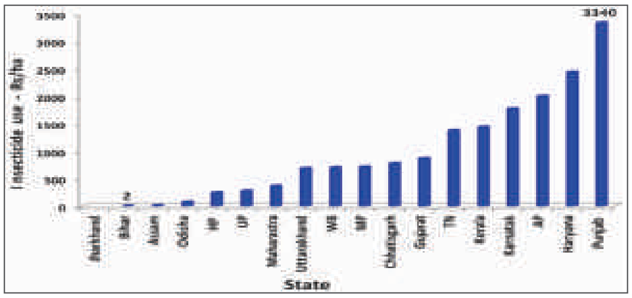


Fig. 5.11. Pesticide use in different states (2010-13)

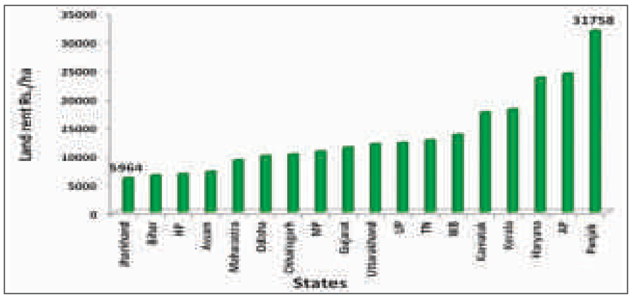


Fig. 5.12. Land rent in different states (2010-13)

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सिंह सीवी, सिंह सीवी, कुमारी चंचिला, रंजन रुपेश, कुमार मनीष, मंडल एनपी, मैती डी, भगत एस एवं कुमार योगेश. २०१६. खेतीबाड़ी आधारित जीविकोपार्जन के विकल्प, केन्द्रीय वर्षाश्रित उपराऊ भूमि चावल अनुसन्धन केंन्द्र, (राष्ट्रीय चावल अनुसन्धन संस्थान)

टेक्नोलॉंजी बुलेटिन सीरीज २०१६-१, प्रष्ठ से. २०

शेखर सुधांशु, कुमारी चंचिला, रंजन रुपेश, कुमार मनीष, सिंह सीवी, मैती डी, मंडल एनपी, कुमार योगेश एवं भगत एस. २०१६. उत्तरी छोटानागपुर में विभिन्न फसलों एवं पशुओं के रख-रखाव की मासिक कार्य विवरणिका, केन्द्रीय वर्षाक्षित उपराऊ भूमि चावल अनुसन्धन केंन्द्र, (राष्ट्रीय चावल अनुसन्धन संस्थान) टेक्नोलॉंजी बुलेटिन सीरीज २०१६-३, प्रष्ठ से. १२

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Mukherjee AK, Behera S, Swain H, Aravindan S and Bag MK. 2016. *Bipolaris oryzae* isolate NRRI-BS-1 internal transcribed spacer 1, partial sequence; 5.8S ribosomal RNA gene, complete sequence; and internal transcribed spacer 2, partial sequence. Gen Bank ACC:KX881383.1.

Mukherjee AK, Behera S, Swain H, Yadav MK and Jena M. 2016. *Magnaporthe oryzae* isolate NRRI-PO-2 internal transcribed spacer 1, partial sequence; 5.8S ribosomal RNA gene, complete sequence; and internal transcribed spacer 2, partial sequence. Gen Bank Acc: KX881384.1.

Mukherjee AK, Swain H, Patro R and Behera S. 2016. *Trichoderma atroviride* strain CRRI-T5 internal transcribed spacer 1, partial sequence; 5.8S ribosomal RNA gene and internal transcribed spacer 2, complete sequence; and 28S ribosomal RNA gene, partial sequence. Gen Bank: KX853518.1.

Mukherjee AK, Swain H, Behera S and Adak T. 2016. *Trichoderma harzianum* strain CRRI-T1 internal transcribed spacer 1, partial sequence; 5.8S ribosomal RNA gene and internal transcribed spacer 2, complete sequence; and 28S ribosomal RNA gene, partial sequence. Gen Bank: KX853519.1.

Mukherjee AK, Swain H, Patro R, Behera S and Jena M. 2016. *Trichoderma atroviride* strain CRRI-T13 internal transcribed spacer 1, partial sequence; 5.8S ribosomal RNA gene and internal transcribed spacer 2, complete sequence; and 28S ribosomal RNA gene, partial sequence. Gen Bank: KX863695.1.

Mukherjee AK, Swain H, Behera S, Yadav MK, Bag MK and Jena M. 2016. *Trichoderma atroviride* strain CRRI-T9 internal transcribed spacer 1, partial sequence; 5.8S ribosomal RNA gene, complete sequence; and internal transcribed spacer 2, partial sequence. Gen Bank: KX863696.

Prabhukarthikeyan SR, Ragu S, Yadav MK, Aravindan S, Lenka S, Bag MK, Mukherjee AK and Jena M. *Sarocladium oryzae* isolate S1, internal transcribed spacer 1, partial sequence; 5.8S ribosomal RNA gene and internal transcribed spacer 2, complete sequence; and 28S ribosomal RNA gene, partial sequence. ACC:MF033171.

Prabhukarthikeyan SR, Ragu S, Yadav MK, Aravindan S, Lenka S, Bag MK, Mukherjee AK and Jena M. *Sarocladium oryzae* isolate S2, internal transcribed spacer 1, partial sequence; 5.8S ribosomal RNA gene and internal transcribed spacer 2, complete sequence; and 28S ribosomal RNA gene, partial sequence. ACC:MF033170.

Prabhukarthikeyan SR, Ragu S, Yadav MK, Aravindan S, Lenka S, Bag MK, Mukherjee AK and Jena M. *Sarocladium oryzae* isolate S3, internal transcribed spacer 1, partial sequence; 5.8S ribosomal RNA gene and internal transcribed spacer 2, complete sequence; and 28S ribosomal RNA gene, partial sequence. ACC:MF033169.

Prabhukarthikeyan SR, Ragu S, Yadav MK, Aravindan S, Lenka S, Bag MK, Mukherjee AK and Jena M. *Sarocladium oryzae* isolate S4, internal transcribed spacer 1, partial sequence; 5.8S ribosomal RNA gene and internal transcribed spacer 2, complete sequence; and 28S ribosomal RNA gene, partial sequence. ACC:MF033168.

Prabhukarthikeyan SR, Ragu S, Yadav MK, Aravindan S, Lenka S, Bag MK, Mukherjee AK and Jena M. *Sarocladium oryzae* isolate S5, internal transcribed spacer 1, partial sequence; 5.8S ribosomal RNA gene and internal transcribed spacer 2, complete sequence; and 28S ribosomal RNA gene, partial sequence. ACC:MF033167.

Prabhukarthikeyan SR, Ragu S, Yadav MK, Aravindan S, Lenka S, Bag MK, Mukherjee AK and Jena M. *Sarocladium oryzae* isolate S6, internal transcribed spacer 1, partial sequence; 5.8S ribosomal RNA gene and internal transcribed spacer 2, complete sequence; and 28S ribosomal RNA gene, partial sequence ACC:MF033166.

Prabhukarthikeyan SR, Ragu S, Yadav MK, Aravindan S, Lenka S, Bag MK, Mukherjee AK and Jena M. *Sarocladium oryzae* isolate S7, internal transcribed spacer 1, partial sequence; 5.8S ribosomal RNA gene and internal transcribed spacer 2, complete sequence; and 28S ribosomal RNA gene, partial sequence. ACC: MF033165.

Prabhukarthikeyan SR, Ragu S, Yadav MK, Aravindan S, Lenka S, Bag MK, Mukherjee AK and Jena M. *Sarocladium oryzae* isolate S8, internal transcribed spacer 1, partial sequence; 5.8S ribosomal RNA gene and internal transcribed spacer 2, complete sequence; and 28S ribosomal RNA gene, partial sequence. ACC: MF033164.

Prabhukarthikeyan SR, Ragu S, Yadav MK, Aravindan S, Lenka S, Bag MK, Mukherjee AK and Jena M. *Fusarium proliferatum* isolate F2, internal transcribed spacer 1, partial sequence; 5.8S ribosomal RNA gene and internal transcribed spacer 2, complete sequence; and 28S ribosomal RNA gene, partial sequence. ACC: MF033172.

Prabhukarthikeyan SR, Ragu S, Yadav MK, Aravindan S, Lenka S, Bag MK, Mukherjee AK and Jena M. *Fusarium fujikuroi* isolate F3, internal transcribed spacer 1, partial sequence; 5.8S ribosomal RNA gene and internal transcribed spacer 2, complete sequence; and 28S ribosomal RNA gene, partial sequence. ACC: MF033174.

Prabhukarthikeyan SR, Ragu S, Yadav MK, Aravindan S, Lenka S, Bag MK, Mukherjee AK and Jena M. *Fusarium proliferatum*isolate F4, internal transcribed spacer 1, partial sequence; 5.8S ribosomal RNA gene and internal transcribed spacer 2, complete sequence; and 28S ribosomal RNA gene, partial sequence. ACC: MF033172.

Prabhukarthikeyan SR, Ragu S, Yadav MK, Aravindan S, Lenka S, Bag MK, Mukherjee AK and Jena M. *Fusarium oxysporum* isolate F5, internal transcribed spacer 1, partial sequence; 5.8S ribosomal RNA gene and internal transcribed spacer 2, complete sequence; and 28S ribosomal RNA gene, partial sequence. ACC: MF033175.

Prabhukarthikeyan SR, Ragu S, Yadav MK, Aravindan S, Lenka S, Bag MK, Mukherjee AK and Jena M. *Fusarium proliferatum* isolate F6, internal transcribed spacer 1, partial sequence; 5.8S ribosomal RNA gene and internal transcribed spacer 2, complete sequence; and 28S ribosomal RNA gene, partial sequence. ACC: MF033164.

Radio/TV Talks

- Dr. Yogesh Kumar delivered two TV talks on 6 May and 12 May 2016 on various aspects of rice production technology.
- Drs. NP Mandal and CV Singh delivered TV talks dealing with varietal selection and production enhancement aspects on 12 May 2016.

- Dr. S Bhagat delivered two radio talks on "Rice diseases and management" and "Disease management in vegetables" which was broadcasted by Hazaribagh Radio Station of Prasar Bharati on 24 September 2016.
- Dr. Yogesh Kumar delivered two radio talks on 'Suitable varieties of *kharif* pulses and their package and practices in Jharkhand' and "Cultivation of Kulthi and Sarguja and their packages and practices in Jharkhand" on 8 July 2016 and 19 August 2016, respectively which were broadcasted by All India Radio, Hazaribagh, Jharkhand.
- Dr. Yogesh Kumar delivered TV talk on 'System of Rice Intensification (SRI) and Traditional Method' and 'Management of paddy and *kharif* pulse crops' on 7 July 2016 and 27 August 2016, respectively which were telecasted by Krishi Darshan Programme, Doordarshan Ranchi, Jharkhand.
- Smt. Sujata Sethy delivered a radio talk on 'Storage and processing of pulses' (ଡାଲି ଜାତୀୟ ଶସ୍ୟର ସଂରକ୍ଷଣ ଓ ପ୍ରକ୍ରିୟାକରଣ) broadcasted by AIR, Cuttack on 5 October 2016.
- Dr. RK Mohanta delivered a radio talk on 'How to get a good milch cow' (ଭଲ ଗାଈ ପାଇବା କିପରି) broadcasted by AIR Cuttack on 20 October 2016.
- Dr. PC Rath delivered a radio talk on 'How to store paddy and rice safely' (ଧାନ ଓ ଚାଉଳକୁ ସାଇତି ରଖିବା କିପରି) which was broadcasted by AIR Cuttack on 15 February 2017 in Krushi Sansar Programme.
- Dr. Lipi Das delivered a radio talk on 'Women empowerment in Rice Farming' (ଧାନ ଚାଷରେ ମହିଳା ସଶକ୍ତି କରଣ) in AIR, Cuttack on 21 February 2017.
- Dr. DR Sarangi delivered a radio talk on 'Cultivation of Pulses for Improving Soil Health' (ମାଟିର ଉର୍ବରତା ବୃଦ୍ଧି ପାଇଁ ଡାଲି ଜାତୀୟ ଫସଲ) which was broadcasted by AIR Cuttack on 7 March 2017 in Krishi Sansar programme.

Events and Activities

IJSC, IMC, IRC, RAC and SAC Meetings

Institute Joint Staff Council

The Institute Joint Staff Council meeting was held on 29 September 2016 at NRRI, Cuttack under the chairmanship of Dr. H Pathak, Director. The members present during the meeting were Dr. SD Mohapatra, Principal Scientist, Crop Protection Division, Shri SR Khuntia, CF&AO, Shri BK Sinha, Sr. AO, Shri DK Mohanty, AAO (Technical & Secretary official side), Shri RC Pradhan, CJSC Member, Shri SK Sahoo, Secretary staff side, Shri P Moharana, STA, Shri DR Sahoo, STA, Shri B Pradhan, Technician, Shri KC Ram, SSS, Shri Meru Sahoo, SSS and Shri MC Nayak, SSS. Various administrative and financial matters were discussed and finalized.

Research Advisory Committee

The 22nd meeting of the Research Advisory Committee (RAC) of NRRI was held from 16 to 17 November 2016 at NRRI, Cuttack. Prof. VL Chopra, Chairman, RAC and members Dr. BV David, Dr. (Mrs.) Krishna Srinath, Dr. VK Dadhwal, Dr. AK Singh, Shri Kulamani Rout and Shri Utkal Keshari Parida were present during the meeting. Dr. V Ravindra Babu, Director, IIRR attended the meeting as special invitee. The chairman along with the members conducted a pre-meeting briefing with the Director followed by an open session. Dr. H Pathak, Director, NRRI presented the highlights of the research achievements and infrastructural developments since the last RAC meeting.

Visit of the RAC Members to experimental fields

Dr. H Pathak, Director, NRRI presenting before RAC

Dr. JN Reddy, Member Secretary presented the details of the action taken report (ATR) on the recommendations of the 21st RAC. Research and extension achievements made between November, 2015 and October, 2016 were presented by different Programme Coordinators/Co-Programme Coordinators (Dr. JN Reddy, Dr. AK Nayak, Dr. (Mrs.) M Jena, Dr. SG Sharma and Dr. BN Sadangi). This was followed by a brief presentation by Dr. D Maiti, Officer-in-Charge, NRRI Regional Station, Hazaribag, Jharkhand and Dr. KB Pun, Officer-in-Charge, NRRI Regional Station, Gerua, Assam on overall activities of the respective stations. Mr. BK Sinha, Senior Administrative Officer presented details of staff, budget and administration related issues before the RAC. The RAC members also visited different experimental fields and facilities in the divisions and had discussion with the scientists of concerned disciplines.

Institute Research Council

The 35th meeting of the Institute Research Council (IRC) was held in the Auditorium of the Institute from 6 to 9 September 2016 for presentation of results of 2015-16 and work plan for 2016-17 under the chairmanship of Dr. H Pathak, Director and Chairman, IRC. In the opening session, the secretary, IRC welcomed the Director and other members of the house including all newly joined scientists.

The house greatly acknowledged the contribution of Dr. T Mohapatra, the former Director of NRRI and present DG of ICAR and also the cooperation and contribution of superannuated scientists, Dr. M Variar

IRC Meeting in progress

and Dr. (Mrs.) U Dhua to rice research. The Director, NRRI extended a warm welcome to the external expert members, Dr. JK Roy, Dr. LM Gadnayak, Shri RC Dani, Shri SK Nayak and Dr. C Satpathy. Project-wise presentation of results of all the 40 projects for the year 2015-16 was made by the concerned PIs. The IRC as well as the expert members evaluated the projects programme-wise through minute observation and active interaction. The meeting was concluded with a business session at the end.

SAC Meeting of Krishi Vigyan Kendra

KVK, Santhapur

The 18th Scientific Advisory Committee (SAC) meeting of KVK Cuttack, Santhapur was held on 15 March 2017 at its campus under the chairmanship of Dr. Himanshu Pathak, Director, ICAR-NRRI, Cuttack. The meeting was attended by the members, invited guests, and SMSs of KVK Cuttack.

Smt. Sujata Sethy, SMS (Home Science) & OIC, KVK Cuttack welcomed the chairman and the members and presented the Action Taken Report (ATR) of last SAC meeting along with a brief presentation of report on achievements of KVK Cuttack. The activities namely trainings, OFTs, FLDs etc., taken up during 2016-17 and proposed activities of 2017-18 in the area of Home Science, Soil Science, Plant Protection and Animal Science were presented by the concerned Subject Matter Specialists of the KVK. After presentation, discussion was held and suggestions for improvement were sought.

The chairman made his critical observations after listening to each member present in the meeting. The overall suggestions of the chairman, other members and invited guests were recorded for taking appropriate actions. At the end of the meeting Dr. DR Sarangi, SMS (Soil Sc.) proposed a vote of thanks.

KVK, Koderma

Scientific Advisory Committee (SAC) meeting of Krishi Vigyan Kendra, Koderma, Jharkhand was held on 7 March 2017 under the chairmanship of Dr. NP Mandal, Act. Officer-In-Charge, Central Rainfed Upland Rice Research Station (ICAR-NRRI-CRURRS), Hazaribag. Meeting was attended by scientists of the station and representatives of ICAR from other research institutes and KVKs located in north Chotanagpur and stakeholders. Progress report (2016-17) and Annual Action Plan for 2017-18 of KVK Koderma and NICRA were presented by Mrs. Chanchila Kumari, I/C -PC, KVK, Koderma and Dr. Sudhansu Shekhar, PI, NICRA, respectively. Representatives of NABARD, Koderma, suggested that demonstration of lacin in the district should be included in the action plan and linkages with banks be strengthened for technology interventions. Trainings to farmers on IPM, intercropping and seed treatment to manage pest and diseases in different crops were emphasized for inclusion in future programs. In addition to these, cultivation of fruits, mushroom, lac and its promotion among the farmers, need based training programs and FLDs on vegetables and orchard establishment were also suggested for inclusion in the action plan by majority of the representatives.

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

Particulars	Participants
Participated in 'Kisan Gosthi' organized by KVK Holycross under Pradhan Mantri Fasal Bima Yojna (PMFBY) on 2 April 2016	Dr. D Maiti
Attended '51st Annual Rice Workshop at IGKVV', Raipur from 3 to5 April 2016	Drs. AK Nayak, JN Reddy, SK Pradhan, P Swain, K Chattopadhyay, SSC Patnaik, D Maiti and NP Mandal
Participated in 'Kisan Gosthi' organized by KVK, Koderma under Pradhan Mantri Fasal Bima Yajna (PMFBY) at Jainagar, Koderma on 4 April 2016	Drs. CV Singh and Yogesh Kumar
Participated in one day workshop-cum-meeting 'Strengthen of Rural Enterprises programme in Jharkhand' organized by NABARD at KVK Hollycross, Hazaribagh on 5 April 2016	Dr. Yogesh Kumar
Attended the 'Physiologist Meeting' of N 22 Mutant Project at NRCPB, New Delhi on 8 April 2016	Dr. P Swain
Attended Brainstorming on 'Strengthening the Linkages among OUAT, State Government, Local ICAR Institutes and Govt. of India Institutes' at OUAT, Bhubaneswar on 18 April 2016	Dr. AK Nayak
Attended 'Field Day Programme on Greengram' organized by DDA, Cuttack at Nischintakoili and Mahanga blocks on 16 and 25 April 2016, respectively	Drs. SM Prasad and M Chourasia
Attended the Annual Review & Planning meeting of STRASA at Bhubaneswar from 25 to 28 April 2016	Drs. JN Reddy, SK Pradhan, P Swain, K Chattopadhyay, SSC Patnaik, D Maiti, NP Mandal and MS Anantha
Attended one training programme on 'Farm Machinery' organized by Farm Machinery Deptt., OUAT at Tentuliragadi (Tigiria) on 28 April 2016	Dr. DR Sarangi
Attended review meeting on 'Mera Gaon Mera Gaurav programme' and presented the progress of activities at ICAR-NRRI, Cuttack for the year 2015-16 at ICAR-ATARI, Zone-VII, Jabalpur on 30 April 2016	Dr. Biswajit Mondal

Attended workshop on 'Farmer's First Project' and presented the project proposal submitted by ICAR-NRRI, Cuttack at ICAR-ATARI, Zone-VII, Jabalpur on 1 May 2016	Dr. Biswajit Mondal
Attended the 'Second Green Revolution Meet' at ICAR-RCER, Patna on 3 May 2016	Drs. D Maiti and Yogesh Kumar
Attended the 'Pre-Zonal Workshop' at OUAT, Bhubaneswar from 4 to 5 May 2016	Dr. SM Prasad
Attended Zonal Workshop of KVKs of Odisha at OUAT, BBSR from 6 to 7 May 2016 and presented the Annual Action Plan 2016-17 of KVK Cuttack	Dr. SM Prasad
Attended the 'RAC meeting' of IIRR at Hyderabad from 10 to 11 May 2016	Dr. AK Nayak
Attended the National Workshop on Oilseed and Seed Production Programme" at NASC Complex, New Delhi from 16 to 17 May 2016	Dr. SM Prasad
Attended the meeting on 'Second Green Revolution from the Eastern Region' at New Delhi on 18 May 2016	Dr. AK Nayak
Attended a meeting on 'Developing roadmaps (agricultural development) for eastern India' at New Delhi on 18 May 2016	Dr. D Maiti
Attended the joint workshop on DUS testing under Indo-German bilateral cooperation in seed sector organized by PPV&FR Authority, New Delhi at NAAS Lecture hall, New Delhi from 23 to 24 May 2016	Dr. BC Patra
Attended a meeting on the subject 'Strengthening KVKs and State A gricultural programme in Jharkhand' organized by Department of Agriculture, Govt. of Jharkhand at Project Bhawan, Ranchi on 4 June 2016	Dr. Yogesh Kumar
Attended the 'World Education Congress meeting' and received the 'ABP News National Education Awards' at Taj Lands End, Bandra, Mumbai on 23 June 2016	Dr. AK Nayak
Attended an awareness workshop on 'Guidelines for access to biological resources under the Biological Diversity Act, 2002' at Centre for Research in Nanoscience and Nanotechnology, University of Calcutta, Kolkata on 24 June 2016	Dr. BC Patra
Attended 'the ICAR-Regional Committee-II meeting' at NAARM, Hyderabad from 24 to 15 June 2016	Dr. AK Nayak
Attended the workshop on 'Take it to Breeders & Researchers – the Plant Breeders and Researchers Rights through awareness and streamlining of Farmers varieties' at NASC Auditorium, New Delhi on 30 June 2016	Dr. BC Patra

Attended the Standing Technical Committee (STC) meeting of National Mission for Sustainable Agriculture (NMSA) at Krishi Bhavan, New Delhi on 8 July 2016	Drs. JN Reddy and SK Pradhan
Attended the BSS on 'Strengthening Agricultural Extension Research and Education' at NAAS Committee room, New Delhi on 9 July 2016	Dr. GAK Kumar
Attended meeting on Seed Hub Programme with state Govt. Officials on at IMAGE, Bhubaneswar 18 July 2016	Dr. SM Prasad
Attended a short course on 'Developing Agribusiness Skill among Farmers for Maximizing Farm income' IARI, New Delhi from 11 to 20 July 2016	Dr. M Chourasia
Attended 'Extension Education Council and Seed Council meeting' held at Birsa Agricultural University, Ranchi on 20 July 2016	Dr. Yogesh Kumar
Participated in 'District Level Monitoring Team for planning of BGREI programme' at DDA, Cuttack on 30 July 2016	Dr. M Chourasia
Attended a short course on ' Designing Impact Evaluation for Agricultural Technologies' at ICAR-NRRI, Cuttack from 1 to 10 August 2016	Drs. DR Sarangi and RK Mohanta
Attended a meeting on 'Doubling Farmers Income by 2022' at NABARD office Cuttack on 2 August 2016	Dr. SM Prasad and Mrs. S Sethy
Attended and delivered a lecture in the ICAR Sponsored Summer School on 'Recent innovations in management of organic production systems' at IARI, New Delhi on 16 August 2016	Dr. H Pathak
Attended and delivered a lecture in the SAARC-ICAR training programme on 'Climate change impact on soil carbon storage, turnover under different land use systems and adaption strategies' at IISS, Bhopal on 17 August 2016	Dr. H Pathak
Attended the project meeting on the proposed plan of work under the News Indo-UK project on 'Increasing N use efficiency in rice-wheat cropping systems' at CESCRA, IARI, New Delhi on 18 August 2016	Dr. H Pathak
Participated in the 'Executive Development Programme on Leadership Development' at NAARM, Hyderabad from 27 August to 1 September 2016	Dr. H Pathak
Attended '*Parasparik Bichar Bimash Baithak*' under Chairmanship of Hon'ble Agriculture Minister, GOI, Shri Radha Mohan Singh at ICAR-IIWM, Bhubaneswar on 2 September 2016	Dr. SM Prasad
Attended the meeting with the Hon'ble Minister of Agriculture & Farmers Welfare regarding the present status of the agricultural development in the State of Odisha as a lead speaker at IIWM, Bhubaneswar on 3 September 2016	Dr. H Pathak

Attended 'the Zonal Workshop of KVKs of Zone VII' at ICAR-Central Institute for Freshwater Aquaculture, Bhubaneswar from 3 to 5 September 2016	Drs. SM Prasad, S Sethy, M Chourasia, DR Sarangi and RK Mohanta
Attended 'the 3rd Prof. S.N. Patnaik Memorial lecture at Regional Museum of Natural Historys', Bhubaneswar on 5 September 2016	Dr. BC Patra
Attended 'the RPSC meeting of AIR', Cuttack on 16 September 2016	Drs. SM Prasad and RK Mohanta
Attended as Chief Guest in 'the Hindi fortnight' at BSNL, Cuttack on 19 September 2016	Dr. H Pathak
Attended as Chief Guest in the Model training course on 'Climate change mitigation and adaptation strategies through efficient water management' at IIWM, Bhubaneswar on 20 September 2016	Dr. H Pathak
Attended 'Expert Committee Meeting' at IGNOU, New Delhi from 26 to 27 September 2016	Dr. H Pathak
Attended 'the State Level Farmers Meet on Doubling of Farmers' Income by 2022' at KIIT school of Rural Management on 28 September 2016	Dr. RK Mohanta
Attended 'the review meeting of KVKs, state Government activities and ICAR institutes' at Birsa Agricultural University, Ranchi on 27 September 2016	Dr. Yogesh Kumar
Participated in monitoring of crop demonstrations conducted by farmers under National Food Security Mission (NFSM) in Chaibasa and Saraikela districts of Jharkhand from 29 to 30 September 2016	Dr. Yogesh Kumar
Attended 'BGREI -Third Meeting of Central Steering Committee' at Krishi Bhawan, New Delhi on 4 October 2016	Dr. H Pathak
Reviewed and monitored the progress of BGREI activities in Patna, Vaishali, Bhojpur, Rohtas and Kaimur districts of Bihar from 4 to 9 October 2016	Dr. M Shahid
Attended 'the Central Executive Committee meeting of Animal Nutrition Society of India' at ICAR-NDRI, Karnal on 5 October 2016	Dr. RK Mohanta
Attended a meeting with Meteo-France representatives on 'Integrat ed solution for weather and climate information system and services incorporating agriculture knowledge base' at ICAR, New Delhi on 6 October 2016	Dr. H Pathak
Attended Workshop on 'Strategizing Pulse Production in Rice Fallow Areas in Eastern India' at Swosti Premium, Bhubaneswar on 7 October 2016	Dr. SM Prasad

Attended 'World Food Day function' as Chief Speaker at Bhubaneswar on 15 October 2016	Dr. H Pathak
Attended the interactive video conferencing session of Hon'ble Minister of Agriculture & Farmers Welfare with KVKs and District Agriculture officials at NIC, Collectorate, Cuttack on 25 October 2016	Drs. SM Prasad, S Sethy, M Chourasia, DR Sarangi and RK Mohanta
Attended 'Kisan Mela' at CRURRS, Hazaribagh, Jharkhand on 26 October 2016	Dr. H Pathak
Attended a National Seminar 'Soil Health Assessment with Mrida parikshak' at Indian Institute of Soil Science, Bhopal from 4 to 5 November 2016	Dr. DR Sarangi
Attended the meeting of experts to review the ICAR-IRRI Work Plan at NASC Complex, New Delhi on 5 November 2016	Dr. H Pathak
Attended conference on 'International Agro-biodiversity Congress 2016' at New Delhi from 6 to 9 November 2016	Dr. MK Yadav
Participated in X Biennial Conference of Animal Nutrition Association on the theme 'Newer Perspectives in Animal Nutrition Research for Augmenting Animal Productivity' at Tirupati from 9 to 11 November 2016	Dr. RK Mohanta
Visited RRLRRS, Gerua to review the progress of the station from 12 to 13 November 2016	Dr. H Pathak
Participated in Winter School training Programme on 'Use of ICT in Education and Rural Development' at Swami Keshwanand Rajasthan Agricultural University (SKRAUB), Bikaner, Rajasthan from 4 to 24 November 2016	Smt. Chanchila Kumari
Attended 'the 1st International Agro biodiversity Congress, 2016' on the theme Science, Technology, Policy and Partnership held at NASC, New Delhi from 6 to 9 November 2016	Dr. BC Patra
Attended 'the review meeting of Pulse Seed Hub Programme' under the chairmanship of Dr RS Saini, National Consultant, NFSM at OUAT, Bhubaneswar on 15 November 2016	Dr. SM Prasad
Attendeda 'pre-conference workshop on Application of R in Bioinformatics' at ICRISAT, Hyderabad on 20 November 2016	Dr. NN Jambhulkar
Attended the 50th anniversary celebration of IR8, "The Rice that Changed the World" at Taj Hotel, New Delhi on 21 November 2016	Dr. H Pathak
Attended "4th International Agronomy Congress" at IARI, New Delhi on 22 November 2016	Drs. H Pathak and MK Bag

Participated in international conference on 'Statistics & Big Data Bioinformatics in Agricultural Research' on at ICRISAT, Hyderabad from 21 to 23 November 2016	Dr. NN Jambhulkar
Attended 'Annual conference securing the forest, land and soils for all-Coherence in policies and actions for healthy ecosystems' at Max Mueller Marg, New Delhi on 24 November 2016	Dr. H Pathak
Attended the 57th Annual conference & International Symposium of Association of Microbiologists of India on "Microbes and Biosphere: What's New What's Next" at Gauhati University, Guwahati from 24 to 27 November 2016	Drs. P Panneerselvam and U Kumar
Attended 'the SAC Meeting' of KVK, Jajpur on 25 November 2016	Dr. DR Sarangi
Attended 'the Annual Seminar of Fertilizer Association of India' at New Delhi on 30 November 2016	Dr. H Pathak
Attended 'the joint workshop under the Indo-German bilateral cooperation on seed sector development' at NASC, New Delhi from 29 to 30 November 2016	Dr. BC Patra
Attended the 14th International Workshop on '*Trichoderma* and *Gliocladium* (TG2016): Principles and Practice' at Nagpur from 27 to 30 November 2016	Dr. AK Mukherjee
Attended the National Symposium on "Managing Agriculture in a Changing Environment" at IARI, New Delhi on 1 December 2016	Dr. H Pathak
Attended an 'International rice Symposium' at AAU, Gujarat from 6 to 8 December 2016	Dr. P. Sanghamitra
Attended National Conference on "Managing Soil Resources for Environmental Sustainability: Challenges and Perspectives" at Banaras Hindu University, Varanasi on 9 December 2016	Dr. H Pathak
Attended a meeting of the NAAS Journal Score Committee in the Academy's Secretariat for finalizing the journals scores effective from 1st January 2017 at NAAS, New Delhi on 10 December 2016	Dr. H Pathak
Attended one day orientation training of Plant Protection experts on 'Safe Storage of Grains' by WDRA at DES, JNKVV, Jabalpur on 14 December 2016	Dr. M Chourasia
Attended 2nd Foundation Day of ICAR-Indian Institute of Rice Research, Hyderabad on 15 December 2016	Dr. H Pathak
Attended 'Review workshop of NICRA' at Darjeeling KVK, Kalimpong from 15 to 17 December 2016	Dr. Sudhanshu Shekhar

Attended 'the RPSC Meeting of AIR Cuttack' and 'SAC Meeting of KVK Jagatsinghpur' on 16 and 17 December 2016, respectively	Dr. RK Mohanta
Attended '5th meeting to examine issues relating to doubling of farmers' income by the year 2022' at ICAR, New Delhi on 19 December 2016	Dr. H Pathak
Attended the 7th Odisha Environment Congress, 2016 at CSIR-Institute of Minerals and Materials Technology, Bhubaneswar from 20 to 22 December 2016	Dr. BC Patra
Attended review meeting on progress of Cluster Front Line Demonstration programme (2016-17) at BAU, Ranchi on 21 December 2016	Dr. Sudhanshu Shekhar
Attended the International Conference on The Green Planet: Past, Present and Future at University of Calcutta, Kolkata from 21 to 23 December 2016	Dr. Kutubuddin Molla
Attended the National Conference on Use of Microbial Resources for agriculture at RAU, Pusa, Samastipur from 22 to 23 December 2016	Dr. D Maiti
Attended the National Symposium on New Horizon in pest management for sustainable developmental goals at OUAT, Bhubaneswar from 23 to 24 December 2016	Drs. (Mrs.) Mayabini Jena, PC Rath and S Lenka
Attended the National Conference on "Diagnosis and management of plant diseases: Integrated approaches and recent trends" organized by the Indian Phytopathology Society at ICAR-Research Complex for NEH, Umiam, Meghalaya from 9 to 11 January 2017	Drs. D Maiti and Amrita Banerjee
Attended the workshop on 'Paddy Growing Culture in India' organized by the Janapada Sampada Division of Indira Gandhi National Centre for the Arts (IGNCA), Ministry of Culture, Govt. of India at New Delhi from 10 to 11 January 2017	Dr. BC Patra
Attended a meeting on Biotic Stresses of Paddy and ICAR preparedness for their management and discussion with DDG (CS) on AICRIP at IARI, New Delhi on 12 January 2017	Dr. H Pathak
Attended NEWS project meeting and SCON meeting at IARI, New Delhi on 13 January 2017	Dr. H Pathak
Attended 'the Agri-Tech commercialization workshop' at NASC Complex, New Delhi organized by Indian Institute of Corporate affairs, Govt. of India in collaboration with IP & TM unit of ICAR from 18 to 20 January 2017	Dr. BC Patra
Attended 'the Review Workshop of cluster demonstration of oilseed and pulses for KVKs of Odisha' at OUAT, Bhubaneswar on 24 January 2017	Dr. SM Prasad

Attended a 'Workshop of Nodal Officers of ICAR Research Data Repository for Knowledge Management' at NASC Complex IASRI, New Delhi from 24 to 25 January 2017	Dr. NN Jambhulkar
Attended the Selection Committee Meeting at ASRB, New Delhi from 30 January to 2 February 2017	H Pathak
Attended 'State Credit Seminar 2017-18 of Odisha state' at Mayfair Lagoon, Bhubaneswar on 3 February 2017	Dr. P Samal
Attended Scientific Advisory Committee meetings (SAC) of KVK, Holy Cross, Hazaribagh on 8 February 2017	Dr. Yogesh Kumar
Attended the 2nd International Conference of Maharashtra Society of Agricultural Economics (MSAE) at Mahatma Phule Krishi Vidyapeeth (MPKV), Rahuri, Maharashtra from 10 to 11 February 2017	Dr. Biswajit Mondal
Attended the Brainstorming Session on 'Role of Plant Breeding and Genetics in Meeting Sustainable Development Goals' and also receive the award at Dr. BP Pal Auditorium at IARI, New Delhi on 11 February 2017	Dr. H Pathak
Attended Hills Rice Workshop at NBPGR, New Delhi on 13 February 2017	Dr. H Pathak
Attended 'the Directors' Conference' at NASC Complex, New Delhi from 14 to 15 February 2017	Dr. H Pathak
Attended the seminar at SATSA, Kolkata on 19 February 2017	Dr. H Pathak
Attended 'the XII Agricultural Science Congress 2017' at UAS, Bangalore on 20 February 2017	Dr. H Pathak
Attended & Co-chair in Inter Drought-V Conference at CRIDA, Hyderabad on 22 February 2017	Dr. H Pathak
Attended '13th Agricultural Science Congress' at University of Agricultural Sciences, Bengaluru from 21 to 24 February 2017	Drs. P Samal, P Swain
Attended 'Brainstorming Workshop on NICRA Project: Thus Far and Way Forward meeting' at NASC, New Delhi on 23 February 2017	Dr. H Pathak
Attended meeting of Indo-UK Project at IARI, New Delhi on 25 February 2017	Dr. H Pathak
Visited Dept. of Plant Protection, PSB, Viswa Bharati, as an external expert on 21 February 2017 for evaluation of Thesis seminar of a Ph. D. Scholar	Dr. D Maiti

Attended a three days training workshop on 'Competency Enhancement Programme for Effective Implementation of Training Functions by HRD Nodal Officers of ICAR' conducted at ICAR -NAARM, Hyderabad from 23 to 25 February 2017	Dr. Sanghamitra Samantaray
Visited and monitored in the tribal village Gacherigaon of Tumudibandha Block, Dist. Phulbani along with team of Scientists and Extension Officers from 24 to 25 February 2017 on 'Unique farming technique adopted for doubling the rice production in the Region'	Dr. S Lenka
Attended a programme on Stakeholders Workshop on Doubling of Farmers Income at Conference Hall of ATMA, Cuttack on 28 February 2017	Dr. DR Sarangi
Attended the 9th National Seminar on 'Water resources management in the context of climate change for growing India' at OUAT, Bhubaneswar from 27 February to 1 March 2017	Drs. PC Rath, SK Dash and S Lenka
Attended a meeting on 'AICRIP Bifurcation' organized at IIRR, Hyderabad from 1 to 5 March 2017	Drs. PC Rath, AK Mukherjee and NN Jambhulkar
Attended the 'CEC meeting of Animal Nutrition Society of India' at ICAR NDRI, Karnal on 3 March 2017	Dr. RK Mohanta
Attended 'the Scientific Advisory Committee (SAC) meeting of KVK, Koderma' on 7 March 2017 at KVK, Jainagar, Koderma	Drs. NP Mandal and Yogesh Kumar
Attended 'the meeting of National Steering Committee for Agriculture Sector in TNA project' at TIFAC, DST, Government of India, New Delhi on 20 March 2017	Dr. H Pathak
Attended 1st meeting of the Cadre Review of Scientific Strength of ICAR Institutes' at DG Committee Room, Krishi Bhawan, New Delhi on 21 March 2017	Dr. H Pathak
Attended 'one day review meeting on Pulse Seed Hub Programme' at ATARI, Jabalpur on 22 March 2017	Dr. DR Sarangi
Attended the 'World Water Day, 2017 (Theme-Waste water)' at Department of Botany and Biotechnology, Ravenshaw University, Cuttack organized by Indian Climate Congress-SCET, Cuttack on 22 March 2017	Drs. S Lenka and PC Rath
Attended 'Scientific Advisory Committee meeting' organized by Doordarshan Kendra at Ranchi, Jharkhand on 24 March 2017	Dr. Yogesh Kumar
Attended a one day workshop on 'Protecting and exploiting inventions through IPR' at Odisha Bigyan Academy, Sahid Nagar, Bhubaneswar on 29 March 2017	Dr. BC Patra

Participation in Exhibition

The institute participated and displayed its exhibits in the following for showcasing the NRRI technologies.

KVK organized awareness programme on 'Pradhan Mantri Fasal Bima Yojanan' at NRRI, Cuttack on 8 April 2016. Shri P Jana, Assistant Chief Technical Officer, Ms. Gayatri Sinha, Sr. Technical Assistant, Shri DR Sahoo, Sr. Technical Assistant, Shri AK Parida, Sr. Technical Assistant and Shri SK Tripathy, Technical Assistant represented the institute.

70th Foundation Day at NRRI, Cuttack on 23 April 2016. Shri P Jana, Assistant Chief Technical Officer, Shri DR Sahoo, Sr. Technical Assistant and Shri AK Parida, Sr. Technical Assistant represented the institute.

Akshaya Tritiya Celebration and Farmers Fair at NRRI, Cuttack on 9 May 2016. Shri P Jana, Assistant Chief Technical Officer, Ms. Gayatri Sinha, Sr. Technical Assistant, Shri DR Sahoo, Sr. Technical Assistant, Shri AK Parida, Sr. Technical Assistant and Shri SK Tripathy, Sr. Technician represented the institute.

Shree Shrikshitra Soochana (SSS) organized '7th Krishi Fair-2016' at Puri from 4 to 8 June 2016. Drs. SK Pradhan, Principal Scientist, SK Dash, Sr. Scientist, SSC Patnaik, Sr. Scientist, Crop Improvement Division, Dr. BB Panda, Principal Scientist (Crop Production Division), Dr. S Lenka, Sr. Scientist (Crop Protection Division), Dr. SK Mishra, Principal Scientist (Social Science Division), Shri P Jana, Assistant Chief Technical Officer, Shri B Behera, Technical Officer, Shri DR Sahoo, Sr. Technical Assistant Shri AK Parida, Sr. Technical Assistant, Shri BD Ojha, , Sr. Technical Assistant, Shri SK Tripathy, Sr. Technician and Shri NN Bhoi, SSS represented the institute.

NRRI participated and displayed its exhibits in the '23rd Zonal Workshop of KVKs' at ICAR-CIFA, Bhubaneswar from 3 to 5 September 2016. Shri P Jana, Assistant Chief Technical Officer, Shri B Behera, Technical Officer, Shri BD Ojha, Sr. Technical Assistant, Shri DR Sahoo, Sr. Technical Assistant, Shri AK Parida, Sr. Technical Assistant and Shri NN Bhoi, SSS represented the institute.

World Food Day at Institute of Engineers, Sachivalaya Marg, Bhubaneswar on 16 October 2016. Dr. BN Sadangi, Head, SSD, Dr. SK Mishra, PS, Shri B Behera, Technical Officer, Shri BD Ojha, Sr. Technical Assistant and Shri AK Parida, Sr. Technical Assistant represented the institute.

Kisan Mela at CRURRS, Hazaribagh on 26 October 2016. Shri P Kar, Chief Technical Officer and Shri P Jana, Assistant Chief Technical Officer represented the institute.

4th International Agronomy Congress at IARI, New Delhi from 22 to 26 November 2016.Shri KK Suman, Technical Officer and Shri DR Sahoo, Sr. Technical Assistant represented the institute.

Agriculture Education Day at NRRI, Cuttack on 18 November 2016. Shri P Jana, Assistant Chief Technical Officer and Shri AK Parida, Sr. Technical Assistant represented the institute.

Organization of Events, Workshops, Seminars and Farmers' Day

Akshaya Tritiya and Farmers Fair

The auspicious agricultural festival of the region 'Akshaya Tritiya' which falls on *Vaishakh Sukla pakhya Tritiya* and marks the beginning of agricultural season was celebrated at NRRI, Cuttack on 9 May 2016. Shri Radha Mohan Singhji, Hon'ble Union Minister of Agriculture and Farmers Welfare, Govt. of India graced the occasion as Chief Guest and planted a few sacred rice seeds in the soil (*Muthi Anukula*) of NRRI farm and gave his best wishes to the efforts of the scientists and staff. He later on laid the foundation stones of two important buildings namely, NRRI Auditorium and Central Genomics-cum-Quality laboratory.

The Hon'ble Minister also inaugurated the exhibition showcasing all aspects of agriculture and addressed a big gathering of farmers, farmwomen from all blocks of Odisha and officers of line departments and ICAR institutes. In his address, he referred to the development profile of the institute and expressed his satisfaction on the investment being made here in the current budget. He further highlighted on various flagship programmes of the Central Government like, Pradhan Mantri Krishi Sinchai Yojana, Soil Health Card Scheme, Pradhan Mantri Fasal Bima Yojana, e-NAM (National Agriculture Market) for establishment of e-Mandis for proper marketing of farm produce, Gram Uday Se Bharat Uday Abhiyan, Mera Gaon Mera Gaurav and Paramparagat Krishi Vikas Yojana for promoting organic farming for the benefits of farmer. He emphasized on adoption of villages under 'Mera Gaon Mera Gaurav' programme for demonstration of new farm technologies. He appreciated the efforts of NRRI scientists for developing protein-rich rice variety, CR Dhan 310, first of its kind in the world with protein content of 11 per cent and developing the Mobile App 'riceXpert' available in Google Play store for the benefit of the farmers. He released four publications and felicitated nine innovator farmers and farmwomen for their accomplishments.

Shri Dharmendra Pradhan, Hon'ble Minister of State (Independent Charge) Petroleum & Natural Gas, Govt of India, Shri Bhartruhari Mahatab, Hon'ble Member of Parliament (Lok Sabha), Cuttack, Dr. T Mohapatra, Secretary, DARE and Director General, ICAR, New Delhi, and Mr. Chhabilendra Roul, IAS, Addl. Secretary, DARE and Secretary, ICAR, New Delhi, Prof. SN Pasupalak, Vice Chancellor, OUAT, Bhubaneswar and Dr. Anupam Mishra, Director, ATARI, Zone VII, Jabalpur were the Guests of Honour in the function. Hon'ble MP, Shri Bhartruhari Mahtab advised that the scientists should work effectively on climate change and water conservation technology. On this occasion, he requested the Chief Guest for establishment of Regional Research Centers on Pulse and Groundnut of ICAR-IIPR, Kanpur and ICAR-NRCG, Junagarh for addressing the real needs of the state. He added that success can be achieved when the technologies are transferred from the laboratory to land. Hon'ble Union Minister of State, Shri Dharmendra Pradhan in his address expressed his concerns for agricultural development of Odisha. He emphasized on the establishment of good numbers of cold storage, market and other agricultural infrastructures. In the beginning of the program, Dr. T Mohapatra gave a warm welcome to the Chief Guest and others present on this occasion. While welcoming, he highlighted recent policies and schemes of Central Government for development of agriculture in the country, especially for Eastern India. Dr. AK Nayak, Director of institute offered the vote of thanks at the end of the program. ICAR-NRRI, other ICAR institutes/centers located in the state of Odisha, OUAT through its KVKs, seed companies, agri-input dealers and financial institutions participated in the exhibition and a Farmers-Scientists Interaction was held on various aspects of farming. The programme was coordinated by Dr. SK Mishra, Principal Scientist & Organizing Secretary.

Hon'ble Union Minister addressing the audience

Dignitaries releasing the Mobile App riceXpert

NRRI developed mobile app 'riceXpert' to help rice farmers

National Rice Research Institute (NRRI), Cuttack has developed a mobile app 'riceXpert' that provides information on rice cultivation and enable farmers to consult panel of experts. This was launched by Union Agriculture & Farmers welfare Minister Shri Radha Mohan Singh at ICAR-National Rice Research Institute, Cuttack on the occasion of Akshaya Tritiya and Farmers Fair in presence of Hon'ble Minister of State (Independent Charge), Petroleum and Natural Gas, Shri Dharmendra Pradhan, Hon'ble MP (Loksabha), Cuttack constituency, Shri Bhartruhari Mahtab, Hon'ble Secretary, DARE & DG, ICAR, Dr. T Mohapatra, Hon'ble, Additional Secretary, DARE & Secretary, ICAR Shri Chhabilendra Roul, Hon'ble

Vice Chancellor, OUAT, Bhubaneswar Prof. S Pasupalak and Director, ICAR-NRRI Dr. AK Nayak, Director, ICAR-ATARI, Jabalpur, Dr. A Mishra, other dignitaries and farmers on the occasion of Akshaya Tritiya and Farmers Fair on 9 May 2016 in our institute.

The App provides information to farmers in real time on insect pests, nutrients, weeds, nematodes and disease-related problems, rice varieties for different ecologies, farm implements for different field and post harvest operations. It is a web-based application systems which facilitates flow of information from the farmer to the farm scientist and get their instant solution. Farmers can use this App as a diagnostic tool in their rice fields and make customize queries for quick solution of their problems by sending text, photo and recorded voice. This would be a real boon to farmers, he added.

The App is developed for Android platform and can be downloaded from Google Playstore or from www.nrri.in web portal. This APP may also be a very useful tool for the researchers, students and village level workers working on rice crop.

Agriculture Minister congratulated the team of NRRI scientists for developing this unique IT-enabled handheld mobile app.

70th Foundation Day and Dhan Diwas

The NRRI, Cuttack celebrated its "70th Foundation Day and Dhan Diwas" on 23 April 2016. Dr. T Mohapatra, Secretary, DARE and DG, ICAR, New Delhi and Chief Guest inaugurated the Foundation Day programme and delivered the Foundation Day Lecture which was attended by Directors of ICAR

Chief Guest addressing the audience

Institutes, scientists and staff of the institute. He spoke on vision-2050 of agriculture and called upon the stakeholders to find out models of production for Indian agriculture, quality enhancement, doubling of farm income through appropriate market strategy, food processing and value chain. In the Foundation Day Programme, he emphasized that the technology transfer system must understand very well the needs and problems of the farmers and advised to hold zonal review meetings to assess the technology application and success. Chief Guest addressing the audience

Prof. SN Pasupalak, Vice Chancellor, OUAT, Bhubaneswar and Guest of Honour of the programme stressed the need for proper working linkage among various organizations concerning agricultural research & development, education, transfer of technologies, agro-industries and farmers welfare organizations. Dr. AK Singh, DDG (Agril. Extension), ICAR and Guest of Honour highlighted the role of KVKs in agricultural development of the districts and requested the research institutes to provide their technologies for further refinement in their locations. In the beginning of the programme, Dr. AK Nayak, Director (Acting) and Chairman highlighted the significant achievements of the institute, especially the recently released varieties including high protein rice and their suitability for different ecologies, rice-value chain and IT-based riceXpert mobile App.

On this occasion, the chief guest inaugurated an Agricultural Exhibition showcasing technologies of NRRI including its regional stations and KVKs, all ICAR institutes and centers located in Odisha, OUAT through its KVKs and state line departments. He also felicitated distinguished retired scientists, the best scientists and workers of the institute and progressive rice farmers and farmwomen from Odisha, Jharkhand and Assam for their innovative practices in rice-based farming system. Four research and technology bulletins were released by the dignitaries. At the outset, Dr. BN Sadangi, Head, Social Sciences and Co-Chairman welcomed the guests, dignitaries, invited guests and farmers and Dr. Lipi Das, Organizing Secretary offered vote of thanks at the end of the program. Special programs like planting of saplings by the guests, field visit for the farmers, scientists-farmers interaction involving about 250 farmers and farmwomen under 'Mera Gaon Mera Gaurav' programme of the institute, various competitions among the staff, their children and research scholars and cultural events were organized for the farmers and the staff of the institute. In the evening programme, winners of different competitions, meritorious children of staff and participants of the cultural events were awarded with certificates and prizes by Mrs. Kalpana Mohapatra, wife of the Secretary, DARE and DG, ICAR.

DG, ICAR laid the foundation stone of Administrative Building of KVK Cuttack

The foundation stone of KVK Cuttack administrative building, a unit of NRRI, Cuttack was laid by Dr. T Mohapatra, Secretary (DARE) and DG (ICAR) on 23 April 2016 in the presence of Dr. AK Singh, Deputy Director General (Agricultural Extension) and Dr. AK Nayak, Director (Acting) ICAR-NRRI, Cuttack. The other dignitaries present on the occasion were Dr. Anupam Mishra, Director, ATARI, Zone VII, Heads of Divisions and other officials of NRRI, Cuttack, Shri RK Shami, Chief Engineer, CPWD and team of CPWD officials. The Hon'ble DG convened a meeting with the officials to review the infrastructural facilities and execution of the plan.

Dignitaries at the proposed site of KVK, Cuttack administrative building

Swachh Bharat Abhiyan

On the occasion of 'Gandhi Jayanti', the 'Swachh Bharat Abhiyan', an initiative of the Hon'ble Prime Minister of India, was organized at NRRI, Cuttack, Odisha on 2 October 2016. The Chief Guest of the function Dr. T Mohapatra, Hon'ble Secretary, DARE and DG, ICAR inaugurated the programme with floral offerings to the wall sculptures of father of the nation, Mahatma Gandhi and Jawahar Lal Nehru the former Prime Minister of India.

Dr. T Mohapatra, Secretary, DARE & DG, ICAR addressing the staff of ICAR-NRRI

NRRI staff gathering for 'Swachha Bharat Abhiyan'

Speaking on the occasion, Dr. Mohapatra described the objectives of the mission started by our Hon'ble Prime Minister Shri Narendra Modi two years back and emphasized on the need of cleanliness at all levels for healthy mind leading to good health, higher work efficiency and for overall national development. The Director, NRRI, Dr. H Pathak urged everyone to keep their surroundings clean. He recalled the great teachings of Mahatma Gandhi with respect to cleanliness and advised to maintain the spirit of cleanliness in all spheres of life. On this occasion various activities like Swachhta rally, planting of saplings by the Chief Guest and cleaning drive were organized at the Institute. The programme was coordinated by the Institute Swachh Bharat Committee.

Observation of Swachhta Pakhwada

'Swachhta Pakhwada' (16-31 October, 2016) celebration was inaugurated at NRRI, Cuttack along with several other ICAR institutes across the country. Director of the institute Dr. H Pathak inaugurated the function with ‘Swachhta Sapath’ (Administering Oath) along with all staff of the Institute on 17 October 2016. He appealed all the staff to join hands to fulfil the commitment to make self, community, society, offices, villages, cities, states and the nation clean. A motivational talk on the topic 'Achieving Success' (Saphalta) of a Swatantra Bharat, Swachh Bharat, Sundar Bharat, Saphal Bharat and Samridh Bharat, as dreamt of by Gandhiji was delivered by the Director. As part of the Swachhta Pakhwada, 'Field Days' were organized on 18 and 20 October 2016 to upkeep the cleanliness and maintenance of experimental plots and net houses of the institute. Events like quiz, debate, essay writing and painting competition relating to Cleanliness and Environment were successfully organized at NRRI on 19, 21, 22 and 24 October 2016, respectively, for the staff, research scholars of the institute and children of NRRI High School.

As part of the Swachhta Pakhwada, a 'Village Awareness-cum-Cleaning Drive' was organized on 25 October 2016 at Gurujanga village of Tangi-Chowdhar block of Cuttack district. Director in his address to the villagers relate cleanliness and holiness for elucidating the necessity of cleanliness of self, family and village.

Sj. Baijayant 'Jay' Panda, Hon'ble Member of Parliament, Lok Sabha graced as the Chief Guest of the closing function of the Pakhwada on 1 November 2016. Speaking on the occasion, he emphasized that cleanliness/ swachhta is required in all facets – individual, family, village, office and region for all-round development of the nation. Prizes were distributed to the winning school children and staff. The programme was coordinated by the Institute Swachh Bharat Committee (ISBC) and Dr. (Mrs.) Lipi Das, Chairperson, ISBC.

Field Day organized in Experimental plots on 18 October 2016

Chief Guest addressing the staff, students and children during the closing function

Agriculture Education Day

The institute celebrated its 5th “Agriculture Education Day” on 18 November 2016 in its premises with the participation of more than 210 students of secondary and higher secondary standard from 21 schools and junior colleges around the city along with their teachers. The Chief Guest of the inaugural function Dr. T Mohapatra, Secretary, DARE & DG, ICAR, Govt. of India, New Delhi inaugurated the programme by lighting the lamp as well as the Agricultural Science Exhibition showcasing the projects developed by the students of all participating institutions on the theme “Sustainable Agricultural Technologies for accelerating Farm Production”. Speaking on the occasion, the Chief Guest advised the students that they might opt for agriculture and allied subjects as a potential career in changing national priorities. Students would get enough scope to utilize their intelligence and showcase their innovative ideas for their own as well as national development.

The Guest of Honour, Padma Bhusan Prof. VL Chopra, Chancellor, Central University of Kerala and former Secretary, DARE & DG, ICAR highlighted the impact of education on any society and threw lights on the need for agricultural education in developing a powerful nation. Dr. (Mrs.) Krishna Srinath, former Director, CIWA, Bhubaneswar and Dr. AK Singh, Professor & Head of Genetics, IARI, New Delhi were Special Guests of the function. Later, the guests released one educational bulletin entitled “Agriculture: Innovations for Nutritional Security and Sustainability” brought out on the occasion for the benefits of the students.

Dr. H Pathak, Director, NRRI & Chairman of the inaugural function welcomed the guests, dignitaries, delegates from ICAR institutes, teachers and students and sensitized the students about the scope of agricultural sciences. Dr. BN Sadangi, Head, Social Science Division and Co-Chairman briefed about the objectives of observing the day. Dr. (Mrs.) Lipi Das, Senior Scientist and Organizing Secretary proposed vote of thanks at the end.

The day-long celebration was highly exciting with special events for the participating students like debate, quiz and exhibition competition. The students were sensitized and provided counseling on the scope and opportunity in the agricultural sciences through a special counter on "Career Counseling in Agriculture". In the closing function, the winners of the various competitions along with all the participating students were awarded with trophies and certificates by the Director.

Guest of Honour Prof. VL Chopra speaking on the occasion

Release of an educational bulletin by the guests

ISO Meeting

An ISO Meeting was held on 30 September 2016 at NRRI, Cuttack under the Chairmanship of Dr. H Pathak, Director. BSCIC auditor Shri S Basu conducted the audit surveillance for renewal of the certificate for 3rd year 9001:2008. The members present during the meeting were Drs. AK Nayak (Management Representative), ON Singh, BN Sadangi, SG Sharma, M Jena, P Samal, JN Reddy, MK Kar, GAK Kumar, S Saha, SK Mishra, SD Mohapatra, Lipi Das, JL Katara, Shri BK Sinha, Shri SR Khuntia, Shri SK Mathur, Shri BK Sahoo and all AAOs.

25th Dr. Gopinath Sahu Memorial Lecture

The 25th Dr. Gopinath Sahu Memorial Lecture was jointly organized by Association of Rice Research Workers (ARRW), Dr. Gopinath Sahu Memorial Trust and National Rice Research Institute, Cuttack on 17 January 2017. Dr. V Rabindrababu, Director, IIRR, Hyderabad delivered the memorial lecture on "Present Scenario and Future Prospects of Rice in India". Dr. H Pathak, Director, NRRI, Cuttack presided over the function.

Dr. V Rabindrababu, Director, IIRR, Hyderabad delivering the memorial lecture

Hindi Fortnight 2016

The Hindi Fortnight-2016 was celebrated at NRRI, Cuttack from 14 September to 29 September 2016. During this period five Hindi Competitions *viz.*, Correct & Speed Hindi Writing, Hindi Reading, Hindi Transliteration Writing, Hindi Shabdantakshari Competition and General Knowledge Competition

Release of pocket diary during the occasion

were organized for the officers/employees of the Institute. A total of 82 staff members enthusiastically participated in the above competitions. The closing ceremony of Hindi Fortnight-2016 was organized on 29 September 2016 at the Institute. On this occasion Dr. PK Rath, Deputy Chief Labour Commissioner (Central), Bhubaneswar was the Chief Guest and Shri SN Samal, Assistant Director (Official Language), All India Radio, Cuttack was the Guest of Honour. Dr. H Pahtak, Director, NRRI presided over the function.

The winners of the various Hindi competitions were given prizes and certificates by the Chief Guest. On this occasion, two pocket diary in Hindi namely, "Diagnostic Guide for Rice Insect Pests and Nematodes" and "Diagnostic Guide for Rice Diseases" were released.

The Chief Guest congratulated all the winners of the Hindi competitions and opined that the need and use of Hindi in agriculture is more because most of the farmers of the country use Hindi as a link language. He also said that if simple and colloquial Hindi is used, then it will be more popular and basic scientific writing and research achievements can reach to the people.

Dr. H Pahtak, Director, NRRI in his presiding address said that this Institute has been using Hindi medium in its extension activities since long. He stressed upon the compliance of rules pertaining to Official Language implementation and urged the staff to do their work in Hindi. Shri AK Tiwari, AD (OL), Shri BK Mohanty, Senior Technical Officer (OL) and Shri R Sahoo, UDC coordinated all the activities of the fortnight.

Vigilance Awareness Week

The Director of the Institute Dr. H Pathak administered the pledge to all staff. A Speech Competition on the theme of the week "Public Participation in Promoting Integrity and Eradicating Corruption" was organized on 3 November 2016 at this Institute in Odia, Hindi and English languages.

Chief Guest giving away prize to the winner of speech competition

A "Grama Sabha" was organized on 4 November 2016 by this Institute in the village "Paramahansa" and more than 100 villagers both men and women participated in the meeting. The closing function of Vigilance Awareness Week-2016 was held on 5 November 2016. Shri Saumyendra Kumar Priyadarsi, IPS, Inspector General of Police (Central Range), Odisha, the Chief Guest, gave away the certificates and cash prizes to the winners of the speech competition. The Chief Guest in his address emphasized on how corruption is taking place in various spheres of the society including Govt. organizations, Public sectors and Corporate sectors and the remedies to overcome. He also expressed that this year's theme is unique as it suggests to eradicate corruption through public participation. Dr. SG Sharma, Director (I/c) gave a brief historical perspective of the Institute and narrated the steps taken at International, National and State level to check corruption. Dr. BN Sadangi, Vigilance Officer welcomed the guest and Shri BK Sahoo, Administrative Officer offered the vote of thanks.

Hindi Workshop

A one day Hindi Workshop on "Unicode system & Hindi computer typing" was organized at National

Rice Research Institute, Cuttack on 5 December 2016 for the staff of the institute. Dr. H Pathak, Director, NRRI inaugurated the workshop. Shri Bana Bihari Sahu, Deputy Manager (OL), State Bank of India, Administrative Office, Sambalpur Circle was invited as the speaker for the workshop. A total of fourteen technical and administrative staff members participated in this workshop.

Pre-*Kharif* Farmers Meet

NRRI, Cuttack organized a "Pre-*Kharif* Farmers Meet" under the Tribal Sub Plan (TSP) programme in the adopted village Ramthenga of Danagadi block, Jajpur, Odisha on 3 June 2016. Over two hundred tribal farmers and farmwomen of the village attended the meet apart from scientists & staff of the institute associated with this programme, and staff of the Tata Steel Rural Development Society (TSRDS), a field level collaborating organization and functionaries of the local Gram Panchayat.

Director Dr. AK Nayak addressing the gathering

International Day of Yoga

The International Day of Yoga (IDY) was observed at NRRI, Cuttack on 21 June 2016 with the participation of staff members which was coordinated by institute Swachh Bharat Mission Committee. Dr. AK Nayak, Director (Acting) of the institute highlighted about the importance of yoga every day. The various types of yogasans were demonstrated by two trained Yogacharyas from Regional Centers of Art of Living Organization, Cuttack and Patanjali Yogpeeth, Cuttack.

Awareness Programme-cum-Workshop on 4S4R

A one day Awareness Programme cum Workshop

Dr. AK Nayak, Director (Acting) addressing the participants

was organized on 4S4R (Self-sufficient Sustainable Seed System for Rice) on 27 July 2016 at NRRI, Cuttack, Odisha. The programme was inaugurated by Dr. AK Nayak, Director (Acting) in presence of scientists, farmers and state officials. Dr. GAK Kumar, PI of the project, explained that the programme aimed at creating awareness about the 4S4R concept which focuses on local seed production, processing and marketing system. This system has taken into the consideration the problems of formal seed system and provides solutions using IT and FPO in 4S4R model which will make seed available at local level to all farmers according to their need, in right quantity, of right quality, with lower cost of production & supply and with timely delivery which present Formal Seed System has failed to deliver. SWOT analysis and Analytical Hierarchy Process were employed to prioritise the issues related to local seed system. Lecturettes were delivered by Dr. GAK Kumar, PI, Dr. RK Sahu, CoPI and Sri MK Sharma, DAO Salepur during the workshop. The programme ended with vote of thanks by Dr. BC Patra, ITMU.

Short course on "Designing Impact Evaluation for Agricultural Technologies"

A short course sponsored by Education Division, ICAR on "Designing Impact Evaluation for Agricultural Technologies" held from 1 to 10 August 2016 was inaugurated by Dr. H Pathak, Director on 1 August 2016 at NRRI, Cuttack. Dr. Pathak in his presidential remarks emphasized the requirement of re-orientating the impact assessment methodology to encompass all types of direct and indirect impact in shifting environmental perspective. Earlier, Dr. B Mondal, Senior Scientist and Course Director

Dr. H Pathak, Director addressing the participants

presented the trainees profile and briefed about the course and Dr. BN Sadangi, Head, Social Science Division elucidated the importance of impact evaluation techniques in social science research. Twenty five participants from 11 states representing various SAUs, KVKs and ICAR Institutes attended the course.

National Productivity Week

The National Rice Research Institute, Cuttack celebrated National Productivity Week–2017 from 12 to 18 February 2017. In the inaugural day of the National Productivity Week Celebration, Er. Kishor Bhusal, Assistant Director, National Productivity Council, Regional Centre, Bhubaneswar delivered a special lecture on the theme of the year "From Waste to Profit through reduce, recycle, reuse". Speaking on the occasion, Er. Bhusal emphasized on the use of treated sewage water for irrigation purpose in agricultural crops. The inaugural function was presided over by Dr. AK Nayak Director (I/c) and enlightened the audience about the tremendous potential of rice straw recycling. Dr. SD Mohapatra,

Dr. H Pathak, Director, NRRI delivering a talk in valedictory session of National Productivity Celebration Week

Chairman, National Productivity Week Celebration – 2017 Committee (NPWCC) welcomed the guest and all the dignitaries and briefed about the weeklong events of the National Productivity Week – 2017.

On 14 February 2017, a special lecture was delivered by Shri Alok Jha, Regional Manager, Clarivate Analytics on the topic entitled "Research Assessment and Research quality through citation". On the next day, Dr. Adam H Price, Professor, Plant Molecular Genetics, Institute of Biological and Environmental Sciences, University of Aberdeen, UK delivered a lecture on "Accurate Genetic Mapping in rice at last".

A field awareness programme on the Vermicomposting of rice straw was organised in the NRRI premises. In the event series, Debate, Slogan and Quiz competition were organized among the student and staff of the institute.

Valedictory function of the National Productivity Week Celebration-2017 was graced by Dr. H Pathak, Director, NRRI. He delivered a special talk on 'Projects for People: A Logical Framework' on the occasion. Dr. Rahul Tripathi, Member of the Committee briefed about the series of events organized as a part of the celebration. Prizes for the winners of different competitions were distributed. The programme was ended with the remarks of Director and a formal vote of thanks by Dr. KA Molla.

Director visit to Hazaribagh Regional Station

Dr. H Pathak, Director, NRRI, Cuttack visited Central Rainfed Upland Rice Research Station (CRURRS), Hazaribagh, Jharkhand on 13 September 2016. On the way, he visited Jokee Tola under Village Dasokhap


Dr. H Pathak, Director, NRRI, Cuttack, visiting the research fields

and apprised about activities of the Sub-station there under Tribal Sub-Plan.

During afternoon, he visited the field to review research and seed production activities of the station. Issues related to fencing of boundary wall, farm roads, demonstration of farm implements to villagers/ farmers, organization of farmers' fair, etc. were also discussed with the Scientists and Technical staff. An interaction meeting with the staff of CRURRS, Hazaribagh was arranged during evening and relevant issues were thoroughly discussed aiming at all-round development of the Sub-station. During second day, Kana Band village under Churchu block was visited where many HYVs are being demonstrated by the sub-station. After return from the village, a meeting with the Nodal Officer (IARI-Jharkhand), Director, SCD, DVC and Executive Engineer, CPWD was held to discuss the progress and issues related to establishment of IARI-Jharkhand. Later, he visited the Krishi Vigyan Kendra, Jainagar, Koderma and reviewed various activities being undertaken by the KVK at its own farm as well as farmers' field.

Kisan Mela

Focusing on "Climate Resilient Agriculture for Jharkhand" as central theme, Central Rainfed Upland Rice Research Station Hazaribagh, Jharkhand organized Farmers' Fair (Kisan Mela) on 26 October 2016. It was inaugurated by the Hon'ble MLA Shri Manish Jaiswal (Hazaribagh) who was the Chief Guest of the event. Programme was presided over by Dr. H Pathak, Director, NRRI, Cuttack. Dr. D Maiti, OIC, CRURRS, Hazaribagh, welcomed the chief guest and other dignitaries present on the occasion. Three technical bulletins published by the Research Station were released by the Chief Guest. Dr. H Pathak, Director, NRRI, Cuttack described the research efforts for climate resilient rice production by NRRI. State agricultural officials including PD, ATMA, Hazaribagh, farmers, scientists and bank officials attended the event and interacted among themselves for making Jharkhand agriculture climate resilient. 'Kisan Gosthi' was organized in the afternoon wherein Scientists and experts replied the queries raised by the participating farmers. Stalls were put by various institutes and agriculture input and equipment dealers and the exhibition of information on agricultural technology was also inaugurated by the Chief Guest. Scientists of the station including Drs. NP Mandal, CV Singh, Somshwar Bhagat and Yogesh Kumar were actively involved in the celebration of the event. Other scientists and experts who participated in activities like display of information, discussions and field trips were Smt. Chanchila Kumari, Drs. Sudhanshu Shekhar, Rupesh Kumar, Manish Kumar of KVK, Koderma and Dr. RK Singh, SN Chowdhury of KVK, Holy Cross, Shri BB Nayak, Deputy District Manager of NABARD. About 400 farmers from various districts of state attended the mela.

Hon'ble MLA, Hazaribagh Shri Manish Jaiswal addressing the gathering

A section of audience at Hazaribagh

Director, ICAR-NRRI reviews the progress work of RRLRRS, Gerua

Dr. H Pathak, Director, NRRI visited Rainfed Lowland Rice Research station (RRLRRS), Gerua (Assam) from 12 to 13 November 2016 in order to have first-hand knowledge about the station and review the progress of station activities. He made note of various activities being undertaken by the station, *viz.*,

Director, NRRI visited the experimental farm of RRLRRS, Gerua

physical and financial activities, activities related to research, seed production and infrastructural development, and the constraints being faced by the station. On the occasion, an interaction meeting with a group of progressive farmers from Nalbari and Darrang districts was also organized. The farmers, in general, expressed their concern over the rising cost of cultivation due to shortage of agricultural labourer and lack of farm mechanization. The progressive farmers from flood-prone ecology of Nalbari district expressed their satisfaction over performance of Naveen as summer rice and late planted *sali* rice/winter rice. The progressive farmers from Darrang district expressed their happiness on the performance of CR Dhan 909 and Chandrama in *kharif* 2016. Despite water stressed situation during PI stage of the crop during September, these varieties yielded 4.5 to 5.5 t/ha. Director suggested the scientists to expand the activities of the station under Tribal Sub-Plan in order to encompass more number of tribal farmers under the programme. He also urged to explore the possibilities of establishing custom hiring centres under TSP.

Awareness Programme on Pradhan Mantri Fasal Bima Yojana

Krishi Vigyan Kendra Cuttack, a unit of NRRI organized an awareness programme on 'Pradhan Mantri Fasal Bima Yojana (PMFBY)', a flagship programme of Govt. of India, in the premises of NRRI, Cuttack with active participation of 200 farmers/farmwomen covering all the 14 blocks of Cuttack district, scientists of NRRI and subject matter experts of KVK on 8 April 2016. It aimed at bringing greater awareness among farming community on the benefits of the new scheme and secure large scale enrolment in the scheme. The Member of Legislative Assembly, Choudwar-Cuttack, Sj. Pravat Ranjan Biswal and Chief Guest of the function called upon the farmers and farmwomen to realize the importance of crop insurance for maintenance of their sustainability in agriculture. As farmers provide food and nutrition to the countrymen, their sustainability will help India prosper, he further stressed. Dr. AK Nayak, Director (Acting), NRRI, Cuttack and Chairman of the programme threw light on the benefits and features of the scheme including insurance for the pre- and post harvest losses due to natural calamities. Sj. Hrushikesh Jena, the farmer representative nominated by ATARI, requested the farmers to take the message and disseminate it among fellow farmers. Dr. BN Sadangi, Head, Social Science Division welcomed the participants and Dr. SM Prasad, Head, KVK Cuttack proposed vote of thanks. In the technical session, Sj. Satya Ranjan Panda (AGM, NABARD), Sj. Sarat Chandra Sahoo (DDA, Cuttack), Dr. Jagdish Mohanty (ADVO, Cuttack), Dr. Parsuram Samal (Principal Scientist, NRRI) and Sj. Pritam Chandra (Branch Manager, Universal Sompo General Insurance, Cuttack) discussed in detail about the insurance schemes available in crop and animal husbandry sector and the special improvements made in the present PMFBY to provide more benefits for the farmers and answered their queries. Experts from KVK Cuttack, namely, Smt. Sujata Sethy, Drs. DR Sarangi, M Chourasia and RK Mohanta coordinated the event. Publication of the Ministry of Agriculture, and Farmer's Welfare and the new extension bulletin on the scheme were distributed for bringing awareness.

Release of an extension leaflet on PMFBY for mass awareness

Skill Development Training Programme on Value Addition

Keeping in view the interest of rural women and household and market demand, a five day on-campus skill development training was organized at KVK Cuttack, Santhapur from 16 to 20 August 2016. The Food & Nutrition Board, Govt. of India, Bhubaneswar was one of the collaborators which provided expert assistance for the programme. Twenty five farmwomen and rural youth from Khetrapal, Mania, Jhadeswar Kadei, Ucchapada and Agrahat villages participated in this programme. In the inaugural session, Dr. BN Sadangi, Head, SSD and Dr. P Samal, Principal Scientist, NRRI inspired the participants and analyzed their needs, situations and expectations. Shri Manoranjan Barik, Senior Demonstrator, Food and Nutrition Board and Mrs. Sujata Sethy, SMS (Home Sc.) conducted theory and practical classes on preparation of value added products from orange, lemon, apple, guava, papaya, tomato, chili and seasonal vegetables and preparation of nutri-feeds for children and adults. Besides awareness on basic health and hygiene in household were discussed. The participating women expressed their happiness for their exposure and presented their future plan on value addition. In the valedictory programme on 20 August 2016, Dr. H Pathak, Director, NRRI, Cuttack, the Chief Guest spoke on application of the training for socio-economic empowerment of women in general and youth in particular. He gave away the certificates and training manual to the participants. The Head of KVK and other SMSs undertook many activities for a conducive training environment.

Parthenium Awareness Week

Krishi Vigyan Kendra Cuttack, Santhapur a unit of NRRI, Cuttack observed "Parthenium Awareness Week" from 16 to 22 August 2016 and organized Krishak Goshthies, Video shows and Awareness Programmes at villages Ganeshwarpur, Uchhapada, KVK Campus and NRRI High School, Cuttack for farmers, farmwomen, rural youth and school children. During this programme, the lectures/talks focused on life cycle of this hazardous obnoxious weed, its ill effect on animals, human beings, crops and biodiversity of plants. Further, its integrated management practices were described by the KVK personnel to the 556 participants of different programmes. KVK also appealed to share this knowledge so that its effective and early control can be done with all social groups.

Pradhan Mantri Ujjwala Yojana

The first programme on "Pradhan Mantri Ujjwala Yojana" in the state of Odisha at a KVK was organized at KVK Cuttack, Santhapur, a unit of NRRI, Cuttack on 23 September 2016. In the programme, Shri Jitamrit Dutta, Nodal Officer, PMUY, Cuttack District welcomed the participants and briefed about the scheme. Smt. Sujata Sethy, SMS (Home Science) told about the scheme in local language and how the benefits can be taken by the rural women. Dr. SM Prasad, Head, KVK told about the theme of the programme and what benefits it can bring to family and environment. All the staff of the KVK, Cuttack and distributors from gas agencies were also present in the programme along with 100 beneficiaries from different areas of Cuttack district. The rural women were presented related documents and gas stoves from the guests after a brief demonstration and film show on handling and safety issues of LPG Gas.

World Food Day

KVK Cuttack, Santhapur observed "World Food Day" at Juanga village of Cuttack district on 16 October 2016 on the theme "*Climate is changing: Food and agriculture must too*" along with inauguration of 'Swachhata Pakhwada'. Dr. H Pathak, Director, NRRI, Cuttack and Chief Guest drew attention on different adaptation strategies to manage the climate change in agriculture by the farming community. Dr. Prabhu Lenka, Former Prof., OUAT, Bhubaneswar highlighted on the prevailing regional climate and changing agricultural practices for overall development of the rural community. Effect of climate change on the socio-economic conditions especially for the vulnerable groups like women and children was elaborately discussed by Dr. BN Sadangi, Head, Social Science Division. Dr. SM Prasad, Head, KVK, Cuttack delivered the welcome address. The programme ended with vote of thanks by Smt. Sujata Sethy, SMS (Home Sc) and facilitated by Drs. DR Sarangi and RK Mohanta. In this occasion 10 progressive farmers and farmwomen were felicitated for their initiatives and contribution for improved agricultural practices. A "*Kissan Gosthi*" was organized on adaptation to climate change, where more than 200 members of farming community from nearby villages actively participated.

Method Demonstration under Pulse Seed Hub Programme

Under Pulse Seed Hub programme, an interactive meeting was done to make aware the farmers about the importance of the pulse seed production and its role in Food and Nutritional Security. Dr. RS Saini, National Consultant, NFSM, Department of Agriculture and Farmers Welfare visited Sundarda-Juanga cluster of KVK Cuttack a unit NRRI, Cuttack on 17 November 2016 and interacted with the farming community. Shri Santosh Behera, AAO (Pulse), Govt. of Odisha, elaborated about different schemes of the government, i.e. rain-gun, solar pumps, sprinkler set and seed treating drum. On this occasion a method demonstration was done on seed priming with phosphorus and molybdenum along with fungicide, insecticide and Rhizobium culture treatment. Under this programme, black gram (IPU2-43) is being used for seed production in this cluster after the seed priming and treatment. Dr. P Lenka, Rtd Professor, OUAT, Bhubaneswar and team of experts from KVK Cuttack motivated the farmers to take advantages of government schemes, particularly of this pulse seed hub programme and help the Nation in production of quality seeds of pulses.

World Soil Day and Pre-Rabi Mela

KVK Cuttack organized Pre-Rabi Mela & World Soil Day awareness programme on the theme "Soils & Pulses: symbiosis for life" at NRRI, Cuttack on 5 December 2016. Dr. D Panda, Ex-Director, WALMI, Cuttack and eminent Soil Scientist & Chief Guest of the programme laid emphasis on importance of soil

Release of an educational bulletin during the occasion

health maintenance & distributed 470 Soil Health Cards. Dr. H Pathak, Director, NRRI, Cuttack discussed about the importance of proper soil sampling and restitution of nutrients into soil for maintenance of soil fertility and getting optimal production. Dr. AK Nayak, Head, Crop Production Division elaborated the importance of the day.

Dr. P Samal, Head, Social Science Division asked the farming community to take the benefit of Central Govt. flagship programme on Soil Health Card. A total 100 farmers/farmwomen/rural youth from all parts of Cuttack district and Barchana block of Jajpur, 20 school children, Scientists and staff of ICAR-NRRI actively participated in the programme. A leaflet on "Soil & Pulses, a comprehensive view" and a technical bulletin on "Scientific cultivation methods for participatory pulse seed production" were released during this programme.

World Soil Health Day

Dr. (Smt.) Neera Yadav, Hon'ble Minister distributing the soil health card to the farmwomen

World Soil Health Day was celebrated on 5 December 2016 at KVK Koderma. Kisan Gosthi (Pre-Rabi) also organized simultaneously and both the events were inaugurated by Chief Guest Dr. (Smt.) Neera Yadav, Hon'ble Education Minister, Govt. of Jharkhand. Programme was presided over by Officer-In-Charge, CRURRS, Hazaribagh, who welcomed the Chief guest, other dignitaries and the farmers present on the occasion. A technical bulletin "*Mrida Parikshan Ka Mahatva Evam Takneek*" published by the KVK, Koderma, was released by the Chief Guest. Forty-five 'Soil Health Cards' were distributed among farmers. Various agencies and Line departments *viz.,* ATMA, Bank of India, BAIF institute, input dealers, KVK, Koderma and CRURRS, Hazaribagh exhibited their technologies in the stalls set up in the exhibition. Staff of CRURRS, Hazaribagh and KVK Koderma was acknowledged by the Chief Guest for its active involvement in technology dissemination to farming community. About 200 farmers from various blocks of Koderma district participated in this event.

Training-cum-Awareness Programme on PPV & FR Act, 2001

To bring awareness among farming community on the benefits of the 'Protection of Plant Varieties and Farmers' Right Act, 2001' and facilitating registration of farmers' varieties, KVK Cuttack organized a Training-cum-Workshop on the above theme at Tentuliragadi, Tigiria on 27 March 2017. About 120 farmers and farmwomen from Athagarh, Baramba, Banki II, Narasinghpur, Tangi Choudwar and Tigiria blocks of Cuttack district, line department officials and subject matter experts of KVK actively participated in this programme.

The Chief Guest, Dr. BC Patra, Principal Scientist, ICAR-NRRI, Cuttack discussed about the PPV&FR Act and its benefits for the farmers. He also elaborated the importance of preserving the landraces of plant varieties especially rice and horticultural crops. Shri Prafulla Kumar Mati, DAO, Tigiria and Guest of Honour advised the farming community to register and preserve the local landraces to meet future possibility of extracting desirable characters/genes from them. Shri Devi Prasad Prusty, AAO, Tigiria discussed about the futuristic approach and need of desirable genes to combat climatic change.

The participating farmers/farmwomen inspired the visitors by putting up an exhibition displaying seeds of about 89 indigenous varieties of rice, pulses, oilseeds, and vegetables and strengthened the objective of the Act. Smt. S Sethy, OIC, KVK Cuttack welcomed the participants and Dr. DR Sarangi proposed vote of thanks. Experts from KVK Cuttack, namely, Drs. M Chourasia and RK Mohanta coordinated the event.

Exposure Visits

Seven thousand nine hundred fifteen (7915) visitors including farmers, farmwomen, students, agriculture officers and scientists from New York University, Odisha, Chhattisgarh, Tamil Nadu, West Bengal, Gujarat, Jharkhand, Madhya Pradesh, Andhra Pradesh, Punjab, Maharashtra and Tripura visited NRRI experimental plots, demonstrations, agricultural implement workshops, net houses and *Oryza* museum and were addressed by the rice experts of the institute.

Distinguished Visitors

Sri Radha Mohan Singhji, Hon'ble Union Minister of Agriculture and Farmers Welfare, Govt. of India, Shri Dharmendra Pradhan, Hon'ble Minister of State (Independent Charge) Petroleum & Natural Gas, Govt of India, Shri Bhartruhari Mahatab, Hon'ble Member of Parliament (Lok Sabha), Cuttack, Dr. T Mohapatra, Secretary, DARE and Director General, ICAR, New Delhi, Mr. Chhabilendra Roul, IAS, Addl. Secretary, DARE and Secretary, ICAR, New Delhi, Prof. SN Pasupalak, Vice Chancellor, OUAT, Bhubaneswar and Dr. Anupam Mishra, Director, ATARI, Zone VII, Jabalpur visited the institute on 9 May 2016.

Hon'ble Member of Governing Body, ICAR visiting the Oryza Museum

Hon'ble Member of Governing Body, ICAR Shri Suresh Chandel visited the institute on 6 August 2016. The Director and Heads of the Division/Section of the institute welcomed him and presented the scientific progress in different disciplines. Dr. H Pathak, Director of the Institute briefed him about the contributions of the Institute since independence to rice development.

Many important issues namely water use efficiency, drought, climate change, quality rice, mechanization, rice in eastern India, dissemination of rice production technology were discussed in light of the findings of the Institute. He visited the *Oryza* museum and gene bank and appreciated the role of the institute for its widely acclaimed status.

Dr. T Mohapatra, Secretary, DARE and Director General, ICAR, New Delhi, Dr. AK Singh, DDG (AE) and Dr. Anupam Mishra, Director, ATARI, Zone-VII visited the institute on 23 April 2016.

Shri Manoj Ahuja, IAS, Private Secretary, Agriculture and Farmers Empowerment Department, Govt. of Odisha visited the institute on 13 July 2016.

Dr. T Mohapatra, Secretary, DARE and Director General, ICAR, New Delhi visited the institute on 2 October 2016.

Sj. Baijayant 'Jay' Panda, Hon'ble Member of Parliament, Lok Sabha visited the institute on 1 November 2016.

Shri Saumyendra Kumar Priyadarsi, IPS, Inspector General of Police (Central Range), Odisha visited the institute on 5 November 2016.

Dr. T Mohapatra, Secretary, DARE and Director General, ICAR, Padma Bhusan Prof. VL Chopra, Chancellor, Central University of Kerala and former Secretary, DARE & DG, ICAR, Dr. (Mrs.) Krishna Srinath, former Director, CIWA, Bhubaneswar and Dr. AK Singh, Professor & Head of Genetics, IARI, New Delhi visited the institute on 18 November 2016.

Shri SK Singh, IAS, AS&FA, Department of Agricultural Research & Education, ICAR and Ministry of Statistics & Programme Implementation, Govt. of India visited ICAR-NRRI on 3 December 2016. He interacted with the scientists and staff of the institute.

Shri SK Singh, IAS, AS&FA, DARE, ICAR visited the Oryza museum

For exposure to different rice production technologies faculty members and students from Steinhardt School, New York University visited NRRI, Cuttack on 15 January 2017.

Dr. V Rabindrababu, Director, IIRR, Hyderabad visited the institute on 17 January 2017.

Foreign Deputation

Dr. RK Sarkar delivered lectures in the Regional Course on Mutation Detection Methods applied to floods at Malayasian Nuclear Agency in Putrajaya, Malaysia from 11 to 15 April 2016.

Dr. U Kumar was deputed to CSIRO, Adelaide, Australia as Visiting Scientist to undergo training on "Application of molecular tools to understand biological functions of agricultural soils" from 10 May to 31 July 2016.

Dr. (Mrs.) Debarati Bhaduri was deputed under 'Endeavour Fellowship 2016' programme at University of New England, Armidale, NSW, Australia from 5 September 2016 to 4 March 2017.

Dr. AK Mukherjee attended the '5th International Conference on Bacterial Blight of Rice' at IRRI, Philippines from 17 to 19 October 2016.

Drs. AK Nayak and R Tripathi attended the 'GLP and DEVIL Annual Project Meeting' at China Convention Centre, China from 26 to 29 October 2016.

Dr. M Shahid attended a training program on 'Digital Agriculture for Food and Soil Security: Training Agricultural Trade Partners (India)' at University of Sydney, Sydney, Australia from 4 to 20 November 2016 which was sponsored by the Department of Foreign Affairs and Trade, Australia under the Round 16 of the Australia Awards Fellowships scheme.

Drs. ON Singh, P Samal and A Anandan attended the compilation and evaluation meeting of the Asian Development Bank (ADB) supported project 'Development and Dissemination of Climate Resilient Rice Varieties for Water-short Areas of South Asia and Southeast Asia (TA-8441)' at IRRI, Philippines from 28 to 29 November 2016.

Dr. (Mrs.) Mayabini Jena visited IRRI, Philippines from 14 to 20 December 2016 under the IRRI (ICAR) India collaborative project on 'New Resources of Resistance to Biotic Stresses/Wild Rice Introgression'.

Dr. H Pathak participated in the fifth meeting of the "Expert Group on Agricultural Co-operation" of BIMSTEC (Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation) at Thimphu, Bhutan from 28 to 29 December 2016.

Dr. H Pathak participated in the workshop on 'Opportunities for Diversification in Rice Based Systems' at Bangkok, Thailand from 28 to 29 March 2017.

Institute Seminar

Dr. RK Sarkar delivered a lecture on "DST's knowledge network in climate change and agriculture" on 20 May 2016.

Dr. A Janaiah, Scientist, IRRI, Phillipines delivered a lecture on 'Farmers Suicides: Whom should be blames? on 23 September 2016.

Dr. NN Jambhulkar delivered an institute seminar on "KRISHI: Knowledge based Resources Information Systems Hub for Innovations in Agriculture" on 19 January 2017.

Dr. SG Sharma, Head, Plant Physiology & Biochemistry, NRRI, Cuttack delivered a seminar on "Rice-Quality, Nutrition and Beyond" at CRURRS, Hazaribagh on 4 February 2017.

Awards/Recognition

NRRI Receives Rajbhasha Shield

National Rice Research Institute, Cuttack was awarded with Rajbhasha shield for the best institute among all the Central Govt. Offices located in Cuttack city by the Town Official Language Implementation Committee (TOLIC), Cuttack for full implementation and execution of Official Language for the year 2015-16. Dr. H Pathak, Director, NRRI received the Rajbhasha Shield along with citation from Shri Suhas Mohanty, Director, AIR, Cuttack and Chairman, TOLIC in the 47th TOLIC meeting held on 28 October 2016 at the Institute.

Dr. H Pathak, Director, NRRI receiving the Rajbhasa shield

Individual Award/Recognition

Dr. SK Mishra has been nominated by Secretary, DARE & DG, ICAR as a member of the "Institute Management Committee (IMC)" of ICAR-CRIJAF, Barrackpore for three years w.e.f. 7 March 2016 and of ICAR-ATARI, Zone-II, Kolkata for three years w.e.f. 13 November 2016.

Dr. P Panneerselvam has been conferred "Outstanding Scientist Award 2016" in IJTA 3rd International Conference on Agriculture, Horticulture and Plant Science held at New Delhi, India from 25 to 26 June 2016 organized by IJTA and Serials Publication Pvt. Ltd, New Delhi, India.

Dr. P Bhattacharyya elected as Fellow of National Academy of Agricultural Sciences (NAAS) from 1st January 2017.

Dr. P Bhattacharyya got offer of appointment as ICAR-National Fellow on February, 2017 on the project entitled "Accounting greenhouse gases (GHGs) emission and carbon flow in temporal shift of tropical mangrove to agriculture".

Dr. TK Dangar acted as a Member, Board of Studies of Botany, 2016-17, Ravenshaw University, Cuttack, Odisha

Dr. TK Dangar acted as an ICAR nominated member for CAS of Agricultural Microbiology scientists at IISS, Bhopal.

Dr. U Kumar was recognized as editorial member in World Journal of Microbiology (Premier publishers, USA).

Dr. U Kumar was recognized as editorial member in EC Microbiology (ECronicon Open Access, UK).

Dr. U Kumar received Crawford Fund Fellowship Award from Crawford Fund Organization, Australia to undergo training at CSIRO, Adelaide, Australia on 23 July 2016.

Dr. U Kumar receiving the Crawford Fund Fellowship Award Certificate

Dr. Manas Kumar Bag received Outstanding Scientist Award 2016 in 4th International Conference on Recent Advances in Agriculture and Horticulture Sciences held at Jodhpur, Rajasthan from 30 to 31 December 2016 organized by International Journal of Tropical Agriculture and Serials Publications Pvt. Ltd., New Delhi.

Dr. Manas Kumar Bag received fellowship from the Scientific Society of Advanced Research and Social Change, New Delhi.

Mr. Anjani Kumar received SCON recognition award instituted by Society for Conservation of Nature (SCON), NASC complex, Pusa, New Delhi.

MK Bag receiving the Outstanding Scientist2016 award

Anjani Kumar receiving the SCON recognition award

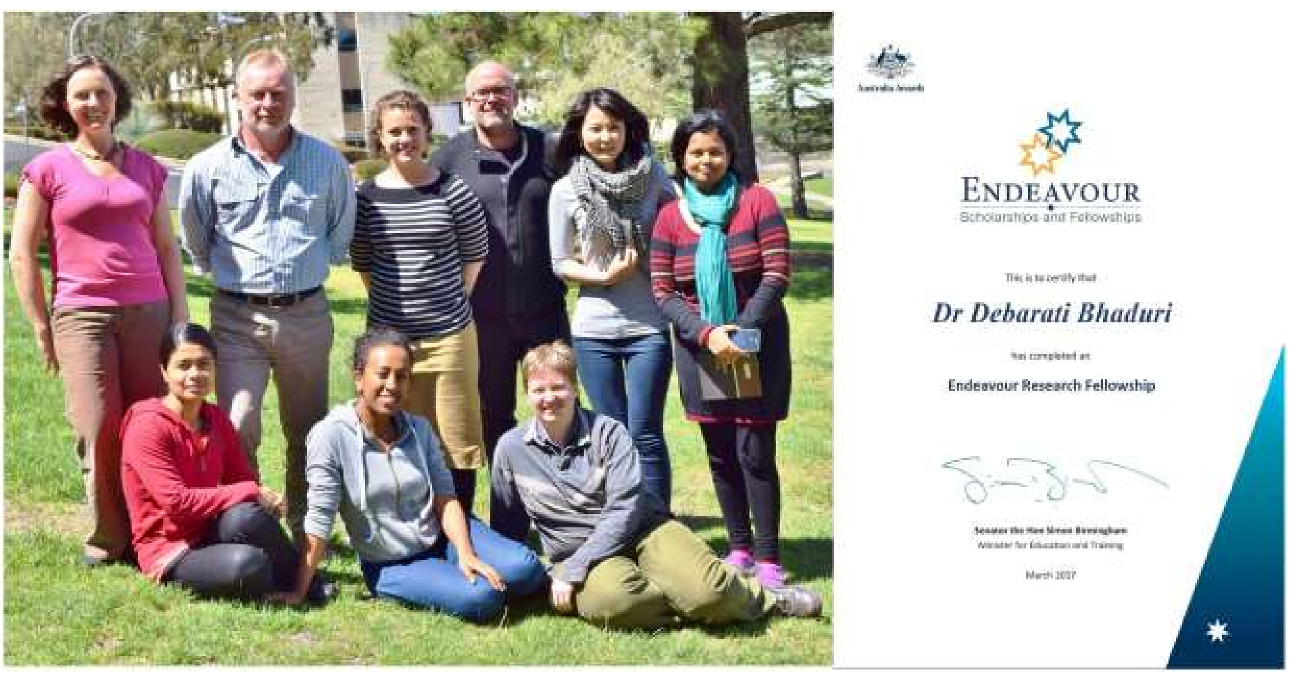
Dr. M Shahid received Australia Award Fellowship from the Department of Foreign Affairs and Trade, Government of Australia for attending a Training Program at The University of Sydney, Australia.

Smt. Chanchila Kumari received Best KVK Scientist Award during 'ISEE National Seminar 2016' organized by Rajmata Vijayaraje Scindhia Krishi Vishwa Vidyalaya, Gwalior, Madhya Pradesh from 28 to 30 November 2016.

Dr. PC Rath and Dr. S Lenka became life member of Satyasai Charitable and Educational Trust of Indian climate congress, Mahanadi vihar, Cuttack w.e.f. 1st March 2017.

Dr.(Mrs.) Amrita Banerjee received the Crop & Weed Science Society Young Scientist Award on the occasion of International Symposium on "Eco-efficiency in Agriculture & Allied Research" at BCKV, WB from 20 to 23 January 2017.

Dr. Debarati Bhaduri pursued her postdoctoral research under Endeavour Research Fellowship-2016 (funded by Australia Awards, Department of Education & Training, Australian Govt.) at Terrestrial Carbon Research Group, University of New England, Armidale (NSW), Australia under supervision of Prof Brian R. Wilson during September 2016 to February 2017.



Dr. Debarati Bhaduri on deputation under Endeavour Research Fellowship-2016
at Terrestrial Carbon Research Group, University of New England, Armidale (NSW), Australia

Dr. SK Pradhan received Outstanding Achievement Award 2017-Society for Agricultural Innovations & the Samanta Chandra Sekhar Award-2015 by Dept of science and Technology, Govt. of Odisha.

Best Worker Award

Name	Category
Dr. Sanjoy Saha	Principal Scientist
Drs. K Chattopadhyay & SK Dash	Senior Scientist
Dr. MS Anantha, CRURRS, Hazaribag	Scientist
Smt. Chanchila Kumari, KVK, Koderma	Technical (T6-T9)
Shri DR Sahoo	Technical (T4-T5)
Shri Bhoopen Kalika, RRLRRS, Gerua	Technical (T1-T3)
Shri BB Polai	Administrative-II (upto UDCs including Stenos)
Shri Kailash Ram	SS Grade

Sports Activities

ICAR sports tournament for Eastern Zone (TEZ 2016)

The ICAR sports tournament for Eastern Zone (TEZ 2016) was successfully organized by the ICAR-National Rice Research Institute, Cuttack from 6 to 9 March 2017. A total of 375 participants from thirteen ICAR institutes of Eastern Zone were participated in the march-past. The ICAR Sport Tournament for Eastern Zone (TEZ 2016) was declared open by Dr. Himanshu Pathak, Chief Guest and Director, ICAR-NRRI, Cuttack on 6 March 2017 at the sports complex of the institute. The Director emphasized that when competitions are held, it given birth to team spirit. Hence, let an ambience of team spirit pervade over all ICAR Institutes. The closing ceremony of TEZ 2016 was graced by Shri Chhabiliendra Roul, IAS, Additional Secretary, DARE and Secretary, ICAR as Chief Guest. Shri Roul hailed the efforts of the institute for organizing the event successfully and appreciated the sportsman spirit shown by all the participants during the tournament. He also declared that the council is planning to organize Sports event as Sports and cultural event in which participants of cultural activities will also be competing with each other. Dr. Himanshu Pathak, Director, NRRI thanked the Chief Guest, the participants and all the staff of NRRI who contributed towards the successful organization of the tournament. Dr.(Mrs) Jatinder Kishtwaria, Director, ICAR-CIWA, Bhubaneswar and Dr. JK Sundaray, Director (Acting), ICAR-CIFA, Bhubaneswar also graced the occasion. The ICAR-NRRI was adjudged the overall champion of the tournament, while the ICAR-IVRI, Izatnagar bagged the runner-up trophy. Shri PK Parida of ICAR-NRRI was adjudged as the Best Athlete (Men) while Ms. Sibna Mols, ICAR-CIFRI was adjudged as the Best Athlete (Women). A total of 375 participants from thirteen ICAR institutes of Eastern Zone participated in the event.

NRRI Kabaddi Team participated in the 64th Senior State Kabaddi Championship

NRRI Kabaddi Team participated in the 64th Senior State Kabaddi Championship held at Nari Seva Sadan groud, Sambalpur from 21 to 23 October 2016 conducted by Odisha Kabaddi Association. NRRI won all the matches against Kalahandi, Bhadrak and Jagatsinghpur and qualify for Pre-quarter final having Group topper. In pre-quarter NRRI Kabaddi team won the match against Jharsuguda and qualify quarter final. The participation of NRRI, Cuttack as affiliated unit of Odisha Kabaddi Association, in the State Championship is a great honour to this institute.

Commercialization of Hybrid Rice and Other Technologies

MoUs Signed

During the period, three MoUs have been signed with Private Seed Companies: M/s Nath Bio-genes (I) Ltd., Aurangabad, Maharashtra for commercial seed production of two NRRI rice hybrids namely, Rajalaxmi (20 July 2016) and CR Dhan 701 (26 July 2016) whereas, M/s PAN Seeds Pvt. Ltd., Kolkata signed only for Rajalaxmi (26 August 2016). In the process, revenue of Rs. 15.0 lakhs was also earned for the institute.

Variety Registration

PPV&FRA Registration

During the period, five applications have been submitted for PPV&FRA Registration. Three of them are for the Extant Notified varieties {Sahabhagidhan, CR Dhan 303 (CR 2649-7) (IET 21589) & CR Dhan 304 (IET 22117)} and New varieties like CRMS 8A and CRMS 51A.

During this year also, four varieties were registered with the PPV&FRA, New Delhi which were submitted in 2013-14. They are Luna Sankhi, Luna Barial, CR Dhan 601 and CR Dhan 701.

NBPGR Registration

The rice germplasm of breeding line, CR 143-2-2 (IC 0513420) has been registered with the Plant Germplasm Registration Committee (PGRC), NBPGR, New Delhi having the unique trait of tolerance to both vegetative and reproductive stage drought stress. It has been allotted with the registration number INGR17019.

Training and Capacity Building

Physical targets and achievements

Sl. No.	Category	Total No. of employees	No. of training planned for 2016-17 as per Annual Training Plan	No. of employees undergone training during 2016-17	% realization of trainings planned during 2016-17
1.	Scientist	97	27	8	29.63
2.	Technical	91	29	4	13.79
3.	Administrative & Finance	69	13	15	115.38
4.	SSS	58	2	Nil	Nil

Category-wise training attended by employees

Category: Scientific

Professional attachment training

Sl. No.	Name of the Scientist	Period	Institution
1.	Dr. Mathew Seikholen Baite	16 May to 16 August 2016	National Research Centre on Plant Biotechnology, New Delhi
2.	Mr. Borkar Narayan Totaram	16 May to 16 August 2016	Central Institute of Agricultural Engineering, Bhopal
3.	Mr. Sumanta Chatterjee	19 May to 18 August 2016	Central Research Institute for Jute and Allied Fibres, Barrackpore, Kolkata
4.	Er. Manish Debnath	18 November 2016 to 17 February 2017	Indian Institute of Soil and Water Conservation, Dehradun
5.	Mr. Gaurav Kumar	18 November 2016 to 17 February 2017	National Research Centre on Plant Biotechnology, New Delhi
6.	Mr. M Annamalai	26 November 2016 to 20 February 2017	Manonmaniam Sundaranar University, Tamil Nadu
7.	Ms. Golive Prasanthi	26 November 2016 to 20 February 2017	University of Agricultural Sciences, Dharwad

National Training

Sl. No.	Name of the Scientist	Period	Name of Training Programme	Institution
1.	Mr. Sumanta Chatterjee	11 April to 11 May 2016	Institute orientation training programme	NRRI, Cuttack
2.	Dr. JL Katara	23 August to 12 September 2016	Innovative Breeding Techniques for Development of Climate Smart Crops	Centre of Advanced Faculty training (ICAR) Department of Plant Breeding and Genetics, PAU, Ludhiana

3.	Dr. Raghu S	7 to 27 September 2016	Perspectives of Plant-microbe interactions in promoting Plant health and disease management	Centre of Advanced Faculty Training (CAFT) in Plant Pathology, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand
4.	Drs. Dibyendu Chatterjee, Naveenkumar B Patil, Basana Gowda G, Sumanta Chatterjee, Guru Prasanna Pandi G	14 to 20 September 2016	Application of multivariate techniques for Agriculture research using SAS software	NRRI, Cuttack
5.	Dr. NC Rath	7 to 11 November 2016	Science and Technology for Rural Societies	Indian Institute of Public Administration, New Delhi
6.	Dr. Dibyendu Chatterjee and Mr. Sumanta Chatterjee	8 to 28 November 2016	Assessing Natural Resource Management, Climate Risk and Environmental Sustainability using Simulation Models	Indian Institute of Soil Science, Bhopal
7.	Drs. NN Jambhulkar and Sutapa Sarkar	1 to 21 December 2016	Advance Computational and Statistical Tools for Omics Data Analysis	IASRI, New Delhi
8.	Dr. Guru Prasanna Pandi G	1 to 21 December 2016	Development and utilization of genetic and genomic resources through Biotechnology for biotic, abiotic stress management and quality improvement in field crops	University of Agricultural Sciences, Dharwad
9.	Dr. RL Verma	2 to 22 December 2016	Rice Breeding Issues, Challenges, and Opportunities in 21st Century	ICRISAT, Hyderabad
10.	Dr. Soham Ray	8 to 28 February 2017	Computational approaches for Next Generation Sequencing (NGS) data analysis in agriculture	IASRI, New Delhi
11.	Dr. Naveenkumar B Patil	2 to 23 January 2017	Stored Grain Pest Detection, Identification and Phytosanitary Treatment (MBR & AlP fumigation)	NIPHM, Hyderabad

International Training

Sl. No.	Name of the Scientist	Period	Name of Training Programme	Institution
1.	Dr. Upendra Kumar	18 to 19 May 2016	Hazardous substances and dangerous goods; PC2 facility	CSIRO, Waite Campus, Adelaide, Australia

Category: Technical

Sl. No.	Name of the Employee	Period	Name of Training Programme	Institution
1.	Shri SK Sethi	28 September to 5 October 2016	Cyber Security for Technical Personnel of ICAR	IASRI, New Delhi
2.	Shri Prem Pal Kumar	2 to 11 November 2016	Statistical Techniques for Data Analysis	IASRI, New Delhi
3.	Shri Prakash Kar and Shri P Jana	30 November to 9 December 2016	Competence Enhancement Programme on 'Motivation and Positive Thinking for Technical Officers of ICAR'	NAARM, Hyderabad
4.	Shri Nakula Barik and Mrs. Rosalin Swain	17 to 31 January 2017	Use of Different Molecular Biology Techniques in Crop Improvement Program	NRCPB, New Delhi

Category: Administrative

Sl. No.	Name of the Employee	Period	Name of Training Programme	Institution
1.	Shri SK Jena, Shri SK Sahoo and Shri MK Sethi	18 to 19 April 2016	Knowledge Enhancement on HR and Payroll	IASRI, New Delhi
2.	Ms. Sabita Sahoo and Shri BB Palei	2 to 3 May 2016	Knowledge Enhancement on HR and Payroll	IASRI, New Delhi
3.	Shri CP Murmu, Shri RC Das and Shri SK Satpathy	9 to 10 June 2016	Supply Chain Management (Procurement and Store) Modules of ICAR-ERP under MIS/FMS Project	IASRI, New Delhi
4.	Shri SK Jena, Shri SK Sahoo and Ms. Sabita Sahoo	28 July 2016	Capacity Building/ Training of DDOs of National Pension System	Salt Lake, Kolkata
5.	Shri NN Mohanty	28 July to 3 August 2016	Enhancing Efficiency and Behavioural Skills of Stenographers Grade-III, PAs, PSs and PPSs	NAARM, Hyderabad
6.	Shri BK Sahoo, Shri CP Murmu and Shri SK Satpathy	26 to 28 September 2016	Implementation NICs e-Procurement Solution through CPB Portal	NAARM, Hyderabad
7.	Shri J Nayak	24 to 30 November 2016	Enhancing Efficiency and Behavioural Skills of Stenographers Grade-III, PAs, PSs and PPSs	NAARM, Hyderabad
8.	Shri N Mahavoi, Shri A Kullu and Shri T Ram	4 to 10 January 2017	Enhancing Efficiency and Behavioural Skills of Stenographers Grade-III, PAs, PSs and PPSs	NAARM, Hyderabad

Category: Progressive Farmers and Govt. Officials

The following State and National level training programmes were organized by NRRI, Cuttack during 2016-17.

Sl. No.	Title of the training/ Short-term Training-cum-Exposure visit Programme	Period	Sponsored by	Target group with number
1.	Protocol for herbicide based weed management	9 September 2016	NRRI, Cuttack	More than 70 farmers from different villages of Cuttack and Jajpur districts
2.	Package of Practices for Improved Rice Production Technology	7 to 11 June 2016	ATMA, Valsad, Gujarat	23 Kisan Saathis and Block Technology Managers (BTMs) from Valsad district of Gujarat
3.	Improved Rice Production and Protection Technology	2 to 4 August 2016	ATMA, Vellore, Tamil Nadu	22 participants
4.	Improved Rice Production and Protection Technology	16 to 17 August 2016	ATMA, Kanyakumari, Tamil Nadu	20 participants
5.	Improved Rice Production and Protection Technology	28 to 31 August 2016	ATMA, Salem, Tamil Nadu	19 participants
6.	Improved Rice Production and Protection Technology	28 August to 1 September 2016	ATMA, Tirunelvelli, Tamil Nadu	25 participants
7.	Improved Rice Production and Protection Technology	4 to 7 September 2016	ATMA, Kanchipuram, Tamil Nadu	22 participants
8.	Improved Rice Production and Protection Technology	13 September 2016	ATMA, Bankura, West Bengal	42 participants
9.	Improved Rice Production and Protection Technology	13 to 17 September 2016	ATMA, Murshidabad, West Bengal	12 participants
10.	Improved Rice Production and Protection Technology	16 to 17 September 2016	ATMA, Ramnad, Tamil Nadu	24 participants
11.	Quality Seed Production and Post-harvest Management in Rice	28 to 29 September and 30 September to 1 October 2016	STRASA	97 officials/workers (37 Assistant Agricultural Officers of Odisha and 60 workers of different NGOs of Odisha
12.	Application of Multivariate Techniques for Agricultural Research using SAS Software	14 to 20 September 2016	NRRI, Cuttack	Scientific staff of the institute

13.	Hybrid Rice Production Technology for increasing Productivity	20 to 24 September 2016	ATMA, Rehmankhera, Lucknow	28 senior officers namely DDAs (Research), PDs, DPDs, DAOs, SDAEOs and ATMA Project Officers covering all the agro-climatic zones of Uttar Pradesh
14.	Improved Rice Production and Protection Technology	25 to 27 September 2016	ATMA, Dantan-1, West Bengal	28 participants
15.	Improved Rice Production and Protection Technology	29 September 2016	ATMA, Pingla, West Bengal	46 participants
16.	Improved Production Technologies for Enhancing Rice Productivity	18 to 22 October 2016	ATMA, Sidhi, Madhya Pradesh	18 Kisan Sathis/ Kisan Mitras/ ATMA BTMs from Sidhi district of Madhya Pradesh
17.	Insect Pest Management in Rice	24 to 26 October 2016	Kerala Pest Centre	Three officers of Kerala
18.	Three Weeks Comprehensive Agribusiness Incubation Programme (CAIP)	30 January to 4 March 2017	Agribusiness Incubation Centre, NRRI, Cuttack	23 participants of Odisha
19.	Quality Paddy Seed Production	28 to 31 March 2017	Agribusiness Incubation Centre, NRRI, Cuttack	for 12 participants of Gwalior, Madhya Pradesh

Financial targets and achievements for 2016-17 of all NRRI employees

Sl. No.	RE 2016-17 for HRD			Actual Expenditure 2016-17 for HRD	% Utilization
	Plan	Non-Plan	Total		
	(Lakh Rs.)			(Lakh Rs.)	2016-17
1.	4.00	-	4.00	4.00	100%

In-charge and Members of Different Cells

Research Advisory Committee

Prof. VL Chopra, Ex-Secretary, DARE & Director General, ICAR, New Delhi, Chairman

Dr. AK Singh, Principal Scientist, Division of Genetics, (IARI), New Delhi, Member

Dr. VK Dadhwal, Director, National Remote Sensing Centre, Balanagar, Hyderabad, Member

Dr. BV David, Chairman, International Institute of Biotechnology & Toxicology, Chennai, Member

Dr.(Mrs.) Krishna Srinath, Emeritus Scientist, Directorate of Extension Education, TANUVAS, Chennai, Member

Director, NRRI, Cuttack, Member

Assistant Director General (FFC), ICAR, New Delhi, Member

Shri Kulamani Rout, Ex-MLA, Bari Derabish, Kendrapara, Odisha, Member

Shri Utkal Keshari Parida, Derabish, Kendrapara, Odisha, Member

Dr. JN Reddy, Principal Scientist, NRRI, Cuttack, Member Secretary

Institute Management Committee

Director, NRRI, Cuttack, Chairman

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

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

Dr. PC Das, Dean of Research, OUAT, Bhubaneswar, Member

Dr. SG Sharma, Head, NRRI, Cuttack, Member

Dr. (Mrs.) M Jena, NRRI, Cuttack, Member

Dr. Shiv Sewak, Principal Scientist, IIPR, Kanpur, Member

Dr. CS Kar, Principal Scientist, CRIJAF, Barrackpore, Kolkata, Member

Dr. IS Solanki, ADG (FC), ICAR, New Delhi, Member

Shri SK Pathak, DD (F)-III, ICAR, New Delhi, Member

Shri Kulamani Rout, Ex-MLA, Bari Derabish, Kendrapara, Odisha, Member (Non-Official)

Shri Utkal Keshari Parida, Derabish, Kendrapara, Odisha, Member (Non-Official)

Shri BK Sinha, SAO, NRRI, Cuttack, Member Secretary

Institute Technology Management Committee (ITMC)

Director, NRRI, Cuttack, Chairman

Dr. P Swain, CIFA, External Member

Dr. ON Singh, Member

Dr. SG Sharma, Member

Dr.(Mrs.) M Jena, Member

Dr. GAK Kumar, Member

Dr. BC Patra, Member Secretary

Institute Joint Staff Council (IJSC)

Director, NRRI, Cuttack, Chairman

Dr. ON Singh, Member

Dr.(Mrs) S Samantaray, Member

Dr. SD Mohapatra, Member

Shri BK Sinha, Member

Shri SR Khuntia, Member

Asstt. Administrative Officer (Technical Section), Secretary (Official side)

Shri Sanjaya Kumar Sahoo, (Administrative Staff Side), Member & Secretary (Staff side)

Shri Rama Chandra Pradhan, (Administrative Staff Side), Member

Shri Dipti Ranjan Sahoo, (Technical Staff Side), Member

Shri Prahallad Moharana, (Technical Staff Side), Member

Shri Bhagyadhar Pradhan, (Technical Staff Side), Member

Shri KC Ram, (Supporting Staff side), Member

Shri Meru Sahoo, (Supporting Staff Side), Member

Shri Markand Charan Nayak, (Supporting Staff side), Member

Central Public Information Officer

Shri BK Sahoo

PME Cell

Dr. (Mrs.) M Jena

Dr. TK Dangar

Shri SSC Patnaik

Dr. JN Reddy

Dr. AK Nayak

Dr. GAK Kumar

Dr. (Mrs.) MK Kar

Dr. NN Jambhulkar

Shri SK Sinha

Dr. R Chandra

Shri J Sethi

Human Resource Development (HRD) Committee

Nodal Officer-Dr. (Mrs.) S Samantaray

Co-Nodal Officer-Dr. SD Mohapatra

Women Cell

Dr. (Mrs.) S. Samantray, Chair person

Mrs. Pravasini Sarangi, 3rd Party Member

President, Odisha Women Housing Development Cooperative Society, Bhubaneswar

Dr. (Mrs.) MK Kar, Member

Dr. MJ Baig, Member

Dr.(Mrs.) A Poonam, Member

Mrs. Manasi Das, Member

Mrs. Chandmoni Tudu, Member

Mrs. Surubali Hembram, Member

Mrs. Priyanka Gautam, Member Secretary

Institute Grievance Cell

Director, NRRI, Cuttack, Chairman

***Dr.(Mrs.) Mayabini Jena,** Member

***Shri BK Sinha,** Member

***Shri SR Khuntia,** Member

Dr. AK Mukherjee, Member

Shri Santosh Kumar Ojha, Member

Shri CP Murmu, Member

Shri Ganesh Chandra Sahoo, Member

Asstt. Administrative Officer (Tech), Member Secretary

(*Subject to nomination by the Institute Management Committee)

Institutional Bio-Safety Committee

Director, NRRI, Cuttack, Chairman

Dr. BP Shaw, Scientist-F, Institute of Life Sciences (ILS), Bhubaneswar, DBT Nominee

Dr. MJ Baig, Member Secretary

Dr. PK Chand, Professor (Botany), Department of Botany, Utkal University, Bhubaneswar, Outside Experts

Dr. Kishore CS Panigrahi, Reader-F, NISER, Bhubaneswar, Outside Experts

Dr. Luna Samanta, Professor & Head, Department of Zoology, Ravenshaw University, Cuttack, Outside Experts

Dr. Jogeswar Pani, Medical Officer, NRRI, Cuttack, Biosafety Officer

Dr. ON Singh, Member

Dr. SG Sharma, Member

Dr. (Mrs.) S Samantaray, Member

Personnel

(as on 31.03.2017)

1. **Dr. AK Nayak,** Director (Acting) : 01.04.2016 to 31.07.2016
2. **Dr. Himanshu Pathak,** Director : 01.08.2016 to till date

Crop Improvement Division

Name of the Scientist	Designation
Dr. Onkar Nath Singh	I/c Head
Dr. J.N. Reddy	Pr.Scientist
Dr. B.C. Patra	Pr.Scientist
Dr.(Mrs.) S. Samantaray	Pr.Scientist
Dr.(Mrs.) Meera Kumari Kar	Pr.Scientist
Dr. Sarat Kumar Pradhan	Pr.Scientist
Dr. Lamobodar Behera	Pr.Scientist
Dr. Hatanath Subudhi	Pr.Scientist
Dr. Lotan Kumar Bose	Pr.Scientist
Dr. K. Chattopadhyay	Pr.Scientist
Dr. Sushant Kumar Dash	Sr.Scientist
Dr. A. Anandan	Sr.Scientist
Shri R.K. Sahu	Scientist (SG)
Shri S.S.C. Pattnaik	Scientist (SG)
Shri B.C. Marndi	Scientist (SG)
Shri J. Meher	Scientist (SG)
Dr. Jawahar Lal Katara	Scientist
Dr. Ramlakhan Verma	Scientist
Dr. Soham Ray	Scientist
Dr. (Mrs.) P. Sanghamitra	Scientist
Dr. N. Umakant	Scientist
Dr. SK Ghrithlahre	Scientist
Dr.(Mrs.) Sutapa Sarkar	Scientist
Dr. Kutubuddin Ali Molla	Scientist
Md. Azharudeen T.P.	Scientist
Shri Parameswaran, C	Scientist
Dr. Somnath Roy	Scientist
Dr. Mridul Chakraborti	Scientist
Dr. Rameswar Prasad Sah	Scientist

Crop Production Division

Name of the Scientist	Designation
Dr. A.K. Nayak	Head
Dr. S.P. Patel	Pr.Scientist
Dr. T.K. Dangar	Pr.Scientist
Dr. P.K. Nayak	Pr. Scientist
Dr. Sanjoy Saha	Pr.Scientist
Dr. Pratap Bhattacharyya	Pr.Scientist
Dr. B.B. Panda	Pr.Scientist
Dr.(Mrs.) Annie Poonam	Sr.Scientist
Dr. P. Panneerselvam	Sr.Scientist
Dr. Rahul Tripathi	Scientist
Dr.(Mrs.) Sangita Mohanty	Scientist
Dr. Mohammad Shahid	Scientist
Shri Anjani Kumar	Scientist
Dr. Upendra Kumar	Scientist
Dr. Banwari Lal	Scientist
Mrs. Priyanka Gautam	Scientist
Dr.(Mrs.) Sushmita Munda	Scientist
Shri Prabhat Kumar Guru	Scientist
Dr. Dibyendu Chatterjee	Scientist
Dr. Debarati Bhaduri	Scientist
Shri B.S. Satapathy	Scientist
Shri B.N.Totaram	Scientist
Shri Sumanta Chaterjee	Scientist
Er. Manish Debanath	Scientist
Mrs. Rubina Khanam	Scientist

Crop Protection Division

Name of the Scientist	Designation
Dr.(Mrs.) Mayabini Jena	Head
Dr. (Mrs.) Urmila Dhua	Pr.Scientist
Dr. P.C. Rath	Pr.Scientist
Dr. S.D. Mohapatra	Pr.Scientist
Dr. A.K. Mukherjee	Sr.Scientist
Dr. Srikanta Lenka	Sr.Scientist
Dr. Manas Kumar Bag	Sr.Scientist
Dr. Totan Adak	Scientist
Shri S.S.Pokhare	Scientist
Shri Manoj Kumar Yadav	Scientist
Dr. Guruprasanna Pandi, G	Scientist
Dr. N.K.B. Patil	Scientist
Dr. Basana Gowda, G	Scientist
Shri Aravindan S.	Scientist
Dr. Raghu S.	Scientist
Dr. Prabhukarthikeyan, SR	Scientist

Dr. M.S.Bite .... Scientist
Shri M. Annamalai .... Scientist
Ms. Golive Prasanthi .... Scientist

Crop Physiology and Biochemistry Division

Name of the Scientist .... Designation

Dr. S.G. Sharma .... Head
Dr. R.K. Sarkar .... Pr.Scientist
Dr.(Mrs.) Padmini Swain .... Pr.Scientist
Dr. M.J. Baig .... Pr.Scientist
Dr. Koushik Chakraborty .... Scientist
Shri Torit Baran Bagchi .... Scientist
Dr. Awadhesh Kumar .... Scientist
Dr. P.K.S. Horjogi .... Scientist
Mrs. Nabaneeta Basak .... Scientist
Shri Gaurav Kumar .... Scientist

Social Science Division

Name of the Scientist .... Designation

Dr. B.N. Sadangi .... Head
Dr. P. Samal .... Pr.Scientist
Dr. N.C. Rath .... Pr.Scientist
Dr. G.A.K. Kumar .... Pr.Scientist
Dr. S.K. Mishra .... Pr.Scientist
Dr.(Mrs.) Lipi Das .... Sr.Scientist
Dr. Biswajit Mandal .... Sr.Scientist
Dr. N.N. Jambhulkar .... Scientist

Central Rainfed Upland Rice Research Station, Hazaribagh, Jharkhand

Name of the Scientist .... Designation

Dr. D. Maiti .... O.I.C.
Dr. N.P. Mandal .... Pr.Scientist
Dr. Shiv Mangal Prasad .... Pr.Scientist
Dr. C.V. Singh .... Pr.Scientist
Dr. Someshwar Bhagat .... Pr.Scientist
Dr. Yogesh Kumar .... Sr.Scientist
Dr. Somnath Roy .... Scientist
Dr.(Mrs.) Amrita Banerjee .... Scientist

Resgional Rainfed Low Land Rice Research Station, Gerua, Assam

Name of the Scientist .... Designation

Dr. Khem Bahadur Pun .... I/c O.I.C.
Dr. Rupankar Bhagawati .... Pr.Scientist
Dr. Kanchan Saikia .... Sr.Scientist
Dr. Teekam Singh .... Sr.Scientist
Shri S.K. Ghritlahre .... Scientist

Technical Staff, NRRI, Cuttack

Category-I

Name .... Designation

Sri Ajaya Kumar Naik .... Technician (Field Asst.)
Sri Alok Kumar Panda .... Technician (Extension Asst.)
Sri Keshab Chandra Das .... Sr.Technician (Machine Operator)
Sri Bhagyadhar Pradhan .... Sr.Technician (Farm Mechanic)
Sri Pramod Ku. Sahoo .... Sr.Technician (Machine Operator)
Sri Gyanaranjan Bihari .... Sr.Technician (Driver)
Sri Debaprakash Behera .... Sr.Technician (Driver)
Sri Pramod Kumar Ojha .... Sr.Technician (Tractor Driver)
Sri Ramudev Beshra .... Sr.Technician (Farm Mechanic)
Sri Chandan Kumar Ojha .... Sr.Technician (Field Asst.)
Sri Sesadev Pradhan .... Sr.Technician (Field Asst.)
Sri Dularam Majhi .... Sr.Technician (Field Asst.)
Sri Baidyanath Hembram .... Sr.Technician (Field Asst.)
Sri Susanta Ku. Tripathy .... Sr.Technician (Field Asst.)
Sri Surendra Biswal .... Sr.Technician (Field Asst.)
Sri Debasis Parida .... Sr.Technician (Tractor Driver)
Sri Ajaya Kumar Nayak .... Sr.Technician (Pharmacist)
Sri Pradeep Kumar Parida .... Technical Assistant (Driver)
Sri Jogeswar Bhoi .... Technical Assistant (Field Asst.)
Sri A.C. Moharana .... Technical Assistant (Field Asst.)
Sri Mansingh Soren .... Sr.Technical Assistant (Field Asst.)
Sri Nakula Barik .... Sr.Technical Assistant (Field Asst.)
Sri Bhakta Charan Behera .... Sr.Technical Asst. (Field Asst.)
Sri Parimal Behera .... Sr.Technical Assistant (Field Asst.)
Sri Srinibas Panda .... Sr.Technical Assistant (Electrician)
Sri Gauranga Charan Sahu .... Sr.Technical Asst. (Mechanic)
Sri Kailash Ch. Mallick .... Sr.Technical Assistant (Field Asst.)
Sri Charan Naik .... Sr.Technical Assistant (Field Asst.)
Mrs. Chintamani Majhi .... Sr.Technical Assistant (Field Asst.)
Sri Bansidhar Ojha .... Sr.Technical Assistant (Welder)
Sri Prasanta Kumar Jena .... Sr.Technical Assistant (Driver)
Sri A.K. Moharana .... Sr.Technical Assistant (Field Asst.)
Sri D.R. Sahoo .... Sr.Technical Assistant (Projectionist)
Sri Prahallad Moharana .... Sr.Technical Assistant (Field Asst.)
Sri Arun Kumar Parida .... Sr.Technical Assistant (Painter)
Sri Ramrai Jamunda .... Sr.Technical Assistant (Fitter)
Mrs. Nibedita Biswal .... Technical Officer (Lab. Technician)
Sri Santosh Kumar Ojha .... Technical Officer (Electrician)
Sri J. P. Behura .... Technical Officer (Supervisor-Civil)

Sri K.C. Palaur ....Technical Officer (Driver)
Sri Arun Panda ....Technical Officer (Library Asst.)
Sri A.K. Mishra ....Technical Officer (Field Assistance)
Sri K.K. Suman ....Technical Officer (Field Assistance)
Sri Aparti Sahoo.............Technical Officer (Field Assistance)
Sri J.C. Hansda ....Technical Officer (Field Assistance)
Sri Srikrishna Pradhan...Technical Officer (Field Assistance)
Sri K.C. Bhoi...........................Technical Officer (Blacksmith)
Sri Bhagaban Behera ....Technical Officer (Photography)

Category-II

Name ....Designation

Smt. Chandamuni Tudu ....Sr.Technical Asst. (Farm Asst.)
Smt. R. Gayatri Kumari ....Sr.Technical Asst. (Farm Asst.)
Smt. Baijayanti Nayak ....Sr.Technical Asst. (Farm Asst.)
Smt. Rosalin Swain ....Sr.Technical Asst. (Farm Asst.)
Smt. Sandhya Rani Dalal......Sr.Technical Asst. (Asst. Editor)
Sri Brundaban Das ....Sr.Technical Assistant (Farm Asst.)
Sri Prempal Kumar ....Sr.Technical Assistant (Farm Asst.)
Sri J. Sai Anand ....Sr.Technical Assistant (Farm Asst.)
Sri P. L. Dehury...............Sr.Technical Assistant (Farm Asst.)
Sri Manoj Ku. Nayak ....Sr.Technical Assistant (Lib. Asst.)
Sri Lalan Kumar Singh .....Sr.Technical Asst. (Training Asst.)
Sri Santosh Ku. Sethi......Sr.Technical Asst. (Computer Asst.)
Sri Smrutikanta Rout.....Sr.Technical Asst. (Computer Asst.)
Sri Sunil Kumar Sinha ...Sr.Technical Asst. (Computer Asst.)
Sri B.K. Mohanty.......Sr.Technical Officer (Hindi Translator)
Sri A.K. Dalai.........................Sr.Technical Officer (Electrical)
Dr Pradeep Ku. Sahoo .....Asst. Chief Technical Officer (Fishery)
Dr. Ramesh Chandra Asst. Chief Technical Officer (Sr.Farm Asst.)
Sri P. Jana Asst. Chief Technical Officer (Rice Production Training)
Sri Prakash Kar ....Chief Technical Officer (Photography)

Category-III

Name ....Designation

Sri K.K. Swain ....Chief Technical Officer (Mechanical)
Dr. Jogeswar Pani ....Medical Officer (On deputation)

CRURRS, Hazaribagh (Jharkhand)

Category-I

Name ....Designation

Sri Ugan Saw ....Technical Assistant (Driver)
Sri Sawan Oran ....Sr.Technical Assistant (Field Asst.)
Sri A.N. Singh ....Technical Officer (Field Assistance)
Sri Ranjit Tirky ....Technical Officer (Field Assistance)
Sri Jitendra Prasad.....................Technician (Extension Asst.)

RRLRRS, Gerua (Assam)

Category-I

Name ....Designation

Sri Haladhar Thakuria...........Technical Officer (Field Asstt.)
Sri Bhupen Kalita ....Technician (Field Asst.)

Category-II

Name ....Designation

Sri Bibhash Medhi ....Sr.Technical Assistant (Farm Asst.)

KVK, Santhpur, Cuttack

Category-I

Name ....Designation

Sri Makardhar Behera ....Technical Asst. (T-3) (Tractor Driver)
Sri Arabinda Bisoi ....Sr.Technician (T-2) (Driver)

Category-III

Name ....Designation

Mrs. Sujata Sethy ....Asstt.Chief Technical Officer T (7-8), SMS (Home Sci.)
Sri Dillip Ranjan Sarangi........................Sr. Technical Officer (T-6) SMS (Soil Science)
Sri Tusar Ranjan Sahoo ....Sr. Technical Officer (T-6) SMS (Horticulture)
Dr.Manish Chourasia ....Sr. Technical Officer (T-6) SMS (Plant Protection)
Dr. Ranjan Kumar Mohanta ....Sr. Technical Officer (T-6) SMS (Animal Science)

KVK, Koderma, Jharkhand

Category-I

Name ....Designation

Sri Sanjay Kumar ....Sr.Technician (T-2) (Driver)

Category-II

Name ....Designation

Sri Rupesh Ranjan..Technical Officer (T-5), Trg. Asst. (A.F)
Sri Manish Kumar..Technical Officer (T-5), Trg. Asst. (Agril.)

Category-III

Name ....Designation

Mrs. Chanchila Kumari............Asstt. Chief Technical Officer T (7-8), STA (H.S.)
Dr. Shudhanshu Sekhar ....Asstt. Chief Technical Officer T (7-8), STA (V. Sc.)
Sri Bhoopendra Singh ....Sr. Technical Officer (T-6) SMS (Horticulture)

Administrative Staff

NRRI, CUTTACK

Name	Designation
Sri S.R. Khuntia	Chief F & AcO.
Sri B.K. Sinha	SAO
Sri Sunil Kumar Das	F & AcO.
Sri Ashutosh Kumar Tiwari	AD (OL)
Sri S.K. Mathur	AO
Sri Basanta Kumar Sahoo	AO
Sri B.K. Moharana	AAO
Sri Sunil Kumar Sahoo	AAO
Sri D.K. Mohanty	AAO
Sri S.K. Das	AAO
Sri N.K. Swain	AAO
Sri C.P. Murmu	AAO
Sri N.C. Parija	AAO
Sri Nabakishore Das	SO
Sri Narayan Mahavoi	Pvt. Sectry.
Sri G.K. Sahoo	Pvt. Sectry.
Sri N.N. Mohanty	Pvt. Sectry.
Sri Janardan Nayak	Pvt. Sectry.
Sri Trilochan Ram	PA
Sri A.Kullu	PA
Smt. Belarani Mahana	PA
Sri Daniel Khuntia	PA
Smt. Nirmala Jena	PA
Sri Manas Ballav Swain	PA
Smt. Snehaprava Sahoo	PA
Miss Sabita Sahoo	PA
Sri Manoranjan Swain	PA
Sri B.C. Tudu	Assistant
Sri K.K. Sarangi	Assistant
Sri Santosh Kumar Behera	Assistant
Sri Satyabrata Nayak	Assistant
Sri Subodh Kumar Sahu	Assistant
Sri Rabindra Kumar Behera	Assistant
Sri Ramesh Chandra Das	Assistant
Smt. Rosalia Kido	Assistant
Sri Narayan Prasad Behura	Assistant
Sri Sanjaya Kumar Sahoo	Assistant
Sri Munael Mohanty	Assistant
Sri Saroj Kumar Nayak	Assistant
Sri Dillip Kumar Parida	Assistant
Sri Santosh Kumar Satapathy	Assistant
Sri Manoj Kumar Sethi	Assistant
Sri Kailash Chandra Behera	Assistant
Sri Pravat Chandra Das	Assistant
Sri Abhaya Kumar Pradhan	Assistant
Sri Rama Chandra Pradhan	Assistant
Sri Vishal Kumar	Assistant
Smt. Gourimani Dei	Assistant
Sri Samir Kumar Lenka	U.D.C.
Sri Sanjeeb Kumar Sahoo	U.D.C.
Smt. Manasi Das	U.D.C.
Sri Ramesh Chandra Nayak	U.D.C.
Sri Sunil Pradhan	U.D.C.
Smt. Ambika Sethi	U.D.C.
Sri Maheswar Sahoo	U.D.C.
Sri Ranjan Sahoo	U.D.C.
Sri Amit Kumar Sinha	L.D.C.
Sri B.K.Gochhayat	L.D.C.
Sri Harihar Marandi	L.D.C.
Sri Santosh Kumar Bhoi	L.D.C.
Sri Dhaneswar Muduli	L.D.C.

CRURRS, Hazaribagh, Jharkhand

Name	Designation
Sri S.K. Jena	AAO
Sri R. Paswan	Personal Assistant
Sri Sanjeev Kumar	Assistant
Sri C.R. Dangi	U.D.C.
Sri Arbinda Kumar Das	L.D.C.
Sri Satish Kumar Pandey	L.D.C.

RRLRRS, Gerua, Assam

Name	Designation
Smt. Jali Das	U.D.C.

KVK, Santhpur, Cuttack

Name	Designation
Sri Bibhuti Bhushan Polai	Stenographer Gr.III

Others (Canteen Staff), NRRI, Cuttack

Name	Designation
Sri Arabinda Jena	Canteen Manager
Sri Meru Sahu	Bearer
Sri Markanda Nayak	Bearer
Sri Madhaba Pradhan	Bearer
Sri Nityananda Naik	Wash Boy

Skilled Support Staff, NRRI, Cuttack

Name	Designation
Sri Sahadev Naik	Skilled Support Staff
Sri Sundara Marandi	Skilled Support Staff
Smt. Gurubari Dei	Skilled Support Staff
Sri Dambarudhar Das	Skilled Support Staff
Sri Fakira Charan Sahu	Skilled Support Staff
Sri Jogendra Biswal	Skilled Support Staff
Smt. Snehalata Biswal	Skilled Support Staff
Smt. Namasi Singh	Skilled Support Staff
Sri Lawa Murmu	Skilled Support Staff
Smt. Surubali Hembram	Skilled Support Staff
Smt. Mukta Hembram	Skilled Support Staff
Smt. Basanti Marandi	Skilled Support Staff
Sri Kailash Chandra Ram	Skilled Support Staff
Sri Dasia Naik	Skilled Support Staff
Sri Krushna Naik	Skilled Support Staff
Sri Duryodhan Naik	Skilled Support Staff
Sri Ganesh Chandra Sahoo	Skilled Support Staff
Sri Bichitrananda Khatua	Skilled Support Staff
Smt.Santi Dei	Skilled Support Staff
Smt. Hadi Dei	Skilled Support Staff
Smt. Deba Dei	Skilled Support Staff
Sri Dharmananda Bhoi	Skilled Support Staff
Sri Kirtan Das	Skilled Support Staff
Sri Sarat Chandra Das	Skilled Support Staff
Sri Narayan Das (B)	Skilled Support Staff
Sri Sudhir Kuamar Bhoi	Skilled Support Staff
Sri Gokuli Majhi	Skilled Support Staff
Smt. Mini	Skilled Support Staff
Smt. Kuni Dei	Skilled Support Staff
Sri Duruja Naik	Skilled Support Staff
Smt. Pramila Dei	Skilled Support Staff
Smt. Ramani Dei	Skilled Support Staff
Sri Biranchi Bhoi	Skilled Support Staff
Sri Pradeep Kumar Das	Skilled Support Staff
Sri Sadananda Naik	Skilled Support Staff
Sri Jagu Marandi	Skilled Support Staff
Smt.Jayanti Dei	Skilled Support Staff
Sri Rabi Naik	Skilled Support Staff
Sri Bijay Naik	Skilled Support Staff
Sri Pandab Naik	Skilled Support Staff
Sri Debaraj Naik	Skilled Support Staff
Sri Bansidhar Naik	Skilled Support Staff

CRURRS, Hazaribag, Jharkhand

Name	Designation
Sri Rameswar Ram	Skilled Support Staff
Sri Liladhar Mahato	Skilled Support Staff
Smt. Sita Devi	Skilled Support Staff
Smt. Nagiya Devi	Skilled Support Staff
Sri Bhuneswar Oran	Skilled Support Staff
Smt. Panwa Devi	Skilled Support Staff
Smt. Karmi Devi	Skilled Support Staff
Smt. Dhanwa Devi	Skilled Support Staff
Sri Tirath Ram	Skilled Support Staff
Sri Shambhu Gope	Skilled Support Staff
Sri Gopal Gope	Skilled Support Staff
Sri Megh Narayan Prasad	Skilled Support Staff
Sri Harish Chandra Bando	Skilled Support Staff

RRLRRS, Gerua, Assam

Name	Designation
Sri Manoranjan Das	Skilled Support Staff

KVK, Santhpur, Cuttack

Name	Designation
Sri Rama Pradhan	Skilled Support Staff

KVK, Koderma, Jharkhand

Name	Designation
Sri Mukesh Ram	Skilled Support Staff

Financial Statement for 2016-17

(As on 31 March 2017)

Plan **(Rs. in Lakh)**

Head of Account	RE	Expenditure
TA	28.00	28.00
HRD	4.00	4.00
Contingency	368.00	368.00
Capital	1150.00	1150.00
TOTAL	**1550.00**	**1550.00**
Non-Plan		
Establishment Charges	2549.00	2549.00
Wages	14.88	14.88
OTA	0.50	0.50
TA	10.00	10.00
Pension	3145.00	3145.00
Repair & Maintenance		
Equipment	22.00	22.00
Office Building	35.00	35.00
Residential Building	20.00	20.00
Minor Works	10.00	10.00
Contigency	493.62	493.47
Capital		
Equipment	6.00	6.00
Library Books	2.00	2.00
Vehicle & Vessels	9.50	5.72
Furniture	3.00	2.92
TOTAL	**6320.50**	**6316.49**

Work Plan 2016-17

Programme 1: Genetic improvement of rice: ON Singh/JN Reddy

Exploration, characterization and conservation of rice genetic resources

Principal Investigator: BC Patra

Co- Principal Investigator (Co-PI): BC Marndi, HN Subudhi, S Samantray, JL Katara, LK Bose, N Mandal, P Sanghamitra, N Umakanta and Muhammed Azharudheen TP

Maintenance breeding and seed quality enhancement

Principal Investigator: RK Sahu

Co-Principal Investigator (Co-PI): ON Singh, RL Verma, SSC Patnaik, L Behera, SK Pradhan, U Dhua, M Jena, T Bagchi, A Poonam, CV Singh, NP Mandal, BC Marndi, P Sanghamitra, MK Bag, SK Ghritlahre and Rameswar P Sah

Utilization of new alleles from primary and secondary gene pool of rice

Principal Investigator: LK Bose

Co-Principal Investigator (Co-PI): HN Subudhi, S Samantaray, P Swain, M Jena, MK Kar, SD Mohapatara, S Lenka, NN Jambhulkar, P Sanghamitra, N Umakanta, Soham Ray and Muhammed Azharudheen TP

Hybrid rice for different ecologies

Principal Investigator: ON Singh

Co- Principal Investigator (Co-PI): RL Verma, JL Katara, S Samantaray, RK Sahu, BC Patra, LK Bose, NP Mandal, D Maiti, AK Mukherjee, Nabaneeta Basak, Rameswar P Sah and Sutapa Sarkar

Development of high yielding genotypes for rainfed shallow lowlands

Principal Investigator: SK Pradhan

Co-Principal Investigator (Co-PI): ON Singh, SSC Pattanaik, JN Reddy, SK Dash, MK Kar, L Behera, S Samantray, P Swain, J Meher, A Anandan, Sutapa Sarkar, M Chakraborti and Rameswar P Sah

Development of improved genotypes for semi-deep and deep water ecologies

Principal Investigator: JN Reddy

Co-Principal Investigator (Co-PI): SK Pradhan, SSC Patnaik, JL Katara, RK Sarkar, P Swain, SD Mohapatra, AK Mukherjee and A Anandan

Breeding rice varieties for coastal saline areas

Principal Investigator: K Chattopadhyay

Co-Principal Investigator (Co-PI): BC Marndi, AK Nayak, A Poonam, JN Reddy, SP Singh, SD Mohapatra, N Umakanta and K Chakraborti

Development of Super Rice for different ecologies

Principal Investigator: SK Dash

Co-Principal Investigator (Co-PI): SK Pradhan, ON Singh, MK Kar, MS Ananta, Yogesh Kumar, J Meher, L Behera, BC Marndi, LK Bose, P Swain, MJ Baig, Susmita Munda, AK Mukherjee, SD Mohapatra, J Berliner, N Umakanta, S Lenka, A Anandan, Muhammed Azharudheen TP and M Chakraborti

Resistance breeding for multiple insect - pests and diseases

Principal Investigator: MK Kar

Co-Principal Investigator (Co-PI): RK Sahu, JN Reddy, SK Pradhan, L Behera, M Jena, SD Mohapatra, AK Mukherjee, U Dhua, S Lenka, KB Pun, SK Ghritlahre, Soham Ray and Amrita Banerjee

Breeding for higher resource use efficiency

Principal Investigator: A Anandan

Co-Principal Investigator (Co-PI): J Meher, SK Dash, ON Singh, A Ghosh, MK Kar, SK Pradhan, LK Bose, L Behera, JL Katara, S Samantaray, HN Subudhi, AK Nayak, U Dhua, P Swain, SG Sharma, NN Jambhulkar and C Parameswaran and Rameswar P Sah

Breeding for aroma, grain and nutritional quality

Principal Investigator: SSC Patnaik

Co-Principal Investigator (Co-PI): K Chattopadhyay, BC Marndi, S Samantray, L Behera, SG Sharma, TB Bagchi, Md. Shahid, P Sanghamitra, SK Ghritlahre, Sutapa Sarkar, A Kumar and M Chakraborti

Improvement of rice through in vitro and transgenic approaches

Principal Investigator: S Samantaray

Co-Principal Investigator (Co-PI): LK Bose, RL Verma, Kutabuddin A Molla, A Kumar JL Katara, N Umakanta and C Parameswaran

Development and use of genomic resources for genetic improvement of rice

Principal Investigator: L Behera

Co-Principal Investigator (Co-PI): M Variar, SK Pradhan, RK Sahu, M Jena, NP Mandal, SK Dash, BC Marndi, J Meher, K Chattopadhay, P Swain, S Samantray, MS Anantha, HN Subudhi, NN Jambhulkar, N Umakanta, Kutabuddin A Molla, C Parameswaran and M Chakraborti

Development of resilient rice varieties for rainfed direct seeded upland ecosystem

Principal Investigator: NP Mandal

Co-Principal Investigator (Co-PI): MS Anantha, Y Kumar, M Variar, D Maiti, SK Dash, P Swain and CV Singh

Development of rice genotypes for rainfed flood-prone lowlands

Principal Investigator: JN Reddy

Co-Principal Investigator (Co-PI): KB Pun, SK Pradhan, L Behera and S Lenka

Programme 2: Enhancing the productivity, sustainability and resilience of rice based production system: AK Nayak/S Saha

Enhancing nutrient use efficiency and productivity in rice based system

Principal Investigator: AK Nayak

Co-Principal Investigator (Co-PI): S Mohanty, Md. Shahid, P Bhattacharya, R Tripathi, U Kumar, R Raja, BB Panda, A Ghosh, Priyanka Gautam, Banwari Lal, S Munda, SS Pokhare, D Chatterjee, P Panneerselvam , A Anandan, D Bhaduri and PK Guru

Agro-management for enhancing water productivity and rice productivity under water shortage condition

Principal Investigator: A Ghosh

Co-Principal Investigator (Co-PI): P Swain, CV Singh, BB Panda, A Poonam, R Tripathi, J Berliner and Priyanka Gautam

Development of sustainable production technologies for rice based cropping systems

Principal Investigator: BB Panda

Co-Principal Investigator (Co-PI): R Raja, AK Nayak, A Ghosh, Teekam Singh, B Lal, R Tripathi, SD Mohapatra, Md. Shahid, A Kumar, SS Pokhare and Sumanta Chatterjee

Farm implements and post harvest technology for rice

Principal Investigator: PC Mohapatra

Co-Principal Investigator (Co-PI): SP Patel, P Samal, S Saha and T Bagchi

Resource Conservation technologies and conservation Agriculture (CA) for sustainable rice production

Principal Investigator: Md. Shahid

Co-Principal Investigator (Co-PI): AK Nayak, R Tripathi, BB Panda, D Chatterjee, S Mohanty, A Kumar, S Saha, A Ghosh, S Munda, B Lal, PK Guru and D Bhaduri

Diversified rice-based farming system for livelihood improvement of small and marginal farmers

Principal Investigator: A Poonam

Co-Principal Investigator (Co-PI): Md. Shahid, PK Nayak, GAK Kumar, NN Jambhulkar SM Prasad, SC Giri (RC of CARI), M Nedunchezhian (RC of CTCRI), PK Guru, S Saha, DR Sarangi and M Chourasia

Management of rice weeds by integrated approaches

Principal Investigator: S Saha

Co-Principal Investigator (Co-PI): B Lal, BC Patra, SK Das, U Kumar, Totan Adak, S Munda and P Panneerselvam

Management of problem soils for enhancing the productivity of rice

Principal Investigator: R Tripathi

Co-Principal Investigator (Co-PI): Md. Shahid, AK Nayak, A Kumar, S Mohanty, R Raja, D Chatterjee and D Bhaduri

Bio-prospecting and use of microbial resources for soil, pest and residue management

Principal Investigator: U Kumar

Co-Principal Investigator (Co-PI): TK Dangar and P Panneerselvam

Soil and crop management for productivity enhancement in rainfed upland ecosystem

Principal Investigator: CV Singh

Co-Principal Investigator (Co-PI): MS Anantha, Y Kumar, M Variar, D Maiti, SK Dash, P Swain and VK Singh

Soil and crop management for productivity enhancement in rainfed flood-prone lowland ecosystem

Principal Investigator: BS Satapathy

Co-Principal Investigator (Co-PI): S Saha, T Singh, A Kumar, KB Pun and NN Jambhulkar

Programme 3: Rice pests and diseases-emerging problems and their management: U Dhua/ M Jena

Management of rice diseases in different ecologies

Principal Investigator: AK Mukherjee

Co-Principal Investigator (Co-PI): U Dhua, SD Mohapatra, S Lenka, T Adak, J Berliner, SS Pokhare, MK Bag, Raghu S Prabhukarthikayan SR, Amrita Banerjee, MS Baite, Arindan S, MK Yadav and MS Baite

Rice endophyte interaction with pathogens and pests in relation to environment

Principal Investigator: U Dhua

Co-Principal Investigator (Co-PI): M Jena, AK Mukherjee, MK Bag, Raghu S, Prabhukarthikayan SR, Arindan S, MK Yadav and MS Baite

Identification and utilization of host plant resistance in rice against major insect and nematode pests

Principal Investigator: M Jena

Co-Principal Investigator (Co-PI): PC Rath, SD Mohapatra, J Berliner, SS Pokhare, RK Sahu, SK Pradhan, Naveenkumar B Patil, GP Pandi G, MS Baite and B Gowda G

Bio-ecology and management of pests under changing climatic scenario

Principal Investigator: SD Mohapatra

Co-Principal Investigator (Co-PI): R Raja, M Jena, PC Rath, J Berliner, SS Pokhare, S Saha, U Kumar, AK Nayak, NN Jambhulkar, T Adak, Raghu S and Naveenkumar B Patil, GP Pandi G and B Gowda G

Formulation, validation and refinement of IPM modules in rice

Principal Investigator: PC Rath

Co-Principal Investigator (Co-PI): M Jena, SD Mohapatra, P Samal, S Lenka, T Adak, Raghu S, Naveenkumar B Patil, P Panneerselvam, Prabhukarthikayan SR, Amrita Banerjee, GP Pandi G, MK Bag, MS Baite, B Gowda G, Arindan S, MK Yadav and MS Baite

Biotic stress management in rainfed upland rice ecology

Principal Investigator: D Maiti

Co-Principal Investigator (Co-PI): M Variar, CV Singh, NP Mandal and Yogesh Kumar

Management of major insect pests and diseases of rice in rainfed flood- prone lowlands

Principal Investigator: K Saikia

Co-Principal Investigator (Co-PI): KB Pun, MK Kar, AK Mukherjee, S Lenka, T Singh and BS Satapathy

Programme 4: Biochemistry and physiology of rice in relation to grain and nutritional quality, photosynthetic efficiency and abiotic stress tolerance: SG Sharma/ P Swain

Rice grain and nutritional quality – evaluation,

improvement, and mechanism and value addition

Principal Investigator: SG Sharma

Co-Principal Investigator (Co-PI): TB Bagchi, BC Marandi, A Ghosh, U Kumar, Md. Shahid, Totan Adak, P Sanghamitra, A Kumar and MK Bag

Phenomics of rice for tolerance to multiple abiotic stresses

Principal Investigator: RK Sarkar

Co-Principal Investigator (Co-PI): P Swain, MJ Baig, TB Bagchi and K Chakraborty

Rice physiology under drought and high temperature stress

Principal Investigator: P Swain

Co-Principal Investigator (Co-PI): ON Singh, NP Mandal, TB Bagchi, MJ Baig, SK Pradhan, J Meher, JL Katara, A Kumar and K Chakraborty

Evaluation and improvement of photosynthetic efficiency of rice

Principal Investigator: MJ Baig

Co-Principal Investigator (Co-PI): P Swain, R Raja and SK Pradhan

Programme 5: Socio economic research and extension for rice in development: BN Sadangi/ P Samal

Socio-economic approaches, mechanism and transfer of technologies for sustainable rice production

Principal Investigator: L Das

Co-Principal Investigator (Co-PI): BN Sadangi, P Samal, NC Rath, SK Mishra, GAK Kumar, SSC Pattnaik, S Saha, M Din, M Jena, RK Sahu, HN Subudhi, PC Rath, NN Jambhulkar, SP Patel, MK Kar, B Mondal, SM Prasad and VK Singh

Characterization of resources and innovations to aid rice research and develop extension models

Principal Investigator: GAK Kumar

Co-Principal Investigator (Co-PI): BN Sadangi, L Das, NN Jambhulkar, M Din, SG Sharma, M Jena, RL Verma, SK Mishra and B Mondal

Impact analysis and database updation in relation to rice technologies, policy and programmes

Principal Investigator: P Samal

Co-Principal Investigator (Co-PI): NN Jambhulkar, BN Sadangi, GAK Kumar, L Das, ON Singh, SK Pradhan, M Din and B Mondal

Ongoing Externally Aided Projects (EAPs)

Project No.	Title of the Project	Principal Investigator	Source of Funding
EAP 27	Revolving fund scheme for seed production of upland rice varieties at CRURRS, Hazaribagh	NP Mandal	AP Cess
EAP 36	National Seed Project (Crops)	RK Sahu	NSP
EAP 49	Revolving fund scheme for breeder seed production	RK Sahu	NSP/Mega seed
EAP 60	Front line Demonstration under Macro-Management scheme of Ministry of Agriculture – New High Yielding Varieties	Y Kumar	DAC
EAP 100	Seed Production in Agricultural Crops and Fisheries – Mega Seed Project	RK Sahu	ICAR
EAP 125	Stress tolerant rice for poor farmers of Africa and South Asia – Drought prone rain-fed rice areas of South Asia – Hazaribagh Centre	NP Mandal	ICAR - IRRI (BMGF)
EAP 126	Stress tolerant rice for poor farmers of Africa and South Asia- Drought prone areas- CRRI Centre	ON Singh P Swain	ICAR - IRRI- (B&MGF)
EAP 127	Stress tolerant rice for poor farmers of Africa and South Asia - Submergence and Flood prone areas (STRASA)	JN Reddy SSC Patnaik RK Sarkar	ICAR-IRRI (B&MGF)
EAP 128	Stress tolerant rice for poor farmers of Africa and South Asia – Salt affected areas (STRASA)	B Marandi A Nayak A Poonam K Chattopadhayay K Chakravorty	ICAR-IRRI (B&MGF)
EAP 130	All India Network Project on Soil Biodiversity - Biofertilizers	D Maiti	ICAR
EAP139	AICRP on energy in agriculture and agro-based industries	PK Guru NT Borkar	AICRP (DRET-SET/ DRET-BCT)
EAP 140	Intellectual Property Management and Transfer/ commercialization of agricultural technology Scheme	BC Patra	ICAR
EAP 141	DUS Testing and documentation	BC Patra	PPV&FRA
EAP 161	Monitoring of the new initiative of "Bringing Green Revolution to Eastern India (BGREI) under the Rashtriya Krishi Vikas Yojana"	H Pathak BB Panda	DAC, GOI

EAP 163	Stress tolerant rice for poor farmers of Africa and South Asia – Sub grant, Seed (CRRI, Cuttack)	RK Sahu	IRRI-ICAR (STRASA)
EAP173	Crop Pest Surveillance and Advisory Project (CROPSAP-Paddy)	M Jena T Adak	Govt. of Maharashtra
EAP 176	Using wild ancestor plants to make rice more resilient to increasingly unpredictable water availability	SK Das P Swain L Behera B Sadangi	DBT-BBSRC (DFI, UK)
EAP 178	National Initiative on Climate Resilient Agriculture	VK Singh	NICRA (ICAR)
EAP 183	Characterization of toxins of *Bacillus thuringiensis* isolated from rice genotypes and their virulence assessment against leaf folder (*Cnaphalocrocis medinalis* Guenee)	Sonali Acharya (TK Dangar)	DST Inspire
EAP 184	Utilization of fly ash on amelioration and source of nutrients to rice-based cropping system in eastern India	Sanghamitra Maharana (AK Nayak)	DST Inspire
EAP 185	Development of crop and nutrient management practices in rice for Odisha state	S Saha BC Patra S Munda	ICAR-IRRI STRASSA
EAP 186	Use of microbes for management of abiotic stresses in rice	AK Mukherjee	ICAR-IRRI
EAP 187	Low carbon resource conservation technologies for sustainable rice production in low land ecology	AK Nayak	ICAR
EAP 189	Front Line Demonstrations under NFSM	NC Rath	DAC – DRR (NFSM)
EAP 190	Multi location evaluation of rice germplasm (CRP on Ag. Bio)	NP Mandal	CRP-ICAR
EAP 191	CRRI-NCIPM collaborative project on development and validation of IPM module for rice	SD Mohapatra S Lenka J Berliner K Saikia KB Pun T Singh T Adak U Kumar	CRRI/NCIP M
EAP 192	DNA marker based pyramiding and study of interactions among QTLs for higher grain number in rice (*Oryza sativa* L.)	Gayatri Gouda (T Mohapatra)	DST Inspire

EAP 193	Future rainfed lowland rice systems in Eastern India 15 (T3) (Development of crop and nutrient management practices in rice)	AK Nayak P Gautam B Lal M Sahid R Tripathy D Bhaduri	STRASSA South Asia
EAP 195	Artificial induction of chlamydospore in *Trichoderma* sp. and identification of genes expressed during the process	HK Swain (AK Mukherjee)	DST Inspire
EAP 197	Consortia research platform (CRP) on bifortification	SG Sharma SK Pradhan S Samantray L Behera K Chattopadhyay SSC Patnaik TB Bagchi A Kumar	ICAR Plan-CRP
EAP 198	Incentivizing Research in Agriculture: Study of rice yield under low light intensity using genomic approaches	L Behera A Kumar SK Pradhan SK Das S Samantaray	ICAR Plan
EAP 199	Incentivizing Research in Agriculture: Towards understanding the C3-C4 intermediate pathway in Poaceae and functionality of C4 genes in rice	MJ Baig P Swain L Behera SK Pradhan S Ray A Kumar K Alimolla	ICAR Plan
EAP 200	Incentivizing Research in Agriculture: Genetic modifications to improve biological nitrogen fixation for augmenting nitrogen needs of cereals	TK Dangar U Kumar	ICAR Plan
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 Kar L Behera A Mukherjee S Aravindan NP Mandal S Samantaray S Ray	ICAR Plan
EAP202	Associated mapping of genes/QTLs for yield under reproductive stage drought stress in rice (*Oryza sativa* l.)	L Behera P Swain SK Dash SK Pradhan BC Patra	BIRAC

EAP 203	Strategic development of water utilization in rice production system for higher crop and water productivity and profitability	BB Panda P Swain SK Pradhan L Behera R Tripathy	CRP – water (ICAR)
EAP 204	Germplasm characterization and multiplication	BC Patra M Jena AK Mukherjee	CRP–Agro biodiversity (ICAR)
EAP 205	Nutrient cycle in agricultural system at field and regional scales	AK Nayak S Mohanty R Tripathy M Sahid A Kumar P Goutam	ISRO – EOAM
EAP 206	Eliciting soil microbiome responses of rice for enhanced water and nutrient use efficiency under anticipated climate changes	AK Nayak MJ Baig Md. Sahid S Raj A Kumar T Adak	NASF - ICAR
EAP 207	Conservation agriculture for enhancing the productivity of rice based cropping system in Eastern India	AK Nayak R Tripathy B Lal BB Panda M Sahid P. Gautam S Munda S Saha SK Mishra SD Mohapatra P Guru	CAP - ICAR
EAP 208	Evaluation of efficiency of zinc metalosate and boron metalosate foliar supplements for maximizing yield through balanced nutrition of important crops grown in India	M Sahid AK Nayak A Kumar B Lal	AICRP (Contract)
EAP 209	CRP on hybrid technology	RL Verma	CRP - ICAR
EAP 210	Fine mapping and identification of candidate gene/QTL for brown plant hopper resistance in rice cultivar, Salkathi	P Patnaik (L Behera)	DST Inspire
EAP 211	CRP on molecular breeding	M Kar L Behera M Jena A Mukherjee S Ray N Umakanta S Aravindan	CRP - ICAR

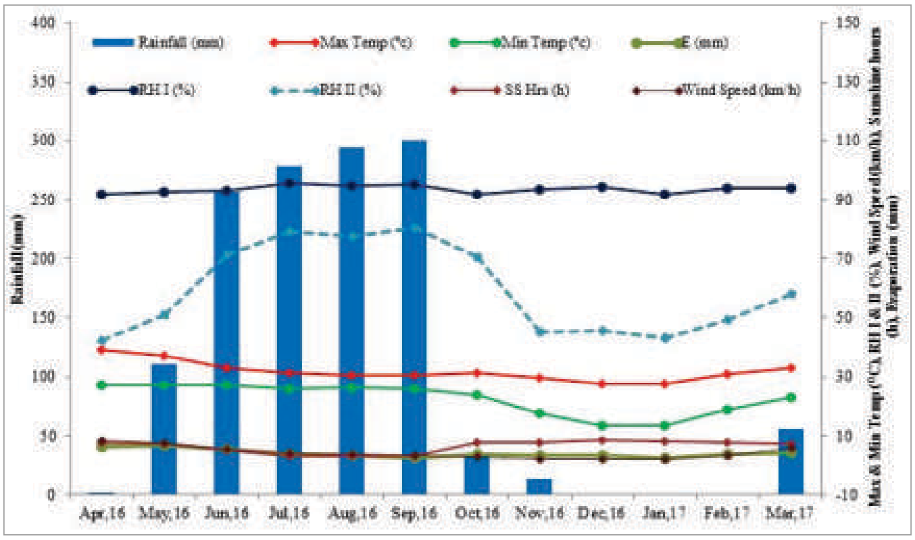
EAP 212	Multilocational monitoring of Rynaxypyr 20SC against *Scirpophaga incertulas* in rice and rice hopper susceptibility survey in India for DPH-RAB55 106SC against *Nilaparvata lugens* and *Sogatella furcifera*	SD Mohapatra M Jena B Gowda	Du Pont
EAP213	Maintenance, characterization and use of EMS of upland variety Nagina 22 for functional genomics in rice – Phase II	M Kar P Swain AK Mukherjee S Ray	DBT
EAP214	Energy and mass exchange in tropical rice-rice system	D Chatterjee R Tripathy AK Nayak	ISRO
EAP215	Agri-Business Incubation Centre	GAK Kumar M Jena BC Patra SG Sharma NC Rath S Saha RK Sahu BB Panda B Mondal AK Mukherjee PK Guru	NAIF, IP&TM – ICAR
EAP216	Evaluating performance of polymer coated urea in terms of enhancing yield and nitrogen use efficiency of rice under different growing condition	S Mohanty AK Nayak A Kumar	Gujarat State Fert & Chem Ltd.
EAP217	Development of high yielding, water and labor saving rice varieties for dry direct seeded aerobic conditions utilizing recent discoveries on traits, QTLs, genes and genomic technologies	ON Singh A Anandan S Sarkar SK dash MS Ramesh	DBT
EAP218	Evaluation of XR-848 benzyl ester alone; XR-848 Benzy ester + cyhalofop-butyl and penoxulam + cyhalofop-butyl for broad-spectrum weed control in wet direct-sown rice under shallow lowland and irrigated ecology	S Saha S Munda	Dow agro sciences India Pvt. Ltd.
EAP219	Genetic enhancement of rice for low moisture stress tolerance	NP Mandal Y Kumar	ICAR
EAP220	Delivering food security on limited land (DEVIL)	AK Nayak M Sahid R Tripathy B Mondal SD Mohapatra	Min. Earth Science, GOI
EAP221	IT enabled self-sufficient sustainable seed system for Rice (4S4R)	GAK Kumar B Mondal A. Sarkar, IIWM	Extra Mural ICAR Project

EAP222	Earth observation application mission	AK Nayak S Mohanty R Tripathy M Sahid A Kumar P Gautam	ISRO
EAP223	Marker-assisted introgression of yield-enhancing genes to increase yield potential in rice	L Behera M Kar SK dash SK Pradhan N Umakanta	DBT
EAP224	Understanding mechanism of tolerance to low light intensity in rice	MJ Baig	NASF -ICAR
EAP225	Forewarning of major crop pests on special scale for their integrated management	SD Mohapatra MK Yadav G Pandi	SAC-ISRO
EAP226	Study of host induced gene silencing (HIGS) and its utility in rice-*R. solani* pathosystem to control sheath blight disease	KA Molla A Mukherjee	DST
EAP227	Creation of seed hub for increasing indigenous production of pulses in India	SM Prasad S Sethy DR Sarangi M Chourasia RK Mohanta	DAC &FW
EAP228	Increasing productivity and sustaining the rice-based production system through farmer first approach	BN Sadangi L Das SK Mishra SSC Patnaik S Saha PK Nayak SD Mohapatra S Lenka R Tripathy P Guru SC Giri M Kumar	ICAR-Farmer FIRST
EAP 229	Phenomics of moisture deficit stress tolerance and nitrogen use efficiency in rice and wheat – Phase II	P Swain S Das J Meher	NASH – ICAR
EAP230	Developing microbial consortium for horticultural crops in rice based cropping system to promote growth, nutrient uptake and disease management in organic farming in Sikkim	P Paneerselvam U Kumar	DBT (NER-BPMC)

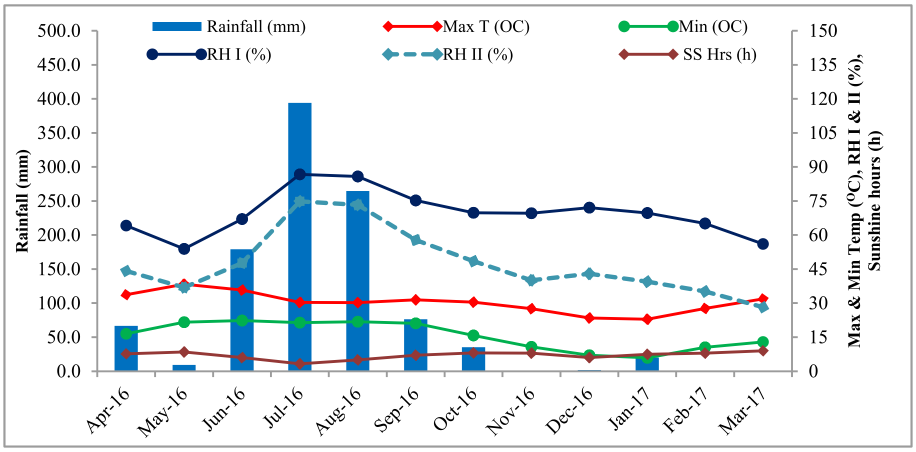
EAP231	Evaluation of bio efficacy and phytotoxicity of NN1-1501 on rice BPH + WBPH	M Jena T Adak GP Pandi	Hyderabad Chem Pvt. Ltd.
EAP232	Double herbicide tolerant transgenic rice: weed management	C Parameswaran KA Molla N Umakant S Samantaray S Saha	NASF
EAP233	Accelerated decomposition of rice straw using novel Trichoderma strain and its mutant s	A Mukherjee	BRNS – DAE
EAP234	Gene staking for submergence tolerance, bacterial blight resistance and yield potential in rice variety Swarna through classical and molecular breeding approaches	SK Pradhan S Mohapatra	DST, Gov. Odisha
EAP235	Study and investigation of major QTLs associated with panicle compactness, ethylene receptor expression and grain filling in rice	S Sekhar (L Behera)	DST, SERB
EAP236	ICAR-CSISA collaborative project (phase III) – Research to quantify near and long term effects of sustainable intensification technologies at National Rice Research Institute (NRRI)	R Tripathy AK Nayak BB Panda M Sahid B Lal	CSISA
EAP237	Effect of time of application and maintaining water level on bio-efficacy of flucetosulfuron (10% WG) against weed complex of direct-sown and transplanted rice	S Saha S Munda	Indofil Industries Limited
EAP238	Efficacy of phosphine fumigant against storage pests of pulses, wheat, rice and coffee beans and residue analysis for quarantine and long term storage purpose	M Jena NKB Patil T Adak	DAC
EAP239	Pyramiding and understanding the interaction of QTLs for deeper rooting and phosphorous uptake in rice (*Oryza sativa* L.)	E Pandit SK Pradhan	DST (WOS-A)
EAP240	Potential gene mining from salt tolerant grasses for improvement of stress tolerance in crops	C Parameswaran	NASF-ICAR
EAP241	Genetic improvement of hybrid rice parental lines for enhancing yield heterosis	ON Singh RL Verma RP Sah JL Katara LK Bose S Samantaray	ASEAN

Weather

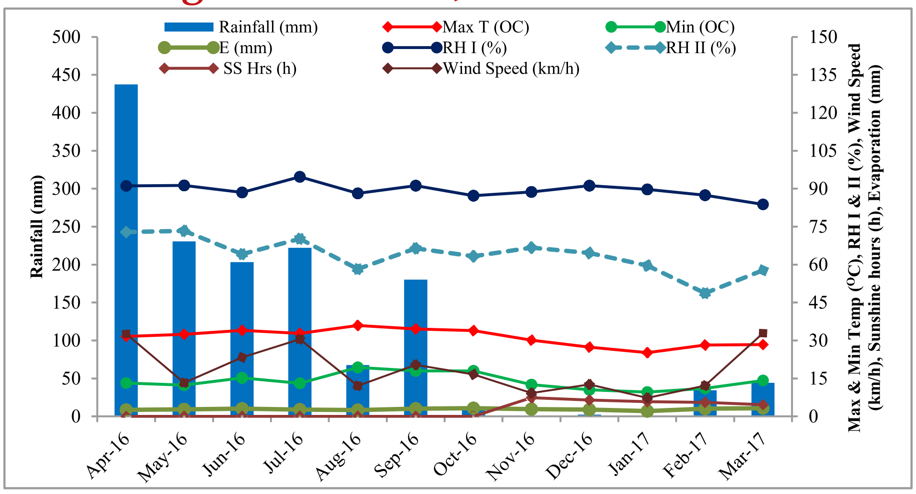
NRRI, Cuttack



NRRI Regional Station, Hazaribag



NRRI Regional Station, Gerua



Acronyms

ADG	:	Assistant Director-General
AICRIP	:	All India Coordinated Rice Improvement Project
AIR	:	All India Radio
AMAAS	:	Application of Microorganisms in Agriculture and Allied Sectors
ANGRAU	:	Acharya N.G. Ranga Agricultural University, Hyderabad
ARIS	:	Agricultural Research Information Service
ASG	:	Aromatic-Short Grain
ASGON	:	Aromatic Short Grain Observation Nursery
ASRB	:	Agricultural Scientists Recruitment Board, New Delhi
ASV	:	Alkali Spreading Value
ATMA	:	Agricultural Technology Management Agency
AVT	:	Advanced Varietal Trial
AWD	:	Alternate Wetting and Drying
AYT	:	Advance Yield Trial
BB/BLB	:	Bacterial Leaf Blight
BMGF	:	Belinda and Bill Gates Foundation
BPH	:	Brown Planthopper
Bt	:	*Bacillus thuringiensis*
CAC	:	Consortium Advisory Committee
CIAE	:	Central Institute of Agricultural Engineering, Bhopal
CIC	:	Consortium Implementation Committee
CIFA	:	Central Institute of Freshwater Aquaculture, Bhubaneswar
CMS	:	Cytoplasmic Male Sterile/Sterility
CRIDA	:	Central Research Institute for Dryland Agriculture, Hyderabad
CRIJAF	:	Central Research Institute for Jute and Allied Fibres, Barrackpore
CRRI	:	Central Rice Research Institute, Cuttack
CRRURS	:	Central Rainfed Upland Rice Research Station, Hazaribag
CSIR	:	Council of Scientific and Industrial Research
CURE	:	Consortium for Unfavourable Rice Environment
DAC	:	Department of Agriculture and Cooperation
DAF	:	Days after Flowering
DAH	:	Days after Harvest
DAO	:	District Agricultural Officer
DARE	:	Department of Agriculture Research and Education, Government of India
DAS	:	Days after Sowing
DBN	:	Drought Breeding Network
DBT	:	Department of Biotechnology, New Delhi
DFF	:	Days to 50 % Flowering
DH	:	Dead Hearts
DNA	:	Deoxyribonucleic Acid
DRR	:	Directorate of Rice Research, Hyderabad
DRWA	:	Directorate of Research for Women in Agriculture
DS	:	Dry Season
DSN	:	Dry Season Nursery
DSR	:	Directorate of Seed Research, Mau
DST	:	Department of Science and Technology, New Delhi
EAP	:	Externally Aided Projects
EC/ECe	:	Electrical Conductivity
EIRLSBN	:	Eastern India Rainfed Lowland Shuttle Breeding Network
FLD	:	Frontline Demonstration
FYM	:	Farmyard Manure
g	:	Gram
GLH	:	Green Leafhopper
GM	:	Green Manuring / Gall Midge

h	:	Hour
ha	:	Hectare
HI	:	Harvest Index
HRR	:	Head Rice Recovery
HYV	:	High-yielding variety
IARI	:	Indian Agricultural Research Institute, New Delhi
IASRI	:	Indian Agricultural Statistics Research Institute, New Delhi
ICAR	:	Indian Council of Agricultural Research
ICRISAT	:	International Crops Research Institute for the Semi-Arid Tropics
IDM	:	Integrated Disease Management
IET	:	Initial Evaluation Trial
IFAD	:	International Fund for Agricultural Development
IGAU	:	Indira Gandhi Agricultural University, Raipur
IGKVV	:	Indira Gandhi Krishi Vishwavidyalaya
IINRG	:	Indian Institute of Natural Resins and Gums, Ranchi
IISS	:	Indian Institute of Soil Science, Bhopal
IIVR	:	Indian Institute of Vegetable Research, Varanasi
IJSC	:	Institute Joint Staff Council
IMC	:	Institute Management Committee
INGER	:	International Network for Genetic Evaluation of Rice
INM	:	Integrated Nutrient Management
INSA	:	Indian National Science Academy
IPM	:	Integrated Pest Management
IPR	:	Intellectual Property Rights
IPS	:	Indian Police Service
IRRI	:	International Rice Research Institute, Philippines
IVRI	:	Indian Veterinary Research Institute, Izatnagar
IVT	:	Initial Varietal Trial
Kg	:	Kilogram
KVK	:	Krishi Vigyan Kendra
L	:	Litre
LB	:	Long-bold
LCC	:	Leaf Colour Chart
LF	:	Leaf Folder
LS	:	Long-slender
LSI	:	Location Severity Index
MAS	:	Marker-assisted Selection
MB	:	Medium Bold
MLT	:	Multilocation Trial
MS	:	Medium-slender
NAARM	:	National Academy of Agricultural Research Management, Hyderabad
NAAS	:	National Academy of Agricultural Sciences
NAIP	:	National Agricultural Innovation Project
NARES	:	National Agricultural Research and Extension Research
NARS	:	National Agricultural Research System
NASC	:	National Agricultural Science Complex, New Delhi
NBAIM	:	National Bureau of Agriculturally Important Microorganisms
NBPGR	:	National Bureau of Plant Genetic Resources, New Delhi
NDRI	:	National Diary Research Institute, Karnal
NDUAT	:	Narendra Dev University of Agriculture and Technology
NFSM	:	National Food Security Mission
NGO	:	Non-governmental Organization
NHSN	:	National Hybrid Screening Nursery
NIL	:	Near-isogenic Lines
NIPGR	:	National Institute for Plant Genome Research, New Delhi
NIWS	:	National Invasive Weed Surveillance

NPK	:	Nitrogen, Phosphorous, Potassium
NPT	:	New Plant Type
NRC	:	National Research Centre
NRCPB	:	National Research Centre for Plant Bio-technology, New Delhi
NSN	:	National Screening Nursery
NSP	:	National Seed Project
OFT	:	On-farm Trials
OUAT	:	Orissa University of Agriculture and Technology, Bhubaneswar
OYT	:	Observational Yield Trial
PAU	:	Panjab Agricultural University, Ludhiana
PDCSR	:	Project Directorate for Cropping System Research, Meerut
PE	:	Panicle Emergence
PI	:	Panicle Initiation
PMYT	:	Preliminary Multilocational Yield Trial
PVS	:	Participatory Varietal Selection
PYT	:	Preliminary Yield Trial
Q	:	Quintal
QTL	:	Quantitative Trait Loci
RAC	:	Research Advisory Committee
RAPD	:	Random Amplification of Polymorphic DNA
RARS	:	Regional Agricultural Research Station
RBC	:	Rice-based Cropping System
RBD	:	Randomized Bock Design
RCC	:	Reinforced Cement Concrete
RFLP	:	Restriction Fragment Length Polymorphism
RH	:	Relative Humidity
RIL	:	Recombinant Inbred Line
RRLRRS	:	Regional Rainfed Lowland Rice Research Station, Gerua
RTV/RTD	:	Rice Tungro Virus/ Disease
SAC	:	Scientific Advisory Committee
SATVT	:	Saline Alkaline Tolerant Varietal Trial
SAU	:	State Agricultural University
SB	:	Short-bold
SBN	:	Salinity Breeding Network
SES	:	Standard Evaluation System
SRI	:	System of Rice Intensification
STRASA	:	Stress Tolerant Rice for Poor Farmers in Africa and South Asia
t	:	Tonne
UBN	:	Uniform Blast Nursery
URSBN	:	Upland Rice Shuttle Breeding Network
WBPH	:	White-backed Plant Hopper
WCE	:	Weed Control Efficiency
WEH	:	White Ear Heads
WS	:	Wet Season
WTCER	:	Water Technology Centre for Eastern Region, Bhubaneswar
WTO	:	World Trade Organization
WUE	:	Water-use Efficiency
YMV	:	Yellow Mosaic Virus
YSB	:	Yellow Stem Borer
ZPD	:	Zonal Project Directorate

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