NRRI

वार्षिक प्रतिवेदन

ANNUAL REPORT 2014-15

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
कटक (ओडिशा) ७५३ ००६, भारत

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CRRI

PREFACE

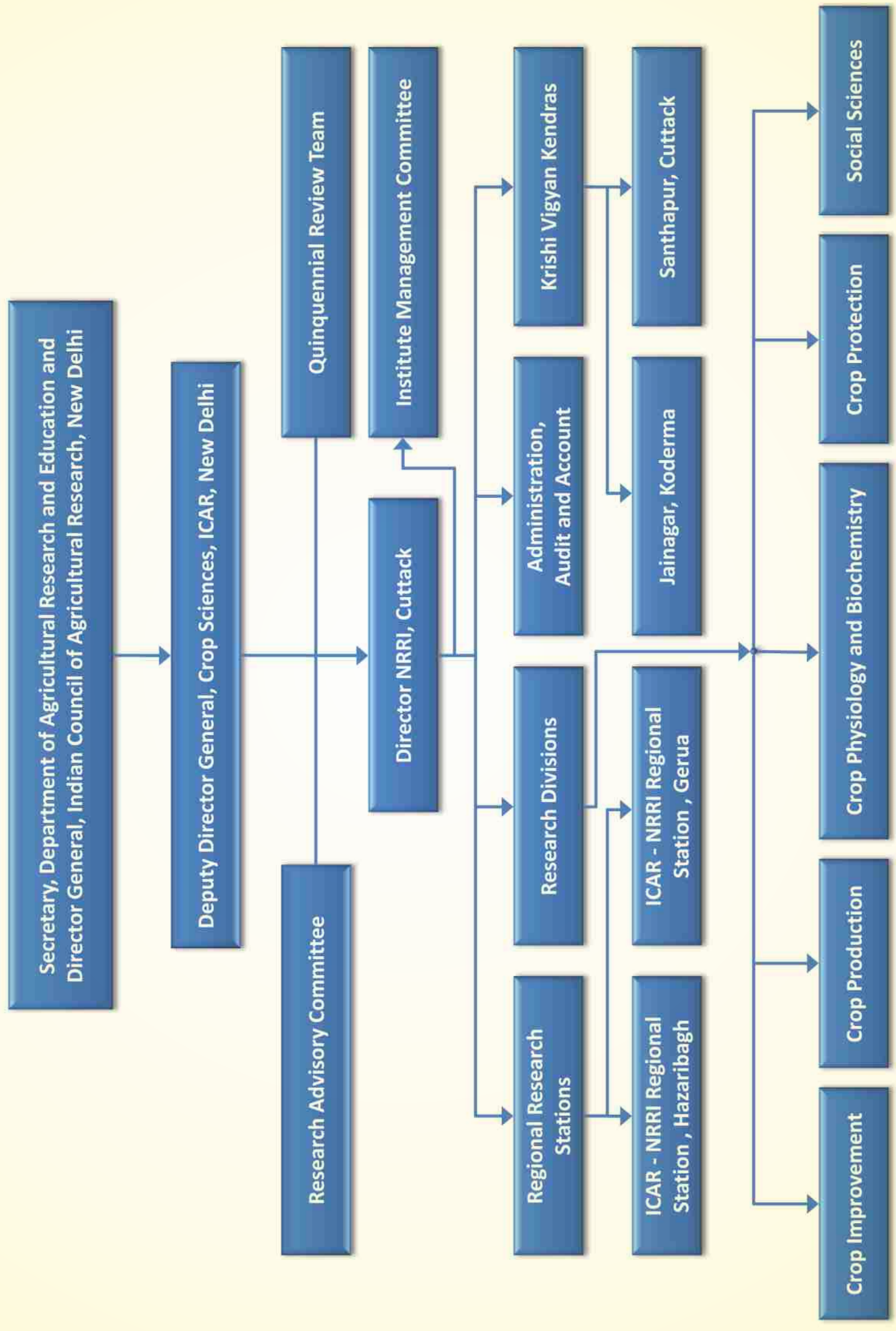
The small and marginal farmers who constitute the backbone of rice farming face problems caused by various biotic and abiotic factors. Rice crop is vulnerable to drought, flash flood, high wind, weed and heavy infestation of pest and diseases etc whose frequency and severity are difficult to predict. Constant vigil on weather elements, technological preparedness and quick dissemination of information are the key steps to mitigate these problems. The research institute is mandated to develop technologies to address the unprecedented changes adversely affecting the farmers and the farming situation in the country.

Under its five approved research programmes, the institute has taken steps to analyze the problems, arrange resources and initiate technology generation processes. A team of scientists are working in each project with an inter-disciplinary and holistic approach to develop sustainable production technologies in rice. During the year 2014-15 the institute has released 10 rice varieties with desirable traits, which are suitable to different ecologies. More than 200 superior performing lines have been nominated to AICRIP for multi-location testing. Conventional breeding methods are being supplemented by molecular, hybrid and doubled haploid approaches for better utilization of the available genetic variation in rice germplasm. Development of appropriate crop management techniques for long term sustainable use of natural resources is our priority. Productivity gain with reduction in cost of production through proper weed management practices and mechanization is high on our research and development agenda. In view of changing pattern of biotic factors affecting rice crop under the changing climate that have brought in new threats in terms of time of outbreak, virulence and some minor pests and diseases posing serious challenges, new surveillance strategies and control measures are being developed. Gender mainstreaming in rice production and entrepreneurship development based on various technologies of the institute have been initiated under the out-reach programmes of the institute. The institute has further strengthened its activities in areas such as capacity building, publications and inter-departmental co-ordination to reach the stakeholders more effectively. The Annual Report 2014-15 is a detailed presentation of progress during the past one year on the aforesaid areas.

I sincerely acknowledge the inspiring guidance of Dr. S. Ayyappan, Hon'ble Secretary, DARE and Director General, ICAR, New Delhi and express my sincere gratitude for upgrading the status of the institute as National Rice Research Institute (NRRI). The valuable inputs, support and guidance provided by Prof. V. L. Chopra, Chairman, RAC, Dr. S. K. Datta, the former Deputy Director General (Crop Sciences), and Dr. J. S. Sandhu, the current DDG (CS), ICAR, New Delhi, the esteemed members of RAC and IRC are gratefully acknowledged. I express my sincere thanks to Dr. J. S. Chauhan, Assistant Director General (FFC and Seed), Dr. I. S. Solanki, the current ADG (FFC), ICAR, New Delhi and other concerned officials of the Council for their involved support. The efforts of Heads of Division, OICs of Regional Research Stations, Publication Committee, Administration, Finance and Publication Unit of the Institute for compiling and editing the Annual Report are highly appreciated. My thanks are due to all the staff of the institute for their whole-hearted support in carrying out institute's activities. I hope that this report will be useful for policy makers, researchers, development functionaries, farmers, farmwomen and students.

(T. Mohapatra)
Director

ORGANOGRAM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Crop Improvement

Executive Summary

The National Rice Research Institute released two rice varieties, while Variety Identification Committee identified another eight rice varieties for release. In aerobic situation CR Dhan 205 was released for the states of Tamil Nadu, Gujarat, Odisha, Madhya Pradesh and Punjab, whereas CR Dhan 306 was released for Madhya Pradesh, Bihar and Puducherry for irrigated mid-early duration. CR Dhan 310, a high protein (mean protein content of 10.3%) rice variety was identified by Varietal Identification Committee, with mean grain yield of 4.48 t/ha for release in Odisha, Uttar Pradesh and Madhya Pradesh. One semi-dwarf aromatic short grain entry, CR Dhan 909 was identified for the states of Uttar Pradesh, Bihar, Assam and Maharashtra. Similarly, IET 23189, possessing aromatic, and medium slender grains was identified for the states of Odisha, West Bengal, UP, Assam and Maharashtra. CR Dhan 408 (Chakaakhi), a high yielding variety, for rainfed shallow lowlands of Odisha; two rice varieties *viz.*, CR Dhan 203 (Sachala) and CR Dhan 206 (Gopinath) for aerobic situation ; CR Dhan 101 (Ankit) for direct seeded upland condition; CR Dhan 307 (Maudamani) for favourable rainfed lowland / irrigated condition were identified for the state of Odisha. CR Dhan 701, country's first late duration hybrid was released for commercial cultivation in the state of Odisha.

During the year, two exploration programmes were conducted in Jharkhand and Chhattisgarh for collection of wild and weedy rice germplasm. Six thousand four hundred and six accessions of rice germplasm were characterized and rejuvenated for conservation. Five thousand two hundred and seventy nine accessions of rice germplasm were supplied to different researchers all over the country.

In wide hybridization programme, two accessions of *O. rufipogon* (AC 100444 and AC 100015) and three accessions of *O. rufipogon* (AC 100263, AC 100005 and AC 100493) were found with moderate resistance against sheath blight. Eleven disomic fertile lines of *O. nivara* and *O. brachyantha* were found promising for grain yield. Validation of Monosomic Alien Addition Line (MAAL) B2-48 using newly developed STS and CAPS markers cross-transferable between *O. sativa* and *O. brachyantha* was effectively used for molecular screening.

In hybrid rice, 23 potential combiners, restorers and 63 maintainers were identified. Bacterial blight resistant genes (*Xa21, xa13, xa5 and Xa4*) were introgressed into CRMS 31A and CRMS 32A. Altogether seven promising hybrids in early and late duration group were developed. Transcriptomic analysis of two hybrids, Ajay and Rajalaxmi was completed. Two MoUs were singed with private seed agencies for production and marketing of the hybrids, Ajay, Rajalaxmi and CR Dhan 701.

Twenty six elite breeding lines were detected as tolerant in comparison to tolerant check FL 478. AC 41585 was identified as tolerant to salt stress both at seedling and flowering stages. Five out of sixty microsatellite markers amplified showed tolerant bulk specific heterozygote bands which were used to genotype BILs. The positive association (R= 0.2) was observed between markers, RM122 on chromosome 5 and RM 22143 on chromosome 7 and stability index for grain yield under stress.

In super rice programme, five genotypes were identified as very high yielding containing super traits viz., high grain number, strong culm, long and wide top three leaves as well as high biomass (fertile grains up to 321). In a study for biomass partitioning it was found that, rate of partitioning to panicle was highest in CR 3936-11-1-1-1-1-1 (2.55 $g/day/m^2$), which was being reflected in highest grain yield.

An efficient and high-throughput non-destructive image based phenotyping protocol (screening technique) was established to assess whole plant area of seedling by image analysis to estimate early seedling vigour.

A total of 200 doubled haploids (DHs) derived from rice hybrid, BS 6444G were screened for three BLB resistance genes (*Xa4*, *xa5* and *Xa21*) using linked/ functional markers. Besides, ASA of Badh2 and grain cooking could discriminate aromatic and non-aromatic lines from DHs. Further, 13 DHs were selected for further yield evaluation. Simultaneously, 46 selected DH lines generated from seven elite rice hybrids were evaluated for their yield. The banding profile obtained using SSR markers in the progenies derived from DHs of CRHR 32 was completely uniform suggesting a high level of genetic fidelity among them. Based on the physico-chemical parameters, three DH lines showed superiority over the parent (CRHR32). Using SSR analysis, a total of 150 DHs of CRHR32 showed complete homogeneity revealing the expected 1:1 ratio for alleles of either parent. A total of 113 DHs were confirmed out of 162 green plants generated from F_1s of Savitri x Pokkali.

Two QTLs for Grain Protein Content were detected, located on chromosome 1 and 2, explaining 13% and 17% phenotypic variances. Similarly, two common QTLs for single grain protein content were detected to be located on chromosome 2 and 7, explaining 7-14% phenotypic variance.

Ten high yielding mega rice varieties of India namely, Swarna, Samba Mahsuri, MTU 1010, MTU 1001, PKM-HMT, PR 113, Pusa 1121, Pooja, Shatabdi and Sahabhagidhan were re-sequenced using NGS technology with an average coverage of 39.62X. High throughput genotyping of RIL mapping population from the cross TN1/Salkathi with 40, 894 SNP markers identified two QTLs *viz.* *Qbph4.3* and *Qbph4.4* on chromosome 4 that explained phenotypic variance of 9.7% and 15.7%, respectively towards resistance to BPH in the cultivar Salkathi. Similarly, high throughput genotyping of RIL mapping populations of the cross Moroberekan/ Kalinga III with 40, 894 SNP markers identified three QTLs *Qbs1*, *Qbs2* and *Qpib6* which explained phenotypic variance of 9.2%, 9.06% and 5.91%, respectively towards the brown spot and the blast resistance. Genotyping of 89 germplasm accessions having extreme phenotype for grain length with markers specific for grain size genes and association analysis revealed significant association of grain length with the *GS3* and *GL7* genes.

In upland breeding programme, CRR 523-2-2-1-1, flowering in 71 days with intermediate plant height and having very good grain quality with long slender grains was found promising in region 3 in the states of Jharkhand, Bihar, Chhattisgarh and Maharashtra. This culture tolerant to drought stress and moderately resistant to leaf blast and brown spot diseases with acceptable quality was recommended for Jharkhand. Similarly, CRR 680-B-B-25-4 (IET 23345) was found highly promising under drought affected locations. It had high Zn (20.1 ppm) in milled rice with good cooking quality parameters. This culture was found promising for the states of Maharashtra and Jharkhand. Grain yield under stress QTLs *DTY12.1* and blast resistant gene *Pi2* were introgressed into popular upland variety Vandana and recorded with significant yield advantage over Vandana with DTY 12.1 under stress condition along with leaf blast tolerance. Similarly, drought QTL introgression lines in Anjali were found promising.

Long term fertilizer experiment proved that application of FYM alone or in combination with chemical fertilizer increased the DTPA-Fe, Mn and Zn compared to unfertilized rice soil. Application of phosphatic fertilizer and organic manure contributed most towards the addition of micronutrients.

Higher root length density (RLD) was recorded in Sahabhagidhan, whereas lowest RLD was in IR 64 variety when a moisture stress up to (-)60 kPa was imposed after 30 days of transplanting. Post-flood urea application substantially increased the chlorophyll, soluble sugars and starch resulting in significantly higher survival, yield attributes and grain yield.

Soil application of 2 kg B/ha recorded highest increase in grain yield both under ambient (23.4%) and high temperature (52.8%) conditions. Application of RDF + rice husk biochar 10 t/ha recorded 29.6% increase in rice grain yield compared to RDF alone.

Integrated nutrient management involving incorporation of cowpea residue with 75% of RDF to rice + straw mulching with RDF to maize/groundnut + 50% RDF to cowpea produced significantly highest REY and recorded 43.9% yield advantage over RDF to each crop of the system.

Among the five resource conservation technologies (RCTs) including brown manuring, green manuring, wet seeding by drum seeder, zero tillage and paired row dry seeding rice with dhaincha under direct seeded condition tested, higher grain yield (4.98 t/ha) as well as energy ratio (9.3) was found in paired row rice with *dhaincha*.

The lime stone based formulations of four Bt (TB 160, 161, 261 and 263) and one each strain of *Beauveria bassiana* and *Metarhizium anisopliae* were prepared which could be preserved up to six months in desiccators with 20% moisture content.

The genetic stock of six thermo-tolerant plant growth-promoting fungi were isolated from Atri and Deulajhari hot springs of Odisha.

One unique strain (KM1) of *Rhizoctonia solani* from naturally infected rice sheath blight was isolated. The entomopathogenic fungi like *Beauveria* (TF6), *Metarhizium* (TF19), *Nomuraea* (TF30) and *Fusarium* spp. (TF26) and chemical insecticides viz. chlorpyriphos, carbofuran, oxydemeton methyl, monocrotophos, quinalphos and imidacloprid were not antagonistic to each other for successfully controlling the rice leaf folder (*Cnaphalocrocis medinalis* Guenee).

Brown plant hopper resistance was confirmed in breeding line CR 3006-8-2 (Pusa 44 x Salkathi) through AICRIP trial. Resistance to BPH was also confirmed in nine earlier identified farmers' varieties through antibiosis study. Seven more varieties were identified as highly resistant through replicated screening. The accession IR 65482-7-216-1-2-B with *Bph 18* gene showed susceptibility to BPH population of NRRI. Out of 61 landraces of rice tested, five landraces (four from Sikkim and one from Jharkhand) had *Pi2* gene type banding pattern.

The precise assessment method to evaluate the severity of the false smut disease was developed which would help the researchers to estimate the yield loss due to false smut in rice. The presence of both mating types (*MAT-1* & *MAT 1-2*) of *Magnaporthe oryzae* were observed in coastal Odisha. Even the presence of both mating types was observed in the same field in irrigated ecosystem. The *MAT 1-2* isolates of *Magnaporthe oryzae* predominated in Jharkhand and Assam, while *MAT1-1* was more predominant in isolates of Odisha. The molecular data of *Sclerotium* sp. causing seedling blight collected in different years indicated the change of genetic structure of the pathogen. Incidence of RTD was observed in rice hybrid PAC 835 in Nalbari district and in traditional cultivar *Ahujoha* in Darrang district during summer and in Swarna, Swarna *sub1*, Mahsuri and rice hybrid JKRH 401 during winter season.

Mealy bug (*Brevennia rehi* Lindinger), an uncommon pest of rice in NE India, was recorded causing mild to severe damage to rice in Baksa and Hailakandi districts of Assam. Increased population of pink stem borer and striped stem borers in low land variety Varshadhan was observed in the year 2014. Brown plant hopper infestation was severe in Odisha, particularly in coastal districts and the damage ranged from 20 - 90% farmer-wise causing 'hopper burn'.

The seedling blight of rice (c.o. *Sclerotium* sp.) was controlled successfully using *Bacillus* sp. isolated from cowshed. Four different *Trichoderma* spp. based formulations enhanced the growth of rice and controlled the seed borne diseases. The *Trichoderma* treated plants showed higher uptake of NPK than the untreated one. The cell free culture filtrate of an endophyte isolated from rice cultivar Lunishree significantly enhanced root and shoot length and also the weight of rice var.

Tricyclazole 45% in combination with Hexaconazole 10% WG was the best combination of fungicides to control sheath blight disease in rice. A net gain of 0.578 t/ha and 0.528 t/ha of grain was recorded in IPM plots over non-IPM plots in Swarna and Pooja variety, respectively. Seed treatment with carbendazim, proper monitoring with proper time of application of quality products could reduce pesticide application by 68% with successful control of BPH in on-farm validation of IPM in shallow favourable lowland ecosystem.

Rice cultivars with high grain protein content, namely ARC 10075 and Heera were found to be richer in nearly all amino acids compared to some popular rice varieties. Rice Heera was found to have highest amount of threonine and lysine. A landrace PB 140 was found to contain 13.5% crude protein in brown rice grains. CR Dhan 907 was found to be the richest in iron (20 ppm) followed by CR 3704 (14 ppm), the latter also had 27 ppm zinc. IC 456959 and IC 459902 were at par with FR13A and better than the other submergence tolerant check Swarna *sub1*. AC 847A was found to have maximum tissue tolerance to salinity at seedling stage. A pokkali accession, AC 39417 was found to be more tolerant than FL 478 (tolerant check) to seedling stage salinity. Another 172 germplasm were found to be tolerant to vegetative stage drought with SES 1; highest yield was recorded in AC 42994 (3.77 t/ha) followed by Brahman nakhi (3.26 t/ha). Among the 220 drought tolerant rice germplasm (longer duration, for rainfed lowland condition) evaluated for root traits, 20 germplasm including Kalakeri, Mahulata and Annapurna showed higher values for more than one root traits. *O.rufipogon, O.punctata, O.barthii, O.eichingeri* and *O.nivara* were identified to be tolerant to low light stress. The 121-135 days duration genotypes showed better photosynthesis and more chlorophyll *b* content under low light (50% of normal) conditions with

Kalinga II as the best performer. In another project, NADP-malic enzyme gene was cloned and used to transform rice Naveen, which was confirmed by Colony PCR results.

In *Kharif* 2014, it was observed that 63% of the total rice area was covered by NRRI varieties in Gurujang-Guali cluster of model village project. Significant positive changes had taken place with respect to attitude towards growing hybrid rice, knowledge of high yielding varieties and rice cultivation especially soil nutrient management, pest control and mechanization. It was observed that small scale rice farmers has very low access to information on institutional credit.

Under the activity 'Designing and testing of gender sensitive approaches in rice farming' it was found that the majority of the farmwomen perceived Naveen, CR Dhan 303, CR Dhan 304, Pooja, raising mat type seedling, line transplanting, fertilizer and pesticides application, seed treatment, 4-row manual drum seeder, finger weeder, rice husk combustor and paddy straw mushroom cultivation more appropriate.

Under feedback study, farmers perceived BGREI programme effective in terms of significant jump in rice productivity (28.82%). About 49.17% progressive farmers reported that they had sold their surplus paddy at MSP.

Cost of cultivation data of rice for 18 states of India for thirty two years (1980-81 to 2011-12) was analysed. It was found that cost of cultivation per hectare had increased over the years, whereas profit margin had not increased commensurately. Though the C_2 cost of cultivation had increased by 63% (Rs.15,412 / ha) between quinquennium ending 1984-85 and 2011-12, the profit had increased only by 35% (Rs.1,452 / ha) during the above period. Human labor accounted for 35.8 per cent of the total cost of cultivation and 53.1 per cent of the operational cost of cultivation and thus, it is the single largest item in the total cost structure. It was observed that there were sharp rise in wages in the recent period in comparison to the previous period. The real wage rate (at constant 2011-12 prices) increase was 7.22% in the recent period (2006-11) in comparison to the real wage rate increase of 1980 (3.61%) and 1990 (3.85%) and therefore, contributed significantly to the increase in cost of cultivation in the recent past.

User-friendly database regarding state-wise area, production and yield of rice in India was constructed basing on data from 1961 to 2012.

कार्यकारी सारांश

राष्ट्रीय चावल अनुसंधान संस्थान ने दो किस्में विमोचित कीं जबकि किस्म पहचान समिति ने आठ चावल किस्मों के विमोचन के लिए पहचान की है। एरोबिक परिस्थिति के लिए सीआर धान २०५ (आईईटी २२७३७) तमिलनाडु, गुजरात, ओडिशा, मध्य प्रदेश तथा पंजाब में खेती हेतु विमोचित की गई जबकि मध्य प्रदेश, बिहार एवं पुडुचेरी में सिंचित मध्यम अवधि खेती हेतु सीआर धान ३०६ (आईईटी २२७०८४) विमोचित की गई। एक उच्च प्रोटीन वाली सीआर धान ३१० (प्रोटीन की मात्रा १० प्रतिशत) चावल किस्म ओडिशा, उत्तर प्रदेश तथा मध्य प्रदेश में खेती के लिए विमोचन हेतु पहचान की गई है। इसकी औसत उपज ४.४८ टन प्रति हेक्टेयर है। एक अर्द्ध बौना सुगंधित धान एवं छोटे दाने वाली किस्म सीआर धान ९०९ को उत्तर प्रदेश, बिहार, असम, तथा महाराष्ट्र में विमोचन हेतु पहचान की गई है। उसी प्रकार आईईटी २३१८९ जो सुगंधित, पारभासी तथा मध्यम पतले दानों की किस्म है ओडिशा, पश्चिम बंगाल, उत्तर प्रदेश, असम एवं महाराष्ट्र के लिए पहचान की गई है। अधिक उपज देने वाली सीआर धान ४०८ (चकाआखी) को ओडिशा के वर्षाश्रित उथली निचलीभूमि में खेती के लिए पहचान की गई। ओडिशा में ऐरोबिक स्थिति के लिए सीआर धान २०३ (सचला) तथा सीआर धान २०६ (गोपीनाथ) एवं ऊपरीभूमि सीधी बुआई के लिए सीआर धान १०१ (अंकित) की पहचान की गई है। ओडिशा के अनुकूल वर्षाश्रित निचलीभूमि एवं सिंचित परिस्थिति के लिए अधिक उपज देने वाली सीआर धान ३०७ (मधुमति) की पहचान की गई। देश की पहली विलंब अवधि वाली संकर चावल सीआर धान ७०१ को ओडिशा में व्यावसायिक खेती के लिए विमोचित किया गया।

वर्ष के दौरान, झारखंड एवं छत्तीसगढ़ में जंगली तथा घासवाले धान जननद्रव्य के संग्रह हेतु दो खोज कार्यक्रमों का आयोजन किया गया। धान जननद्रव्य की चौसठ हजार चार सौ छह प्रविष्टियों का लक्षण वर्णन किया गया तथा संरक्षित रखा गया। धान जननद्रव्य के पांच हजार दो सौ उनासी प्रविष्टियों को देश के विभिन्न अनुसंधानकर्ताओं तथा संस्थान के वैज्ञानिकों को परीक्षण, मूल्यांकन तथा उपयोग हेतु आपूर्ति की गई।

व्यापक संकरीकरण कार्यक्रम में, ओ.रुफिपोगन की दो प्रविष्टियों (एसी १००४४४ तथा एसी १०००१५) तथा ओ.रुफिपोगन की तीन प्रविष्टियों (एसी १००२६३ एसी १००००५ तथा एसी १००४९३) आच्छद अंगमारी रोगजनक के विरुद्ध मध्यम रूप से प्रतिरोधी/सहिष्णु पाए गए। ओ.निवारा तथा ओ.ब्रेकियांथा के ग्यारह उर्वर वंशों को उपज के लिए आशाजनक पाया गया। ओ. सैटाइवा तथा ओ.ब्रेकियांथा के बीच क्रॉस-अंतरणीय हो सकने वाली नई रूप से विकसित एसटीएस एवं सीएपीएस चिन्हकों का प्रयोग करते हुए मोनोसोमिक एलियन एडिशन लाइन बी२-४८ का मान्यकरण आण्विक परीक्षण के लिए किया गया।

संकर चावल में, २३ संभावित मिश्रक, मध्यम से विलंब अवधि वाले पुनर्स्थापकों एवं अनुरक्षकों की पहचान की गई। सीआरएमएस ३१ए तथा सीआरएमएस ३२ए में जीवाणुज आच्छद प्रतिरोधी जीनों (,एक्सए २१, एक्सए१३ एक्सए५ तथा एक्सए४) को प्रवेश कराया गया। कुल मिलाकर सात शीघ्र एवं विलंब अवधि वाले आशाजनक संकर विकसित किए गए। अजय एवं राजलक्ष्मी संकरों का ट्रांसस्क्रिप्टोमिक विशलेषण कार्य पूरा हो गया है। अजय, राजलक्ष्मी तथा सीआर धान-७०१ संकरों के उत्पादन तथा मार्किटिंग के लिए दो निजी कंपनियों के साथ समझौते पर हस्ताक्षर किए गए।

सहिष्णु चेक एफ४७८ की तुलना में छब्बीस श्रेष्ठ प्रजनक वंश लवणता सहिष्णु पाए गए। बुआई तथा फूल लगने के दोनो अवस्थाओं में लवणता दबाव के प्रति एसी ४१५८५ सहिष्णु पाया गया। विस्तारित किए गए ६० माइक्रोसैटेलाइट चिन्हकों में से पांच में सहिष्णु बल्क विशिष्ट हेटेरोजाइगोट पट्टियां पाई गईं जिन्हें जीनप्ररूप बीआईएल के लिए प्रयोग किया गया। दबाव के तहत उपज के लिए क्रोमोसोम ५ पर चिन्हक आरएम १२२ तथा क्रोमोसोम ७ पर एवं स्थायीत्व सूचक हेतु चिन्हक आरएम २२१४३ का सकारात्मक संबंध देखा गया।

सुपर चावल कार्यक्रम में पांच जीनप्ररूप को अधिक दाना संख्या, मजबूत कल्म, लंबे एवं चौड़े तीन ऊपरी पत्ती एवं अधिक जैवपदार्थ गुण वाले अधिक उपज देने वाली किस्मों के रूप में पहचाना गया। जैवपदार्थ के अलगाव पर किए गए एक अध्ययन से यह पता चला कि बाली में अलगाव का दर सीआर ३९३६-११-१-१-१-१-१ (२.५५ ग्राम प्रति दिन प्रति वर्गमीटर) में सर्वाधिक है जिससे अधिक उपल मिली।

चावल में आरंभिक पौद ओज के आकलन हेतु इमेज एनालिसिस द्वारा पूरे पौध क्षेत्र को मूल्यांकन के लिए इमेज आधारित फिनोटाइपिंग प्रोटोकॉल विकसित किया गया।

चावल संकर बीएस ६४४४जी से उत्पन्न कुल २०० डबल हैप्लाएडों का संबद्ध/कार्यक्षम चिन्हक का प्रयोग करते हुए ३ जीवाणुज आच्छद अंगमारी प्रतिरोधी जीनों के लिए (एक्सए४, एक्सए५ तथा एक्सए२१) के लिए परीक्षण किया गया। इसके अतिरिक्त, बीएडीएच२ का एएसए एवं डबल हाप्लाएडों से सुगंधित एवं गैर सुगंधित वंशों के दाना पकाने की भेद का पता लगा। आगे की उपज मूल्यांकन के लिए १३ डबल हाप्लाएडों

को चयन किया गया। इसके साथ, उपज मूल्यांकन के लिए सात श्रेष्ठ चावल संकरों से उत्पन्न ४६ चयनित डबल हैप्लाएडों वंशों का मूल्यांकन किया गया। सीआरएचआर३२ से उत्पन्न डबल हैप्लाएडों की संततियों में एसएसआर चिन्हकों का प्रयोग करते हुए प्राप्त बैंडिंग प्रोफाइल एकसमान था। भौतिक-रासायनिक पैरामीटर के आधार पर, जनक सीआरएचआर३२ की अपेक्षा ३ डबल हैप्लाएड वंश श्रेष्ठ पाये गए। एसएसआर विश्लेषण का प्रयोग करते हुए कुल १५० डबल हैप्लाएडों में संपूर्ण एकरूपता देखने को मिला। सावित्री एवं पोकाली के एफ१ से उत्पन्न कुल १६२ हरी पौधों में कुल ११३ डबल हैप्लाएडों की पुष्टि हुई।

चावल के दाने में प्रोटीन मात्रा के लिए दो क्यूटीएल की पहचान हुई जो क्रोमोसोम १ एवं २ पर स्थित हैं जिससे १३ प्रतिशत और १७ प्रतिशत फिनोटाइप विभिन्नता का पता चला। उसी प्रकार, एकक दाना प्रोटीन मात्रा के लिए दो साधारण क्यूटीएल की पहचान हुई जो क्रोमोसोम २ एवं ७ पर स्थित हैं जिससे ७-१४ प्रतिशत फिनोटाइप विभिन्नता का पता चला।

अधिक उपज देने वाली भारत की दस प्रमुख चावल किस्म स्वर्णा, सांबा महसूरी, एमटीयू १०१०, एमटीयू १००१, पीकेएम-एचएमटी, पीआर ११३, पूसा, ११२१, पूजा, शताब्दी तथा सहभागीधान को एनजीएस प्रौद्योगिकी का प्रयोग करते हुए पुनःअनुक्रमित किया गया। टीएन१/सालकाथी के क्रास से ४०, ८९४ एनएनपी चिन्हकों द्वारा दो क्यूटीएल क्यूबीपीएच४.३ तथा क्यूबीपीएच४.४ की पहचान हुई जो क्रोमोसोम ४ पर स्थित हैं जिससे ९.७ प्रतिशत और १५.७ प्रतिशत फिनोटाइप विभिन्नता का सालकाथी में भूरा पौध माहू के प्रति प्रतिरोधिता का पता चला। उसी प्रकार, मोरोबेरेकान/कलिंग ३ के क्रास से ४०, ८९४ एनएनपी चिन्हकों द्वारा तीन क्यूटीएल क्यूबीएस१, क्यूबीएस२ तथा क्यूबीएस६ की पहचान हुई जिससे ९.७ प्रतिशत, ९.६ और ५९१ प्रतिशत फिनोटाइप विभिन्नता का भूरा धब्बा एवं प्रध्वंस प्रतिरोधिता का पता चला।

८९ जननद्रव्य प्रविष्टियों का जिनोटाइपिंग जिनमें दानों की लंबाई के लिए एवं दानों के आकार के लिए अधिक फिनोटाइप हैं, विशिष्ट चिन्हकों तथा संबंद्ध विशलेषण से पता चला कि जीएस३ तथा जीएल७ जीनों के साथ बहुत संबंध है।

ऊपरीभूमि प्रजनन कार्यक्रम में, झारखंड, बिहार, छत्तीसगढ़ एवं महाराष्ट्र में ७१ दिनों में फूल लगने वाली, मध्यम ऊंचाई की एवं अच्छे दानों एवं लंबे पतले दानों वाली सीआरआर ५२३-२-२-१-१ किस्म को आशाजनक पाया गया। यह किस्म सूखा सहिष्णु है, मध्यम रूप से पत्ता प्रध्वंस एवं भूरा धब्बा रोग प्रतिरोधी है, इसमें अच्छे गुण हैं और झारखंड में खेती के लिए सिफारिश की गई। उसी प्रकार, सूखा पीड़ित क्षेत्रों में सीआरआर ६८०-बी-बी-२५-४ (आईईटी २३३४५) किस्म को बहुत आशाजनक पाया गया। इस किस्म के चावल में कुटाई के बाद जस्ता की मात्रा २०.१ पीपीएम है, एवं खाना पकाने के गुण अच्छे हैं। झारखंड एवं महाराष्ट्र के लिए यह किस्म आशाजनक पाया गया। ऊपरीभूमि लोकप्रिय किस्म वंदना में उपज दबाव वाली क्यूटीएल डीटीवाई १२.१ तथा प्रध्वंस प्रतिरोधी जीन पीआई २ को प्रवेश कराया गया तथा दबाव परिस्थति में अच्छी उपज मिली तथा यह गला प्रध्वंस सहिष्णु है। उसी प्रकार, अंजलि में सूखा क्यूटीएल वंशों को प्रवेश कराने पर आशाजनक पाया गया।

दीर्घकालिक उर्वरक परीक्षण में यह देखा गया कि अन-उर्वरित धान मृदा की अपेक्षा केवल सड़े हुए गोबर या इसके सहित रसायन के साथ मिलाकर प्रयोग करने से डीटीपीए-लौह, मैंगनिज तथा जस्ता की मात्रा बढ़ गई। फॉस्फोरस उर्वरक तथा जैविक खाद के प्रयोग से सूक्ष्मपोषकतत्वों में वृद्धि हुई।

सहभागीधान में जड़ की लंबाई बढ़ गई, जबकि आईआर ६४ में जड़ें छोटी थीं। खेत में पानी भर देने के बाद यूरिया के प्रयोग से पर्णहरित, घुलनशील शुगर तथा स्टार्च बढ़ गए जिससे अधिक उत्तरजीवित्ता हो गई और उपज भी अधिक मिली।

मृदा में २ किलोग्राम बोरोन प्रति हेक्टर के प्रयोग से उचित तापमान में २३.४ प्रतिशत अधिक उपज मिली तथा उच्च तापमान में ५२.८ प्रतिशत अधिक उपज मिली। सिर्फ संस्तुत उर्वरक मात्रा के प्रयोग की तुलना में संस्तुत उर्वरक मात्रा तथा १० टन प्रति हेक्टर धान भूसी के प्रयोग से २९.६ प्रतिशत अधिक उपज मिली।

समन्वित पोषकतत्व प्रबंधन में लोबिया अपशिष्ट के साथ ७५ प्रतिशत संस्तुत उर्वरक मात्रा तथा धान पुआल को दबाकर प्रयोग करने से मकई/मूंगफली फसल में तथा ५० प्रतिशत संस्तुत उर्वरक मात्रा लोबिया में प्रयोग करने से प्रत्येक फसल में चावल के तुलनात्मक ४३.९ प्रतिशत सर्वाधिक उपज मिली।

पांच संसाधन संरक्षण प्रौद्योगिकियों की गई परीक्षण में से जिसमें भूरा खाद, हरी खाद, ड्रम सीडर द्वारा आर्द्र बुआई, जीरो टीलेज तथा सीधी बुआई परिस्थिति में ढैंचा के साथ युग्म कतार शुष्क धान बुआई शामिल है तथा ढैंचा के साथ युग्म कतार धान की खेती से ४.९८ टन प्रति हेक्टर की सर्वाधिक उपज मिली एवं ऊर्जा अनुपात ९.३ था।

चार बीटी (टीबी १६०, १६१, २६१ तथा २६३) का चूनेपत्थर आधारित तथा ब्यूवेरिया बासिआना तथा मेटार्जियम एनिसोप्लिए के प्रत्येक से सूत्रण तैयार किए गए जिसे ६ महीनों तक डेसिकटर में २० प्रतिशत आर्द्रता सहित संरक्षित रखा जा सकता है। ओडिशा के अट्री एवं देउलझरी के हॉट स्प्रिंगस से वियुक्त छह ताप सहिष्णु पौध की वृद्धि करने वाले कवकों का आनुवंशिक स्टॉक पृथककरण किया गया।

प्राकृतिक रूप से आक्रांत चावल आच्छद अंगमारी राइजोक्टोनिया सोलानी के एक विशेष स्ट्रेन को वियुक्त किया गया। कीटरोगजनक कवक जेसे ब्यूवेरिया, मेटार्जियम, नोमुरा तथा फ्यूसारियम एसपीपी. तथा रासायनिक कीटनाशक जैसे क्लोरपाइरिफास, कार्बोफ्यूरन, ऑक्सीडेमेटन मिथाइल, मोनोक्रोटोफास, क्वीनालफोस तथा इमिडाक्लोप्रिड एक दूसरे के साथ अनुकूल हैं, जिससे चावल पत्ता मोड़क का सफल नियंत्रण हो सकता है।

एआईसीआरआईपी परीक्षण के अंतर्गत सीआरआरआई विकसित प्रजनक वंश सीआर ३००६-८-२ (पूसा ४४ ¬ सालकाथी) में भूरा पौध माहू प्रतिरोधिता की पुनः पुष्टि की गई। एंटिबेसिस अध्ययन द्वारा पूर्व में किसानों द्वारा पहचान की गई नौ किस्मों में भी भूरा पौध माहू प्रतिरोधिता की भी पुष्टि की गई। फिर से दोहराई गई परीक्षण में सात अत्यधिक प्रतिरोधी किस्मों की पहचान की गई। भूरा पौध माहू की १८ जीन सहित आईआर ६५४८२-७-२१६-१-२-बी प्रविष्टि में सीआरआरआई की भूरा पौध माहू की प्रति ग्राह्यशीलता देखने को मिला। परीक्षण किए गए ६१ भूमिजातियों में से पांच भूमिजातियों में पीआई२ जीन प्ररूप बैंडिंग पैटर्न मिला। सिक्किम से चार तथा झारखंड से एक भूमिजातियां संग्रह की गईं।

फाल्स स्मट रोग की गंभीरता के मूल्यांकन की सही पद्धति विकसित की गई, जिससे अनुसंधानकर्ताओं को चावल में फाल्स स्मट रोग से होने वाली उपज क्षति के बारे में आकलन करने में सहायता मिलेगी।

तटीय ओडिशा में माग्नापोर्थे ओराइजे के दो मेटिंग प्रकारों (मैट-१ तथा मैट १-२) की उपस्थिति पाई गई। सिंचित पारितंत्र में एक ही खेत में भी दोनो मेटिंग प्रकार देखे गए। असम एवं झारखंड में माग्नापोर्थे ओराइजे के मैट १-२ के वियुक्तों की संख्या अधिकांशतः पाई गई जबकि ओडिशा में मैट-१ प्रकार अधिक देखा गया। मेघालय एवं त्रिपुरा में वियुक्त समान रूप में देखने को मिला। झारखंड में एक एकक वियुक्त दोनों प्रकार के मेटिंग के लिए पूर्ण पाया गया। सेलेरोटियम एसपी. के कारण हो रही पौद अंगमारी रोग का विभिन्न वर्षों में संग्रह किए गए आण्विक आंकड़ों से रोगजनक के आनुवंशिक संरचना के बारे में पता चला। ग्रीष्म में असम के दरांग जिले में पारंपरिक किस्म आहुजोहा तथा नालबाड़ी जिले में संकर पीएसी ८३५ में तथा शीत मौसम में स्वर्णा, स्वर्णासब-१, महसूरी तथा संकर चावल जेकेआरएच ४०१ में आरटीडी रोग देखा गया।

उत्तर-पूर्वी भारत में एक असामान्य नाशककीट मीली बग (ब्रेवेनिया रेही) से असम के बक्सा एवं हैलाकांडी जिलों में सामान्य से गंभीर क्षति की सूचना प्राप्त हुई। वर्ष २०१४ में निचलीभूमि किस्म वर्षाधान में पिंक तना छेदक तथा धारीदार तना छेदक की संख्या में वृद्धि हुई। भूरा पौध माहू का प्रकोप ओडिशा में विशेषकर तटीय जिलों में गंभीर रूप से हुआ एवं २० से ९० प्रतिशत तक क्षति हुई।

चावल पौद में अंगमारी रोग का नियंत्रण गौशाला से जैव-नियंत्रक कारक बैसिलस एसपी. वियुक्तों के प्रयोग से चावल पौद की वृद्धि काफी हुई। ट्राइकोडर्मा एसपीपी. आधारित के चार सूत्रणों से चावल फसल की वृद्धि अच्छी हुई तथा इससे बीज संबंधी रोग का नियंत्रण हुआ। बिन-उपचारित पौधों की अपेक्षा ट्राइकोडर्मा उपचारित पौधों में नत्रजन, फास्फोरस तथा पोटाश के उद्ग्रहण की क्षमता अधिक प्पाई गई। चावल किस्म लूणीश्री से अलग किया गया इंडोफाइट सेल फ्री कल्चर फिल्ट्रेट से जड़ एवं टहनी की लंबाई में वृद्धि हुई तथा चावल किस्म के वजन में भी वृद्धि हुई।

ट्राइसाइक्लाजोल ४५ प्रतिशत के साहित हेक्साकोनाजोज १० प्रतिशत का मिश्रण का प्रयोग चावल के आच्छद अंगमारी रोग के लिए सबसे अच्छा कवकनाशी था। स्वर्णा तथा पूजा किस्मों की खेती में बिन-समन्वित नाशककीट प्रबंधन खेतों की अपेक्षा समन्वित नाशककीट प्रबंधन खेतों में इनके प्रयोग से स्वर्णा से ०.५७८ टन प्रति हेक्टर तथा पूजा से ०.५२८ टन प्रति हेक्टर की उपज मिली। कार्बेडाजिम सहित बीज उपचार, उचित निगरानी एवं गुणवत्ता वाली उत्पादों का सही समय पर प्रयोग से ६८ प्रतिशत तक कीटनाशक प्रयोग को कम किया जा सका, जिससे उथली अनुकूल निचलीभूमि पारितंत्र के खेत में समन्वित नाशककीट प्रबंधन के तहत भूरा पौध माहू के सफल नियंत्रण का मान्यकरण हुआ।

लोकप्रिय चावल किस्मों की अपेक्षा उच्च प्रोटीन मात्रा वाली चावल की किस्मों जैसे एआरसी-१००७५ तथा हीरा में कुल एमिनो एसिड अधिक पाया गया। हीरा किस्म में थ्रियोनाइन एवं लाइसिन की सर्वाधिक मात्रा पाई गई। एक भूमि जाति पीबी-१४० के भूरा चावल दानों में १३.५ प्रतिशत मात्रा प्रोटीन पाया गया। सीआर धान ९०७ में सर्वाधिक लौह (२० पीपीएम) की मात्रा पाई गई जबकि सीआर-३७०४ में (१४ पीपीएम) लौह पाया गया। सीआर-३७०४ में २७ पीपीएम जस्ता भी मिला। आईसी४५६९५९ तथा आईसी४५९९०२ एफआर१३ए के समान था तथा निमग्न सहिष्णु चेक किस्म स्वर्णा-सब-१ की अपेक्षा बेहतर पाये गये। एसी८४७ए के पौद अवस्था में लवणता के प्रति सर्वाधिक ऊत्तक सहिष्णुता देखने को मिला। पौद अवस्था में लवणता के प्रति एफएल४७८ (सहिष्णु चेक) की अपेक्षा एक पोकाली प्रविष्टि एसी३९४१७ अधिक सहिष्णु पाई गई। फसल की वृद्धि अवस्था के दौरान १७२ जननद्रव्य सूखा सहिष्णु पाये गये एवं एसईएस में इनका स्कोर १ था। प्रकाशसंश्लेषण एसी४२९९४ से ३.७७ टन प्रति हेक्टयर की सर्वाधिक उपज

मिली जबकि ब्राह्मनाखी से ३.२६ टन प्रति हेक्टयर की उपज मिली। २२० सूखा सहिष्णु चावल जननद्रव्यों (अधिक अवधि वाले, वर्षाश्रित निचलीभूमि परिस्थिति) में से, जड़ लक्षणों के लिए मूल्यांकन किए गए २० जननद्रव्यों कलाकेरी, महुलता तथा अन्नपूर्णा में एक जड़ लक्षण से अधिक मूल्य पाए गए। ओ.रुफिपोगन, ओ.पंक्टाटा, ओ.बैठी, ओ.इच्छिनगिरि तथा ओ.निवारा को कम प्रकाश दबाव के लिए सहिष्णु पाए गए। १२१-१३५ दिनों वाली जीनप्ररूपें कम प्रकाश (सामान्य का ५० प्रतिशत) परिस्थिति में बेहतर प्रकाशसंश्लेषण तथा अधिक क्लोरोफिल बी की मात्रा पाई गई जिसमें कलिंग क्ष का सबसे श्रेष्ठ प्रदर्शन रहा। एक अन्य परियोजना में एनडीपी-मैलिक इनजाइम जीन को क्लोन किया गया तथा नवीन धान में परिवर्तन हेतु प्रयोग किया गया एवं जिसकी कालोनी पीसीएस परिणामों से पुष्टि हुई है।

वर्ष २०१४ के खरीफ के दौरान गुरुजंग-गुआली के गांवों में यह पाया गया कि अन्य किस्मों की अपेक्षा खेती की जाने वाले चावल क्षेत्रों में सीआरआरआई की किस्मों की प्रतिशतता ६३ है। किसानों में पहले से संकर चावल की खेती करने के लिए रुचि, अधिक उपज देने वाली किस्मों के बारे में एवं चावल की खेती विशेषकर मृदा पोषकतत्व प्रबंधन, नाशककीट प्रबंधन तथा मशीनीकरण का ज्ञान काफी बढ़ा है। चावल की खेती करने वाले छोटे किसानों की कर्ज लेने की आवश्यकताओं से पता चला कि सांस्थानिक कर्ज के बारे में इनके पास पर्याप्त सूचना नहीं पहुंच पाती है।

'चावल की खेती में लैंगिक संवेदनशील प्रस्तावों की परिकल्पना एवं परीक्षण' विषय कार्यकलाप के तहत यह देखा गया कि अधिकांश महिला किसान नवीन, सीआर धान-३०३, सीआर-३०४, पूजा किस्म, चटाइदार पौद उगाने, कतार रोपाई, उर्वरक तथा कीटनाशक प्रयोग, बीज उपचार, चार कतार वाला हस्तचालित ड्रम सीडर, फींगर, राइस हस्क कंबस्टर को पसंद करते हैं तथा धान पुआल मशरूम की खेती उचित तरीके से करती हैं।

किसानों से लिए गए अभिमत से यह पता चला कि बीजीआरईआई कार्यक्रम के सफल कार्यान्वयन से चावल उत्पादकता में काफी वृद्धि (२८.८२ प्रतिशत) हुई है। लगभग ४९.१७ प्रतिशत प्रगतिशील किसानों ने यह सूचित किया है कि वे अतिरिक्त धान को न्यूनतम समर्थन मूल्य पर बिक्री कर पाए हैं।

भारत के १९ राज्यों में पिछले दो सालों (२०१०-११ तथा २०११-१२) में धान की खेती करने के लिए लागत के संपूर्ण आंकड़ों को डिजिटाइल करके उन्हें विश्लेषित किया गया। यह पाया गया कि प्रति हेक्टेयर खेती की लागत दो सालों में बढ़ी है जबकि उसी अनुपात में लाभ नहीं मिला है। यद्यपि खेती की लागत में ६३ प्रतिशत वृद्धि (रु.१५४१२/-) हुई है, जबकि उसी अवधि में ३५ प्रतिशत अर्थात रु.१४५२/- प्रति हेक्टेयर लाभ मिला है। कुल खेती लागत में श्रमिक बाबत ३५.८ प्रतिशत खर्च बढ़ा है और कृषि कार्य को संचालन करने में ५३.१ प्रतिशत बढ़ा है और इस प्रकार पूरे लागत संरचना में सबसे अधिक खर्च इस बाबत हुआ है।

भारत में सन १९६१ से धान २०१२ तक राज्यवार चावल की खेती का क्षेत्र, उत्पादन तथा उपज संबंधी आंकड़ों को आसानी से उपयोग किया जाने वाले डेटाबेस में रखा 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, one at Hazaribag, in Jharkhand, and the other at Gerua, in Assam. The NRRI regional substation, Hazaribag 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 Santhapur in Cuttack district of Odisha and the other at Jainagar in Koderma district of Jharkhand. The research policies are guided by the recommendations of the Research Advisory Committee (RAC), Quinquennial Review Team (QRT) and the Institute Research Council (IRC). The NRRI also has an Institute Management Committee (IMC) for formulating administrative policies.

Mandate

The goal is to improve the income and quality of life of rice farmers in India.

The Mandate of the Institute are:

- 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 in farmers' situations and develop remedial measures for their amelioration.
- Maintain database on rice ecology, ecosystems, farming situations and comprehensive rice statistics for the country as a whole in relation to their potential productivity and profitability.
- Impart training to rice research workers, trainers and subject matter/extension specialists on improved rice production and rice-based cropping and farming systems.
- Collect and maintain information on all aspects of rice and rice-based cropping and farming systems in the country.

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 farmers' income.

Research Achievements

The institute has released 114 rice varieties including three hybrids suitable for cultivation in upland, irrigated, rainfed lowland, medium-deep waterlogged, deepwater and coastal 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. Compiled 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 resistant 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 parboiler and power thresher 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 benn 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 modelling 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 climate resilient rice varieties.

Developed suitable rice production technologies for rainfed uplands, lowlands and 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 service 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°55′48" E to 85°56′48" E longitudes and 20°26′35" N to 20° 27′ 20" N latitudes with the general elevation of the farm being 24 m above the MSL. The annual rainfall at Cuttack is 1,200 mm to 1,500 mm, received mostly during June to October (*kharif* or wet season) from the southwest monsoon. Minimal rainfall is received from November to May (*rabi* or dry season).

PROGRAMME : 1

Genetic Improvement of Rice

The Crop Improvement Division is mostly involved in genetic improvement of rice along with enrichment of crop genetic resources vis-à-vis basic studies in genetics, cytogenetics and molecular biology.

The Institute released two rice varieties, while Variety Identification Committee (VIC) identified another eight rice varieties for release. CR Dhan 205 (IET 22737) was released for the states of Tamil Nadu, Gujarat, Odisha, Madhya Pradesh and Punjab under aerobic condition, while CR Dhan 306 (IET 22084) was released for Madhya Pradesh, Bihar and Puducherry for irrigated mid-early duration in the 70th supplementary meeting of Central sub-committee on Crop standards, Notification and Release of varieties for Agricultural Crops.

Three promising cultures were identified for release in 50th AICRIP group meet held at IIRR, Hyderabad. CR Dhan 310 (IET 24780), a high protein (mean protein content of 10.3%) rice variety was identified by VIC with mean grain yield of 4.48 t/ha with Zn content (15 ppm) in polished rice for release for Odisha, Uttar Pradesh and Madhya Pradesh. One semi-dwarf aromatic short grain entry, CR Dhan 909 (IET 23193) was also identified for the states of Uttar Pradesh, Bihar, Assam and Maharashtra. Similarly, IET 23189 (CR 2713-35), possessing aromatic, translucent and medium slender grains, was identified for the states of Odisha, West Bengal, UP, Assam and Maharashtra.

Six cultures were identified for release in Odisha. CR Dhan 408 (Chakaakhi), a high yielding variety, was identified for rainfed shallow lowlands of Odisha. Two rice varieties *viz.*, CR Dhan 203 (Sachala) and CR Dhan 206 (Gopinath) were recommended for aerobic situation along with CR Dhan 101 (Ankit) for direct seeded upland condition for the state of Odisha. CR Dhan 307 (Maudamani) with high grain yield was identified for well managed favourable rainfed lowland / irrigated condition of Odisha. CR Dhan 701, country's first late duration hybrid was released for commercial cultivation in state of Odisha. Besides that, eight cultures were promoted to 3rd year of testing and 13 cultures were promoted to 2nd year of testing under the AICRIP trials. A total of 607.27q of Breeder seed was produced comprising 38 varieties and six parental lines during the year.

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 wild and weedy rice germplasm. They are as below.

Exploration and collection of wild species and weedy rices from eleven districts of Jharkhand state namely, Ranchi, Ramgarh, Chatra, Hazaribag, Koderma, Giridih, Deoghar, Dumka, Godda, Pakur and Lohardaga were conducted in collaboration with CRURRS, Hazaribag from 26 October to 2 November 2014 and a total of 46 accessions of wild (*O. nivara* and *O. rufipogon*) and the introgressed/intermediate lines (the weedy rices) were collected. In many places the traditional varieties have completely been wiped out due to extensive adoption of hybrid rice supplied by different private companies. The occurrence of wild rice is very rare in the eastern districts of Jharkhand like Godda, Pakur and Deoghar. The *O. nivara* is found in seasonal ditches which subsequently dry up by the end of rainy season. This annual wild rice species dies after maturity, dispersing all the shattering grains in the same habitat for the next year's appearance again. The typical *O. rufipogon* grows luxuriantly along the shallow water bodies of perennial source of water with underground rhizomatous stubbles and radical leaves which form a mat on the ground in undisturbed fallow lowlands with uneven maturity of its lax panicles. The weedy introgressed lines known as *O. spontanea* are found in cultivated fields as well as in the nearby adjacent marshy lands along the roadside. The introgressed lines are having weak rooting at nodes, robust panicles with long and fully awned spikelets. The grains are highly shattering in nature, fall down with mild touch. The tribals collect these mixed introgressed rices from knee-deep water in undisturbed water bodies for use in several religious rituals.

Collection of perennial wild rice (O. rufipogon) germplasm in Chatra district, Jharkhand

Scientist collecting the wild rice

Collection of annual wild rice (O. nivara) germplasm in Giridih district, Jharkhand

Tribal women showing the red wild rice and white kernels of wild rice

Collection of wild/weedy rice (O. spontanea) germplasm in Ramgarh district, Jharkhand

Another 'wild species and weedy rices' collection programme was conducted in collaboration with NBPGR from 2 to 9 November 2014 from four districts namely, Bilaspur, Jashpur, Raigarh and Raipur of Chhattisgarh and 43 accessions of wild/weedy rices comprising of *Oryza rufipogon* (06), *Oryza nivara* (36) and *Oryza spontanea* (01) were collected from 39 collection sites.

Rejuvenation of the conserved germplasm and the new collections

The core set of 1548 accessions developed from 15000 accessions of rice germplasm was received from NBPGR. They were rejuvenated in the field for maintenance of seed viability, seed increase (for conservation), screening and evaluation against abiotic stresses *viz*., submergence and drought. Seven hundred and twenty (720) genotypes selected from the core set of materials developed under National Rice Resources Database Project were screened under field condition for vegetative stage drought tolerance during *rabi* season of 2014. Drought stress was imposed to 30 days old seedlings and periodical observations on soil moisture content, water table depth and soil moisture tension were recorded. Soil moisture content was reduced to 8 - 10% from initial value of 28-30%. Water table depth depleted to 85-90 cm and soil moisture tension was (-)45 to (-)55 kPa during peak stress period. Out of 720 genotypes screened for vegetative stage drought tolerance, 132 genotypes were completely tolerant with SES score '1', 200 genotypes had moderately tolerant SES score '3', 150 genotypes were with less tolerant SES score '5', 213 genotypes were moderately susceptible with score '7' and 19 genotypes were completely susceptible with SES score '9'. However, five genotypes were observed to be drought avoiding type which flowered just after the onset of stress.

Apart from these, three hundred and nine (309) accessions of wild and weedy rices were grown in the field. The morphological variations among weedy rices were observed and plants showing variations were tagged. All the data of qualitative and quantitative characters were recorded within the variations.

Another set of 5000 accessions of rice germplasm received from NBPGR under CRP Agro biodiversity project were grown for characterization purpose along with 541 newly acquired accessions. All the thirty morphological observation data on nineteen qualitative characters and eleven quantitative characters were recorded at appropriate stages of plant growth and maturity as per the descriptors. These materials were harvested, processed, packed and stored in the gene bank for future use.

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

A total 6406 germplasm including 309 wild and weedy rice were grown for characterization on agro-morphological traits of 30 DUS characters as per the descriptors.

Morphological characterization of released rice varieties

Six hundred rice varieties were collected from different states of India and transplanted in augmented design during *kharif* 2014. The DUS characters both qualitative and quantitative characters were recorded. Leaf length varied from 23.0 cm (Sneha) to 62.4 cm (Hanseswari). Leaf width varied from 0.60 cm (Khandagiri) to 1.85 cm (Varshadhan). The plant height ranged from 50.0 cm (CSR-10) to 170.4 cm (Nalini). Days to fifty per cent flowering varied from 51 days (Kalyani-2) to 139 days (Varshadhan). Panicle length ranged from 16.2 cm (CSR-10) to 33.0 cm (Basmati 564). The varieties *viz.*, Basmati 564, Pusa Sugandha-3, Ranbir Basmati, Pravathi, Rambha, Nua dhusara, Sonamani, Basmati 370, Nua kalajeera were having long panicles i.e >30.0 cm. Panicle weight varied from 1.0 g (Subhadra) to 5.4 g (Golak). Heavy panicles (>5.0 g) were observed in the varieties like Dandi, Pusa Sugandha-5, Mandakini, Mahalaxmi, Matangini, Padmanath, Jogen, Purnendu and Mandya vijay. The high grain number (>250) was observed in Mahsuri, Ramchandi, CO-45, Nalini, MTU 1075, Purnendu, CR 1014, IET 17400, Pavitra, WGL 32100. Thousand grain weight was found to be highest in Bhalum-2 (35.0 g) and lowest in Palghar-2 (11.0 g). The grain yield was high in varieties like CO-25 (10 t/ha) followed by CO-2 (9.0 t/ha) and CO 40 (8.5 t/ha).

Assessment of genetic variation in weedy rice and wild rice found in Ganjam district as revealed by SSR markers

Genetic variation in different accessions of 19 weedy rice, 14 wild rice (*O.rufipogon* and *O. nivara*) and 8 cultivated rice collected from 10 locations of Ganjam district in Odisha such as Beguniapada, Kodala, Buguda, Polsara, Aska, Hinjilikatu, Berhampur, Digapahandi, Purushottampur and Huma were selected to assess the genetic variation using STMS markers. A total of 104 alleles with an average of 3.58 per locus ranging from 100 to 500 bp were generated by 29 STMS markers (Fig. 1.1). This observation amply suggested that the genotypes selected for this study harbored enough genetic divergence.

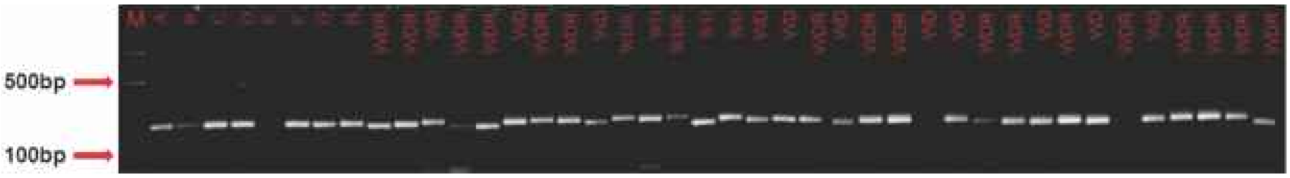


Fig. 1.1. Allelic polymorphism revealed by STMS marker (RM 3501). M:100 bp DNA ladder; A- Swarna Mahsuri, B- Punji Mahsuri, C- Pooja, D- Tikki Mahsuri, E- Maa Mahsuri, F- Cr1001, G- Mahsuri, H- Cultivated "Diesel", WR-Wild rice, WDR-Weedy rice.

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

Six thousand four hundred and six (6406) accessions of rice germplasm were rejuvenated for conservation. These materials included 5532 accessions taken out from gene bank, 568 varieties of DUS testing materials and farmer's varieties and 306 accessions of newly collected wild and weedy rice germplasm. They were conserved in pouches at gene bank of NRRI for Medium Term Storage (MTS).

Five thousand two hundred seventy nine (5279) accessions of rice germplasm/elite lines/ donors/ varieties were supplied to different researchers all over the country and also to the Institute scientists for their screening, evaluation and utilization. Out of 5279 accessions, 458 were shared with different institutes/ organizations through proper signing of Material Transfer Agreement (MTA).

Maintenance Breeding and Seed Quality Enhancement

Panicle progeny rows of 40 varieties were grown for maintenance breeding, during the year 2014 (Table 1.1). After thorough rouging of the border rows, rejection of the variant progeny lines and true to the type panicles were selected and harvested separately. They were threshed separately and after table top examination the finally selected progeny lines were bulked as nucleus seed. The nucleus seeds were used for the production of Breeder seed.

Keeping an eye on the DAC indent, breeder seed of 40 varieties and six parental lines were grown. A total of 607.27 q of breeder seed were produced (Table 1.2).

Participatory seed production

Under National Seed Project, participatory seed production of the variety Pooja and Gayatri (CR Dhan 1018) had been taken up with Mahanga Krushak Vikash Manch in an area of 80 acres and 20 acres respectively, at Goudagop, Mahanga, Odisha with involvement of the farmers and under the supervision of NRRI scientists.

After checking the quality, 874.368 quintals seed that qualified TL seed standard were procured back from the Mahanga Krushak Vikash Manch, which after processing were sold to the farmers as TL Seed.

Table 1.1 : Panicle progeny rows evaluated and selected for nucleus seed

Variety	Panicle progeny evaluated	No. of progeny lines selected
Swarna - Sub1	490	427
Pooja	487	460
Varshadhan	418	375
Gayatri	425	395
CR Boro Dhan 2 (Chandan)	400	358
Geetanjali	460	387
CR 1014	400	347
CR Dhan 70 (Hanseswari)	246	225
Annada	418	327
CR Dhan 10 (IET 18312)	440	364
CR Dhan 401 (Reeta)	250	212
CR Dhan 500	245	195
Khitish	475	397
CR Sugandhdhan 3 (Nua Dhusara)	250	170
Dharitri	285	240
Shatabdi (IET-4786)	450	398
Ketekijoha	395	355
Savitri	380	328
Phalguni (IET 18720)	200	138
Sahabhagidhan	235	195
Luna Suvarna	200	161
Luna Sampad	200	152
Lunishree	200	160
Moti	300	244
Nua Chinikamini	250	220
Ratna	375	357
Nua Kalajeera	250	212
Sarala	400	330
CR Dhan 405 (Luna Sankhi)	250	200
Tapaswini	250	212

Utkalprava	400	335
Jaldi Dhan 6	250	201
Durga	250	210
Ranjit	250	201
CR Dhan 300	250	197
CR Dhan 301	250	195
CR Dhan 404 (Sumit)	250	203
CR Dhan 505	250	207
Padmini	300	263
CR Dhan 501	300	253

Table 1.2: Breeder seed production of rice varieties during the year 2014

Variety name	Production during *rabi* 2013 - 14 (q)	Production during *kharif* 2014 (q)	Total Production (q)
Swarna - *Sub1*	70.00	207.00	277.00
Pooja	-	89.40	89.40
Varshadhan	-	22.80	22.80
Gayatri	-	10.50	10.50
CR Boro Dhan 2 (Chandan)	10.00	-	10.00
Geetanjali	3.50	7.50	11.00
CR 1014	-	3.00	3.00
CR Dhan 70 (Hanseswari)	-	1.20	1.20
Annada	3.00	-	3.00
CR Dhan 10 (IET 18312)	8.00	-	8.00
CR Dhan 401 (Reeta)	-	3.90	3.90
CR Dhan 500	-	3.00	3.00
Khitish	17.00	5.40	22.40
CR Sugandhdhan 3 (Nua Dhusara)	-	1.20	1.20
Dharitri	-	3.30	3.30
Shatabdi (IET 4786)	35.00	-	35.00
Ketekijoha	-	9.60	9.60
Savitri	-	22.50	22.50
Phalguni (IET 18720)	1.00	-	1.00
Sahabhagidhan	6.00	-	6.00
Luna Suvarna	-	0.90	0.90
Luna Sampad	-	1.20	1.20
Lunishree	-	6.30	6.30
Moti	-	2.10	2.10
Nua Chinikamini	-	1.50	1.50
Ratna	8.00	-	8.00
Nua Kalajeera	-	1.20	1.20
Sarala	-	13.20	13.20
CR Dhan 405 (Luna Sankhi)	1.50	-	1.50
Tapaswini	-	0.15	0.15
Utkalprava	-	3.60	3.60
Jaldi Dhan 6	1.00	-	1.00
Durga	-	3.30	3.30
Ranjit	-	1.80	1.80
CR Dhan 300	-	1.80	1.80
CR Dhan 301	-	0.60	0.60
CR Dhan 404 (Sumit)	-	3.00	3.00
CR Dhan 505	-	2.40	2.40
CRMS 31 A	2.42	-	2.42
CRMS 31 B	1.50	-	1.50
CRMS 32 A	1.70	-	1.70
CRMS 32 B	1.20	-	1.20
IR 42266-29-3R	1.75	-	1.75
CRL 22R	1.35	-	1.35
Grand Total (in quintals)	**173.92**	**433.35**	**607.27**

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

Six new crosses were made using *O. meridionalis* (AC 105290) as donor parent to improve yield, and panicle characters of Swarna and MTU 1010. BC_1F_1 of Swarna/*O. rufipogon*(IRGC 105491) /Swarna, Apo/ *O. rufipogon* (IRGC 105491)/Apo and CR 1009/ *O. rufipogon* (IRGC 105491) /CR 1009 were generated and grown in the net house for further back crossing and generation advancement. Fifty selections were made from twenty two (BC_2F_6) populations of Apo/*O. nivara* (AC 100476), CR 143-2-2/ *O. nivara* (AC 100374), Lalat/ *O. nivara* (AC 100476) and IR 64/ *O. nivara* (AC 100476) derivatives. Twenty advance breeding lines of wide cross *O. nivara* derivatives were evaluated for yield and other traits under aerobic condition and the following genotypes i.e. CR 22 (CR 143-2-2/*O. nivara* (AC 100374)) (5.4 t/ha), CR 27 (IR 64/*O. nivara* (AC 100476)) (5.04 t/ha), CR 30 (Lalat/*O. nivara* (AC 476)) (5.5 t/ha), LB 35 (Apo/*O. nivara* (AC 476)) (5.05 t/ha) and LB 45 (Lalat/*O. nivara* (AC 476)) (5.06 t/ha) were found promising.

Ten new disomic plants were selected from thirty BC_2F_2 populations of CR1009/*O. brachyantha*//CR1009. Thirty five advanced generation lines (BC_2F_6) of CR1009/*O. brachyantha*//CR1009 were evaluated for yield and yield related traits along with three checks (Apo, Swarna and Savitri) in RCBD. Eleven promising lines of CR1009/*O. brachyantha*//CR1009 were identified based on various yield attributing characters. Maintenance of wild rice donors such as *O. nivara* (AC 100476, AC 100374) for drought, *O. brachyantha* (AC 1086) for YSB, *O. rufipogon* (AC 100174, AC 100444) for BPH, *O. meridionalis* (AC 105290) for yield under drought and *O. rufipogon* (IRGC 105491) for grain yield was done in the net house. The wide cross derivatives of different morphotypes i.e. large panicle, high biomass, hardy /narrow stem, profuse tillering, narrow leaves and broad leaves were also maintained. Seven new BC_2F_1 plants (CR 1009/*O. brachyantha*//CR 1009) were produced and grown in the net house for further recording of both morphological and cytological characters.

Screening and generation advance for YSB tolerance

Screening of 28 entries comprising of 25 pre-breeding lines of CR 1009/*O. brachyantha* (AC 1086), *O. nivara* (7) and *O. rufipogon* (DS 04) along with one susceptible check TN 1 were undertaken during *kharif* 2014. At vegetative stage, ten neonate of yellow stem borer were released in each pot and replicated five times. Two entries *viz.*, B2 11(4.8%) and DS 04 (6.1%) showed damage score of 1 as against the susceptible check TN1 (43.3%) with damage score of 7 (Table 1.3).

The identified 13 derivatives (BC_2F_4) of *O. sativa*/*O. brachyantha*//*O. sativa* were screened against freshly hatched larvae of YSB. The identified plants were selfed and seeds were harvested for further testing. The identified moderately YSB tolerant (#506) genotype was again crossed with tolerant Ratna and F_1 has been generated for further screening.

Table 1.3: Reaction of yellow stem borer, *Scirpophaga incertulas* to the derivatives of CR 1009/ *Oryza brachyantha* in net house

Damage Scale	Level of damage (% Dead heart)	No. of genotypes	Pre-breeding lines
0	No damage	Nil	-
1	1-10%	2	B2 11, DS 04
3	11-20%	9	B2 17, B2 23, B2 10, B2 24, *O. nivara* (7), B2 25, B2 6, B2 27, B2 36
5	21-30%	1	B2 24
7	31-60%	9	B2 15, B2 2, B2 7, B2 28, B2 26, TN 1, B2, YSB-R, B2 36
9	61% and above	7	KB 502, KB 505, KB 506-6, KB 506-7, KB 506-2-24, KB 506-2-25, KB 514

Screening and generation advance for BPH resistance

F_1s (Swarna/*O. rufipogon* (AC 100174)) and BC_1F_1 (Swarna/*O. rufipogon* (AC 100174) /Swarna) were again screened against BPH along with parents. The F_1 was resistant whereas BC_1F_1s were susceptible to BPH (Fig. 1.2).

Fig. 1.2. Screening of wide cross derivatives for resistance to brown plant hopper

Screening for sheath blight resistance

Thirteen accessions of *O. rufipogon* along with susceptible check Tapaswini were artificially inoculated with the virulent isolate of sheath blight pathogen, *Rhizoctonia solani* Kuhn by inserting five sclerotial bodies with bits of mycelia inside leaf sheath in earthen pots under net house condition. The earthen pots were properly covered with large perforated polythene bags with regular watering. The development of disease symptoms was critically recorded with regards to time taken for expression of sheath blight symptoms. All the thirteen accessions of *O. rufipogon* were found to be infected by the virulent isolate of *R. solani* taking 3-7 days for producing sheath blight symptoms. *O. rufipogon* accessions *viz*., AC 100015, AC 100263 and AC 100444 along with susceptible check Tapaswini took minimum three days for sheath blight symptom expression, whereas the accessions *viz*., AC 100034 and AC 100493 took maximum seven days for producing initial symptoms. Sheath blight incidence with disease score of 2.7 & 3.1 were found in AC 100444, AC 100015 and AC 100263, respectively. Maximum disease score of 6.3 was observed in AC 100045 followed by AC 100047 with score of 6.1 and AC 100174 with a score of 6.0. Two accessions *viz*., AC 100444 and AC 100015 showed moderate resistant reaction while three accessions AC 100263, AC 100005 and AC 100493 were found to be tolerant against sheath blight pathogen, *R. solani* (Table 1.4). Rest eight accessions of *O. rufipogon* showed susceptible reaction. The susceptible check Tapaswini showed disease score of 7.5 .

Table 1.4: Screening of *O. rufipogon* accessions against sheath blight

Sl. No.	Accessions of *Oryza rufipogon*	Reaction to Sheath blight	Time taken for disease symptoms appearance (in days)	Mean disease score*	Reaction
1	AC 100005	+	4	3.4	T
2	AC 100015	+	3	2.7	MR
3	AC 100019	+	6	5.2	S
4	AC 100033	+	5	5.6	S
5	AC 100034	+	7	5.2	S
6	AC 100045	+	5	6.3	S
7	AC 100047	+	4	6.1	S
8	AC 100168	+	5	5.3	S
9	AC 100174	+	6	6.0	S
10	AC 100263	+	3	3.1	T
11	AC 100444	+	3	2.3	MR
12	AC 100493	+	7	3.8	T
13	AC 100494	+	5	5.3	S
14	Tapaswini (susc. check)	+	3	7.5	HS

* 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 (7.1-9.0)

Development and validation of molecular markers capable of detecting alien genome introgression in *Oryza sativa* from *Oryza brachyantha*

African wild rice, *O. brachyantha* (FF), is a distant relative of cultivated rice, *O. sativa* (AA), which potentially carry useful genes to control several pests and diseases. But, molecular marker assisted alien gene introgression from this wild species to domesticated counterpart is largely impeded due to the scarce availability of polymorphic molecular markers in the existing literature that can clearly distinguish these two species. Genomic distance between these two species is the major factor that limits the inter-specific cross-transferability of the markers. Nevertheless, the availability of the whole genome sequence (WGS) of both the species provide a unique opportunity to develop markers which are cross-transferable and can be utilized for molecular screening. Utilizing the WGS information available in both the species, a set of PCR based (STS and CAPS) co-dominant polymorphic markers, distributed on the 12 rice chromosomes was designed (Table 1.5, Fig. 1.3). Usefulness of these markers was demonstrated by validation of a Monosomic Alien Addition Line (MAAL) carrying chromosome 1 of *O. brachyantha* in *O. sativa* background (Fig. 1.3).

Table 1.5: Target genes, physical positions and amplicon/ fragment size of the chromosome polymorphic STS and CAPS markers cross-transferable between *O. sativa* and *O. brachyantha*

Marker IDs	Target genes (MSU IDs)	*O. sativa*			*O. brachyantha*		
		†Chr.	Physical Position (Mb)	‡ Size (bp)	†Chr.	Physical Position (Mb)	‡ size (bp)
STS.01g4.4	LOC_Os01g08780	1	4.4	747	1	3.2	507
STS.01g8.8	LOC_Os01g15660	1	8.8	471	1	7.0	503
STS.01g24.7	LOC_Os01g43320	1	24.7	1547	1	18.3	1320
STS.01g33.4	LOC_Os01g57840	1	33.4	208	1	25.8	254
STS.02g0.1	LOC_Os02g01010	2	0.1	390	2	0.02	475
STS.03g25.1	LOC_Os03g44660	3	25.1	461	3	20.2	507
CAPS.04g32.0	LOC_Os04g53700	4	32.0	184 & 426	4	18.6	611
CAPS.05g20.9	LOC_Os05g35360	5	20.9	209 & 110	5	13.3	319
CAPS.06g3.2	LOC_Os06g06810	6	3.2	265 & 237	6	2.3	502
STS.07g29.3	LOC_Os07g49010	7	29.3	307	7	18.3	288
STS.08g14.4	LOC_Os08g23790	8	14.4	258	8	8.4	277
CAPS.09g22.9	LOC_Os09g40000	9	22.9	267 & 393	9	14.1	670
STS.10g15.6	LOC_Os10g30100	10	15.6	1350	10	8.8	2667
STS.11g8.8	LOC_Os11g15520	11	8.8	311	11	5.4	669
STS.12g27.5	LOC_Os12g44390	12	27.5	1246	12	15.3	1306

† chromosome
‡ amplicon size in case of STS markers andfragment size in case of CAPS marker
Markers marked in yellow were used only for validation

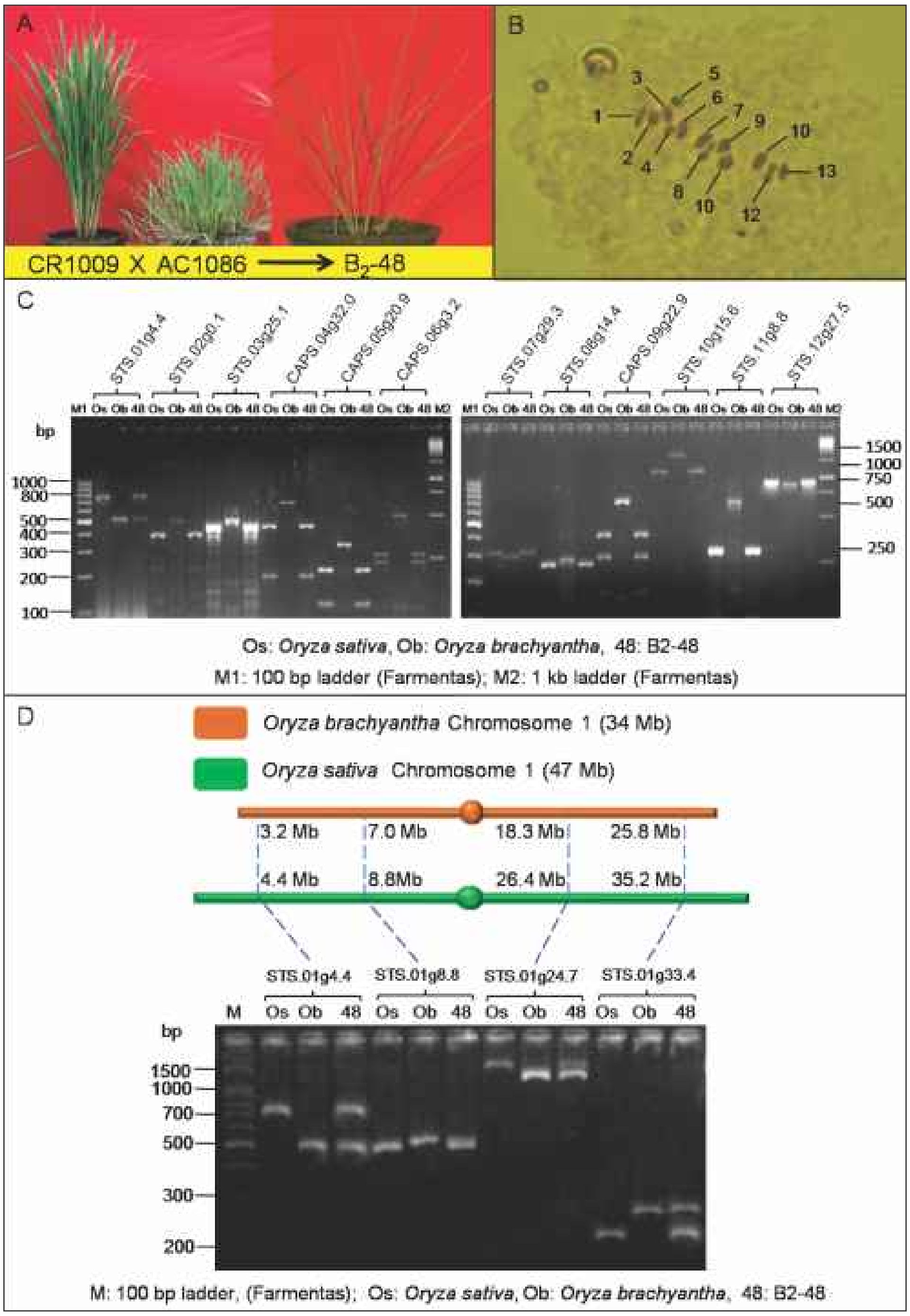


Fig. 1.3. Validation of Monosomic Alien Addition Line (MAAL) B2-48 using newly developed STS and CAPS markers cross-transferable between O. sativa and O. brachyantha

A. Photographs of recipient parent *O. sativa* var. Savitri (CR 1009), donor parent *O. brachyantha* (AC 1086) and MAAL B2-48.

B. Compound light microscopic view of meiotic stage metaphase I chromosome preparation of B2-48 depicting 12 bivalents and 1 monovalent (bivalents and monovalent are not distinguishable separately), making the total to 13.

C. Molecular screening of B2-48 along with its parents suggests it carries chromosome 1 of *O. brachyantha* along with complete complement of *O. sativa* chromosomes.

D. Use of four chromosome spanning markers further validates the fact that B2-48 is really endowed with chromosome 1 of *O. brachyantha* as the alien chromosome.

Hybrid rice for different ecologies

Source nursery

A set of 1126 diverse breeding lines/ varieties including male sterility sources were maintained in source nursery. Out of these, 500 lines were screened for presence of restorer *(Rf)* genes where 287 lines were found with Rf positive (67 with *Rf 3* & *Rf4*, 103 with *Rf4* and 117 with *Rf3* only).

Identification of new CMS source

Identification of new CMS source and broadening the genetic base of parental lines are essential to boost up the present hybrid research and face the future challenges. In this regard, 100 new test crosses between 50 wild accessions and two strong restorers of WA–CMS (IR 42266-29-3R and Pusa 33-30-3R, positive for *Rf3* and *Rf4*) were made for prospective evaluation.

Identification of maintainer, restorer and new hybrid combinations

To test the combining, maintaining and restoring ability of genotypes, altogether six hundred thirty seven test crosses involving five CMS (CRMS31A, CRMS32A, CRMS51A, APMS6A and PMS 17A) were evaluated during 2014. The evaluation result indicated that 63 lines were promising maintainers and 46 lines were effective restorers (restored > 85% fertility in their correspondent F_1). Twenty three, out of 46 identified restorers were good combiners with CRMS 31A and CRMS 32A. A total of 712 new test crosses (involving six CMS lines, CRMS31A, CRMS32A, CRMS 24A, CRMS51A, PMS 17A & APMS 6A) were generated during *kharif*- 2014 (Table 1.7).

Table 1.6: List of promising restorers

CR 716-30-1-1-1, IR 83140-B-36-B, CRL 20R, CR 680-23-4, CRL 100R, CR 1300-301-6, CRL 1450-10-1, CRL 305R, CRL 353R, CR 870-73-7, Akshaydhan, CRHR 4-1048-7, CRL 2R, CRL 110R, CR 870-53-1, CR 1420-61-5, CRHR 3-786-15, CRL 312R, CR 179-16-1, CRHR 15-700-53, CRL 237R, Pant Sugandh 21, Pusa 834, AVT 2-107/3604, CR 1830-8-1-1, Azucena, CR 1830-115-1, CR 1530-18-3-3, CR 1478-36-1-1, CR 2050-136-1-1, CR 690-138-3-3, CR 1520-140-8-1, CRL 143R, CRL 332R, CR 1068-337, CR 1250-6-2, CRL 368R, CRL 359R, CRL 371R, CRL 252R, PANT 12, VIKAS, IET 22781, IET 22753, Pusa 33-30-3, Rajendra Bhagawati.

Table 1.7: Number of test-crosses generated during *kharif* 2014

CMS lines	No. of Crosses
CRMS 31A	356
CRMS 32A	277
CRMS 24A	35
CRMS51A	16
APMS 6A	15
PMS 17A	13
Total	**712**

Fig. 1.4. Seed setting in manually crossed line

Development of new CMS lines

During *kharif*-2014, sixty five backcrosses (BC_2-BC_8) and 15 new sterile test crosses were advanced in their backcross generation. Four late duration, short statured plants were selected from anther culture derivatives (diploids) of cross combinations, CRMS 31B/ CRMS 24B and CRMS 32B/ CRMS 24B and test crosses were made to develop late duration CMS lines. All were evaluated during *kharif* 2014, from which three promising sterile F_1s were advanced to BC_1F_1. Some of the promising lines with stable male sterility, good out crossing, good floret opening, along with appreciable panicle and stigma exsertion are listed in (Table 1.8).

Table 1.8: Promising sterile backcross derived lines advanced during 2014

S.No.	BCN No.	Recurrent parent	Source of cytoplasm	Remarks
1	$BCN^{8}12A$	HR 26-73	WA	Medium duration
2	$BCN^{8}17A$	HR 34-7	WA	Medium duration
3	$BCN^{8}39A$	CR 2234-75	WA	Medium duration
4	$BCN^{7}52A$	PS 92B(69) (Kalinga-I)	Kalinga-I	Purple leaf
5	$BCN^{7}71A$	CRMP 2-1-614(79)	WA	Medium duration
6	$BCN^{8}166A$	Shatabdi	WA	Short duration
7	$BCN^{8}206A$	Abhishek	WA	Short duration, drought tolerant
8	$BCN^{7}199A$	CR 2234-1020 (WA)	WA	Good floret opening
9	$BCN^{7}200A$	CR 2234-1020	Kalinga-I	Good floret opening
10	$BCN^{6}99A$	A 180-12-1(87)	WA	Short duration, drought tolerant
11	$BCN^{7}187A$	Sahabhagidhan	WA	Short duration, drought tolerant
12	$BCN^{7}180A$	CR 2234-834(WA)	WA	Good floret opening and stigma exsertion
13	$BCN^{5}140A$	IR 68301-11-64-3-6-6	Kalinga-I	Complete panicle emergence
14	$BCN^{3}212A$	31B-GP-39	WA	31B Gene pyramid with 4 BLB genes
15	$BCN^{3}213A$	32B-GP- 62	Kalinga-I	32B Gene pyramid with 4 BLB genes
16	$BCN^{2}275A$	CRMP1-07-1010	WA	Good floret opening, mid late
17	$BCN^{2}276A$	CRMP1-07-1010	Kalinga-I	Good floret opening, mid late
18	$BCN^{2}278A$	Kuderat 2	WA	Medium duration
19	$BCN^{2}279A$	Kuderat 2	Kalinga-I	Medium duration
20	$BCN^{2}346A$	CR 172	WA	Late duration
21	$BCN^{1}121A$	CRRP 1	WA	One time more floret opening
22	$BCN^{1}118A$	CRHR 330-1	WA	Complete panicle emergence

Transfer of bacterial blight resistance genes into CMS/restorer lines

In order to improve the desirable parental lines with specific trait (s), MAS based introgression breeding 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 CRL 22R and in IR 42266-29-3R were advanced to BC_2F_1 generation. Improved CRMS 31B, CRMS 32B and IR 42266-29-3R lines were recovered with 93%, 99% and 91% background of recurrent parents respectively. The four pyramided genes in CRMS 31B and CRMS 32B lines were further transferred to their respective CMS lines which were found to be homozygous in BC_2F_1 generation.

Transfer of *Sub-1* and *Saltol* genes into maintainer lines

For the better performance under the abiotic stresses such as lowland and salinity conditions, CRMS 31B and CRMS 32B were introgressed with the *Sub-1* and *Saltol* genes from the donor parents, Swarna *Sub-1* and FL 478 lines, respectively. To combine *Saltol* and *Sub1* in same genetic background, BC_2F_1 Saltol of CRMS 32B and BC_1F_1 *Sub 1* of CRMS 32B were intercrossed to pyramid both the genes into the same background and further backcrossed with the recurrent parent up to BC_3F_1 generations followed by selfing to generate BC_3F_2 population. Foreground selection was carried out using five markers such as AP3206, RM8094, RM493, RM10793 and RM10843 for *Saltol* consisting of three loci (SKC; LOC_Os01g20160, Pectin esterase; LOC_Os01g21630 and SalT; Loc_Os1g24718) localized on the 5Mb genomic fragment of the chromosome 1 (Fig. 1.5). In case of *Sub-1* genes, the gene based markers (IYT3 and Sub1BC2) for foreground selection and flanking markers (RM8300 and RM23911) were used for recombinant selection in the BC_3F_2 population to avoid linkage drag (Fig. 1.6). Out of the 170 BC_3F_2 segregants, a total of 33 lines were found to be positively introgressed with both the *Sub-1* and *Saltol* genes in CRMS 32B background which may be further analyzed for agronomic performance in the field. Similarly, CRMS 31B was also introgressed with *Saltol* and *Sub1* genes in same fashion like CRMS 32B.

An attempt was also made separately to introduce *Saltol* and *Sub1* in CRMS 31B-MAS and CRMS 32B-MAS which were already pyramided with four BLB resistance genes. These were further advanced to BC_1F_1 generation during *kharif* 2014.

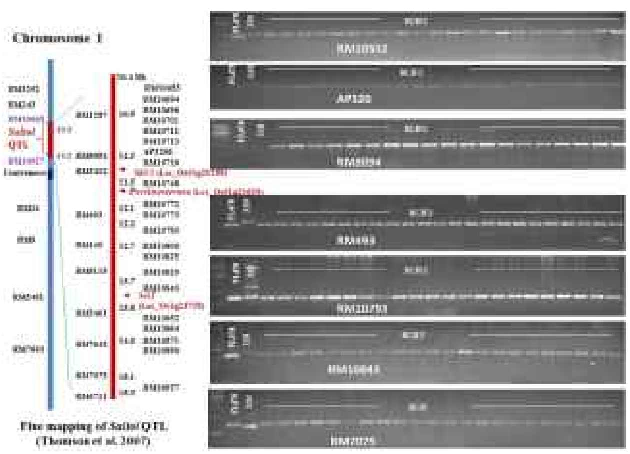


Fig. 1.5. Depiction of Saltol gene introgression in BC_3F_2 population in comparison with parental lines, Fl478: donor; CRMS32B: recurrent parent, BC_3F_2: showing 22 representative plants.

Restorer and maintainer breeding

In order to diversification and improvement of parental line, a total 1911 single plant progenies generated through recombination breeding (from 68 crosses; AxR, RxR and BxB) were evaluated in pedigree nursery. Out of these, total twenty one desirable fixed lines (F_8-F_9) were selected and would be evaluated under station trials. In addition, 56 promising lines were used in crossing programme.

Diversifications of parental lines were also taken up

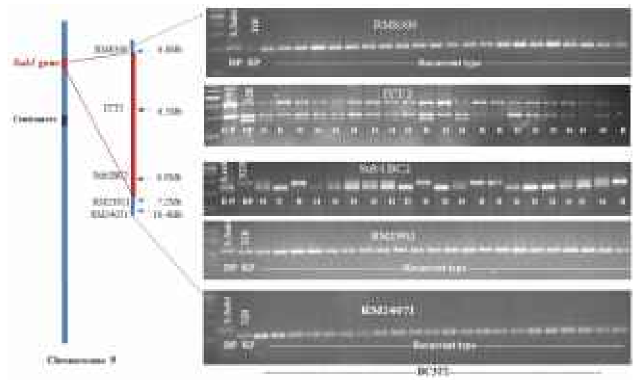


Fig 1.6. Depiction of Sub-1 gene introgression in BC_3F_2 population in comparison with parental lines, FL478: donor; CRMS32B: recurrent parent, BC_3F_2: showing 22 representative plants.

through genetic male sterility (GMS) based recurrent selection, a population improvement approach. In this fashion, four random mating maintainer populations (each population was constructed with five maintainers of a specific trait) and two medium duration random mating restorer populations (each with five well combiner restorers) which were in 4th random mating generation were grown during *rabi* 2013. During *kharif* 2014, 5th random mating generation of the same populations were grown and next random mating cycles were constituted for *rabi* 2014. During *rabi* 2014, one new restorer and maintainer population was generated and evaluated; their next random mating cycle was constituted. During *kharif* 2014, twenty eight new F_1 combinations of GMS with 10 promising restorers and 18 of maintainers were generated.

Development of iso-cytorestorer

To overcome the ill effect of sterile cytoplasm of CMS in hybrids, a total of 96 fertile iso-cytoplasmic restorers of six AxR hybrids were developed and being utlized in crossing programme. During 2014, total 15 crosses of five iso-cytoplasmic restorers with CRMS 31A, CRMS 32 and CRMS 51A were evaluated. Phenotyping of F_1s indicated that the crosses involving these lines expressed 5-6% more heterosis than original parent (hybrids) of respective iso-cytorestorer. Among them, CRHR 3-786-15, derivative of CRMS 31A/ Purnendu F_1 has shown good combining ability with CRMS 31A and CRMS 32A in terms of per plant yield i.e. 53.0g (in TCN 20 with CRMS 31A) (Fig. 1.7) and 49.0g grains/plant with CRMS 32A, respectively.

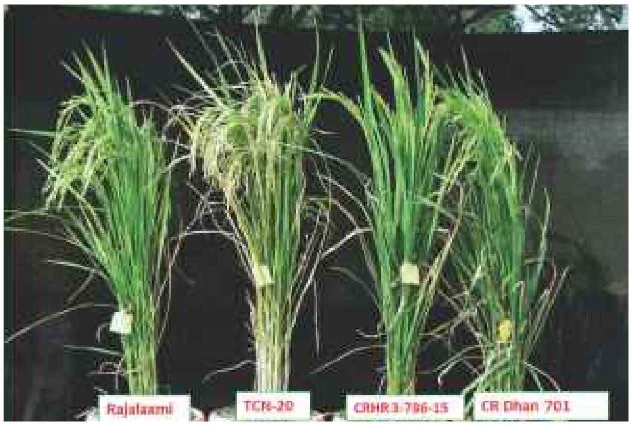


Fig. 1.7. Single plant view of hybrid CRHR 107 (TCN 20) in comparison with parent and standard hybrids

Maintainers (B line) improvement through DH approach

In order to develop genetically diversified CMS with enhanced outcrossing features *viz.*, stigma exsertion and complete panicle emergence, a total of sixty one DHs derived from two maintainer recombinants (CRMS 32B x RTN 12B and CRMS 32B / IR 79156B) were selected and evaluated. These lines would be tested for their maintainer ability and for new CMS development.

Evaluation of fertility restoration efficacy for *Rf3* and *Rf4* genes

To assess the fertility restoration efficiency of *Rf3* and *Rf4* genes, four groups *viz.*, Group-I (*rf3rf3rf4rf4*), Group-II (*Rf3Rf3Rf4Rf4*), Group-III (*Rf3Rf3rf4rf4*) and Group-IV (*rf3rf3Rf4Rf4*) were categorized based on allelic status of *Rf3* and *Rf4* linked markers. Ten varieties from each group were chosen and test crossed with two different CMS lines, *viz.* CRMS 31A (containing WA cytoplasm) and CRMS 32A (containing Kalinga cytoplasm). All the resultant F_1s along with parental lines were evaluated for spikelet fertility. The presence of dominant alleles of both the restorer genes was more effective in fertility restoration. However, the efficacy of *Rf4* is relatively more than *Rf3*. In contrast, two varieties carrying recessive alleles of both the restorer genes were also able to restore fertility indicating the involvement of other fertility restorer gene(s) apart from *Rf3* and *Rf4* genes.

Transcriptome analysis of two NRRI rice hybrids, Ajay and Rajalaxmi using RNA-Seq

Transcriptomes analysis of Ajay, Rajalaxmi and their parental lines, CRMS 31A, CRMS 32A and IR 42266-29-3R in two developmental stages, panicle initiation (PI) and grain filling (GF) were done. About 293 and 302 million hi-quality paired-end reads of Ajay and Rajalaxmi were generated and aligned against the Nipponbare reference genome. Similar pattern of transcriptome profiles were found between Ajay and its female parent CRMS 31A at PI stage and between Ajay and its restorer parent IR 42266-29-3R at GF stage. In contrast, the transcriptome profiles of Rajalaxmi were dissimilar to both the parents at PI stage, though it was similar to its male parent IR 42266-29-3R at GF stage. These observations are consistent with morphological observations, where the hybrids look similar to the female parent at panicle initiation stage and to the male parent at the grain filling stage. Transcriptome profiling of Ajay revealed 2814 and 4819 differentially expressed genes (DEGs) at PI and GF stages, respectively as compared to its parents. In case of Rajalaxmi, 660 and 5264 DEGs were identified at PI and GF stages, respectively. The transcription factors like WRKY, NAC, bHLH, Myb, ERF, HSF, C2H2 and RAV etc. were expressed in both the stages in two hybrids as compared to their parental lines. KEGG pathway analysis indicated significant DEG enrichment in photosynthesis, oxidative phosphorylation and carbon fixation at panicle initiation stage, whereas carbohydrate metabolism related pathways (glycolysis and starch and sucrose metabolism) at grain filling stage. Most of the genes involved in energy metabolism, exhibited upregulation at PI stage whereas genes involved in carbohydrate biosynthesis had higher expression in GF stage. Moreover, ABA responsive element binding factors and Ethylene receptor genes (ETR) were down regulated in both the hybrids. This could be the reason for higher yield and vigour in rice hybrids. By correlating DEGs with yield-related quantitative trait loci (QTL), a potential relationship between differential gene expression and phenotypic changes were revealed. The identification of DEGs at panicle initiation and grain filling stage further extended the understanding of the complex molecular and cellular events which may provide the foundation for unraveling the hidden mechanism of heterosis.

Seed production of hybrids

During the reporting period, truthfully labled seeds of eight hybrid combinations, Rajalaxmi (CRHR 5)(290 kg), Ajay (CRHR 7) (240 kg), CR Dhan 701 (CRHR 32) (85 kg), CRHR 100 (28 kg), CRHR 101(31 kg), CRHR 102 (30 kg), CRHR 103 (20 kg) and CRHR 104 (18 kg) involving the CMS lines, CRMS 31A and CRMS 32A were produced and distributed to the farmers and research communities.

CR Dhan 701 (CRHR 32) released in Odisha

Based on consistent performance under state multilocation trials, CR Dhan 701, country's first long duration hybrid (Swarna duration) was identified by SVRC for release in the state of Odisha (Fig. 1.8). This has medium slender grains with 6.0-6.5 t/ha average yield capacity; it may serve as a plausible sustitute for popular variety Swarna. This is suitable in low light conditions and has moderate resistance to rice tungro, blight, GLH and leaf blast. This was released and notified earlier for cultivation in states *viz.*, Gujarat and Bihar during 2010.

Fig. 1.8. Field view of newly released long duration hybrid, CR Dhan 701

New promising hybrid combinations

Altogether seven new promising hybrid combinations, with five long duration (140-150 days) (CRHR 100, CRHR 101, CRHR 102, CRHR 103 and CRHR 104) and two short duration (110-115 days) (CRHR 105 and CRHR 106) were found highly promising with yield potential of 6.2-8.0 t/ha under station trial. Among them, hybrid CRHR 100 and CRHR 101 were nominated under IVT-Late in AICRIP 2014.

Table 1.9: Performance of new hybrid combinations under station trial, *kharif*-2014

ENTRY	DFF	PH (cm)	EBT/M2	SF%	PL (cm)	Yield/ha	Grain type
CR Dhan 701	108	108.00	348.00	85.55	28.33	7353	MS
CRHR 100	105	107.67	374.67	84.01	27.5	7497	MS
CRHR 101	114	102.33	337.33	83.87	28.5	7979	LS
CRHR 102	113	101.67	366.33	85.30	27.5	7810	LS
CRHR 103	110	108.00	328.00	87.14	29.5	7802	LS
CRHR 104	111	113.33	372.67	85.07	28.5	8086	LS
CRHR 105	88	99.67	397.67	92.39	27.5	7012	MS
CRHR 106	90	103.33	279.67	91.56	27.5	6934	MS
Ajay	99	109.67	331.00	82.79	28.5	7123	LS
Rajalaxmi	102	111.67	331.33	83.58	29.5	7226	LS
SL8H	90	97.33	364.33	81.74	26.5	6283	LB
CD(5%)						357.40	
CD (1%)						487.45	
CV %						2.84	

Fig. 1.9. Panicles of promising hybrid combinations

Registration of hybrids/ parental lines

During 2014, two hybrids, Ajay (Reg. No. 162) and Rajalaxmi (Reg. No. 206) and one parental line, CRMS 31A (Reg. No. 172) were registered with PPV& FR Authority as extant variety.

Evaluation of AICRIP trials on rice hybrids

During *kharif* 2014, altogether four AICRIP hybrid rice trials *viz.*, MLT of released hybrids, MLT-MS, IHRT-M and HRT-MS were evaluated to identify the suitability of the test entry in Odisha and in eastern region as whole.

Under MLT of released hybrids, total twenty one test entries were evaluated.

Under MLT-MS, total eight test entries which were in mid-late to late duration were evaluated.

Initial Hybrid Rice Evaluation Trial (IHRT-M) was conducted to test the suitability of fresh nomination of medium duration hybrids. Under this trial, total thirty three entries were evaluated.

Hybrid rice trial in medium slender grains cetegory (HRT-MS) was conducted with 18 test entries where HRT-MS-2 (28P09) recorded highest grain yield of 6.7 t/ha followed by MLT-15 (DRRH 85) with 6.4 t/ha (Table 1.5). The length breadth ratio of grains revealed that maximum entries were unedr long slender (LS) cetegory.

IHRT-Early trial was conducted in transplanted condition with 30 entries including checks.

Development of high yielding genotypes for rainfed shallow lowlands

In 2014-15, a high yielding variety, CR Dhan 408 (Chaka akhi) was released by State Variety Release Committee (SVRC) for rainfed shallow lowlands of Odisha state. The variety is a strongly photosensitive genotype and it flowers in 1st week of November. It takes around 160-165 days maturity duration. The plant type is non-lodging with a height of 130-140 cm. It has long bold grain, 250-300 panicles per m^2, moderate tillering (6-9) and having seed test weight of 25.6 g (Fig. 1.10). The cultivar can tolerate one week submergence. The variety also possesses desirable quality characters like high head rice (60%), high milling (68%) and intermediate amylose content (23.03%). The line exhibited moderate resistance reaction against the pests like stem borer, leaf folder, white backed plant hopper and rice whorl maggot attack. It showed moderately tolerance reaction to diseases *viz.*, leaf blast, neck blast, bacterial blight and sheath rot. The culture exhibited superior performance under farmers' field under submergence and moderate waterlogging condition.

Fig. 1.10 (a). Field view of variety CR Dhan 408 at dough stage

Fig. 1.10 (b). Panicles of variety CR Dhan 408

Fig. 1.10 (c). Kernels of variety CR Dhan 408

Ten cultures observed to be suitable for rainfed lowland ecology were nominated for national testing under IVT, RSL trial. Two cultures nominated during previous year were promoted to 2nd year on regional basis. The two cultures are IET 24471(CR 2683-45-1-2-2-1) and IET 24480 (CR 2681-2-3-1-1-1). IET 23561 (CR 3607-11-2-1-1-3) a derivative of Savitri / Sudhir // Varshadhan with short bold grains and 135 days to 50% flowering recorded a mean yield of 4380 kg/ha and yield gain of 9.34, 7.78 and 6.44 % over NC, RC and LC, respectively in the AVT-1, RSL trial. It ranked third in southern region with superiority of 10% over the best check. It has good cooking quality characters like HRR (55.3 %), ASV (4.0), AC (24.14%) and GC (30 mm). It is moderately resistant to neck blast.

Creation of variability through hybridization and backcrossing, selection and evaluation of new and existing segregating materials suitable for rainfed shallow lowlands

Ten F_1s of three way cross were advanced to obtain seeds for F_2 generation. Amongst the three parents of each cross, one line was a tropical japonica derivative; another was submergence tolerant parent (Savitri *Sub1*) with third parent (CR Dhan 300) for good grain quality and better yielding ability. The ten multiple crosses are expected to give a broad spectrum of variability in F_2 generation. The ten different tropical japonica derivatives used in the crossing programme were *viz.*, 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 which were used for their heavy panicle, high grain number, strong culm and for dark and upright top leaves characters.

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

F_1 seeds were generated using parents Savitri *Sub1* and CRMAS 2232-85. Savitri *Sub1* was taken as parent as it has good ideotype for shallow lowland ecology and contains *Sub1* QTL. The other parent CRMAS 2232-85 is a bacterial blight tolerant line possessing three resistant genes *Xa21, xa13* and *xa5* in the background of popular variety, Swarna. The third parent, a drought donor line is combined in a three way cross to get submergence, drought and bacterial leaf light in one background.

Male sterility facilitated recurrent selection for improvement of biotic (BB, stem borer & leaf folder) and abiotic (submergence & drought) tolerance

The F_1 generation was advanced to raise the recombination phase for segregation of the assembled traits in the male sterile background during *kharif,* 2014. Variation was noticed for grain yield traits like panicles/plant, grains/panicle, panicle length, spikelet fertility, 1000-seed weight and bacterial blight tolerance among the segregants. Selection was made among the partially sterile lines on the basis of better panicle traits, field tolerance to bacterial blight disease and leaf folder. Resistance traits and high yield have been incorporated from the donor sources *viz.*, bacterial blight from CRMAS 2232-85, stem borer from Nalihazara, leaf folder from Nadiaphula, submergence from Swarna *Sub1*, drought QTLs from IR64 NIL lines and grain yield from yield gene from two NPT lines. The seeds collected from the sterile lines were bulked to raise the next selection cycle.

Development of mapping population, phenotyping, genotyping and mapping genes/ QTLs for reproductive stage drought tolerance

Three hundred eighty recombinant inbred lines of the cross CR143-2-2/Krishnahamsa were used for phenotyping for reproductive stage drought tolerance. The donor line CR143-2-2 was observed to be a good donor for reproductive stage drought tolerance. The mapping population generated from the donor line hybridizing with the susceptible line Krishnahamsa was in F_8 generation. All the lines were observed to be highly variable with respect to the studied traits. There was wide variation for spikelet sterility, total dry matter at maturity, chlorophyll content of boot leaf at maturity, proline content etc.

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

Seeds of 30 elite cultures and recently released varieties have been increased for various testing experiments like national, state, on station and international trials. The following breeding materials under two AICRIP and two INGER trials have been evaluated at Cuttack during the season.

Trials under International Network for Genetic Evaluation of Rice (INGER)

1. International Rainfed Lowland Observational Nursery (IRLON): The 37th International rainfed lowland observational nursery comprised of 52 test entries and four international check varieties were grown for assessment of the entries based on flowering duration, overall phenotypic acceptability, grain yield and submergence tolerance. Top five entries evaluated were IR 12L186, CT 16658-5-2-3SR-3-1-3MP, IR 12L248, IRRI 163 and IR 12L197.

2. Green Super Rice for Rainfed Lowland yield trial (GSR-RFLL): The GSR-RFLL trial was conducted during wet season, 2014 to evaluate the promising GSR for Cuttack situation. Top five entries evaluated were HHZ 8-*DT10-SAL3-SUB1*, HHZ 11-*DT10-SAL1-SUB1*, HHZ 11-Y6-Y2-*SUB1*and HHZ 11-*DT10-SAL1-SUB1*.

Development of improved genotypes for semi-deep and deepwater ecologies

Identification of new sources of submergence tolerance

Generation advancement of the crosses *viz.*, Swarna-*Sub1*/AC 20431B, Swarna-*Sub1*/IC 258990, Pooja/AC 20431B, Pooja/Kaniar made using submergence tolerant donors (IC 258990, AC 20431B and Kaniar) was taken up during *kharif*, 2014.

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

Three hundred and sixty five single plant progenies (F_4-F_7) from 58 cross combinations along with six F_2 bulks were grown under semi-deep water conditions. At the time of maturity, seven hundred and seventy four single plant selections have been made from 48 cross combinations on the basis of tolerance to water logging, photo sensitivity, plant height, other plant and panicle characters, field tolerance to bacterial blight and stem borer during *kharif*, 2014. Besides, 24 uniform progenies were bulk harvested to see their yield performance in the next season (Table 1.10). Furthermore, eighteen new crosses were made using popular high yielding varieties and stress tolerant genotypes as parents (Varshadhan, Sarala, MTU 1064, MTU 1168, CR 2416-12-1-1-1, CRMAS 2232-71, CR Dhan 500, CR Dhan 501, Jalmani, Jayantidhan, IR 88776-*SUB 8*-1-1-2 and Kaniar).

Selection and generation advancement of available breeding material suitable for deepwater areas

Selection and evaluation of ongoing segregating materials were taken up in F_6 and F_7 generations of deepwater rice breeding programme during *kharif*, 2014. During the season, selection of superior progenies from F_6 and F_7 segregating generations of few crosses were made from the segregating pedigree nursery. Around one hundred plant populations comprising three rows were raised and selections were made within and between lines for bulking of uniform and promising similar lines. A total of 26 promising lines were selected and uniform plants were bulked from the populations of seven cross combinations on the basis of moderate elongation ability, good kneeing ability, high panicle and grain number, photo sensitiveness, plant height, field tolerance to bacterial blight disease and stem borer and leaf folder attack. Further, 51 promising single plants were selected on the basis of above selection criteria and harvested separately from the lines where segregation was observed.

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

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

Forty one advance breeding lines along with eight check varieties were evaluated in a randomized block design with two replications under semi-deep water conditions during *kharif*, 2014. Among the different entries, CR 3052-1-1-5-1 performed the best with an average yield of 4.22 t/ha followed by CR 3063-2-1-9-2 (4.13 t/ha), CR 3061-1-1-4-2 and CR 3063-2-1-12-2 with an average yield of 3.99 t/ha against the best check Varshadhan having yield of 3.96 t/ha (Table 1.11).

Table 1.10: List of breeding materials grown and selections made during *kharif*, 2014

Gen	Progenies/bulks grown	SPS	Bulks selected
F_2	6 bulks	200 (6)	
F_4	100 (3)*	149 (3)	-
F_5	60 (12)	50 (8)	-
F_6	179 (34)	375 (31)	13
F_7	26 (9)	0	11
Total	**365 (64)**	**774 (48)**	**24**

*No. in parentheses indicates no. of crosses

Table 1.11: Performance of entries under station trial during *kharif*, 2014

Entry No	Designation	DFF	DFF (Days)	Pl Ht (cm)	Pan/ sqm	PL (cm)	Gr No/ Pan	Pan wt (g)	Grain yield (t/ha)	Survi-val (%)
16	CR 3052-1-1-5-1	07.11.14	147	104.0	161	24.4	199	3.4	4.22	63.9
31	CR 3063-2-1-9-2	10.11.14	150	126.1	161	22.9	162	2.9	4.13	60.4
23	CR 3061-1-1-4-2	10.11.14	150	168.1	145	24.8	251	4.0	3.99	54.9
34	CR 3063-2-1-12-2	10.11.14	150	133.1	179	24.9	392	4.8	3.99	69.3
44	Varshadhan (C)	13.11.14	153	160.7	224	22.3	308	3.9	3.96	68.0
	LSD (5%)	-	**1**	**3.9**	**49**	**1.8**	**85**	**0.9**	**1.05**	-
	CV (%)	-	**0.4**	**1.6**	**17.7**	**3.6**	**19.2**	**12.2**	**19.6**	-

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

Observational yield trial was conducted during *kharif*, 2014 taking 18 elite fixed lines and three checks in randomized block design with two replications. The performances of 10 entries were observed to be better as compared to the three check varieties. CR 2304-5-7-2-3-1 exhibited highest yield of 4.67 t/ha followed by CR 2687-3-3-1-1-3 with 4.35 t/ha and CR 2682-1-1-5-1-1 with 4.32 t/ha from the station trial. Six deep water rice cultures, CR 2416-12-1-1, CR 2681-147-1-1, CR 2251-1-1-1-3, CR 2679-4-2-1-1-1, CR 3599-3-2-1-1-1 and CR 3604-6-3-1-1-1 are in 3rd year of AICRP trial and exhibiting superiority over the three checks namely Jalmagna, Dinesh and CR Dhan 500.

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 nine entries including three check varieties (Sabita, Purnendu and Varshadhan) were evaluated in a randomized block design with two replications under semi-deepwater conditions. Among the different entries, Entry No. 712 (IET 24490; OR 2436-11) performed the best with an average grain yield of 5.41 t/ha followed by Entry No. 728 (IET 24506; CR 2583-1-1-1-20) with 5.14 t/ha and Entry No. 737 (IET 24514; CR 2582-1-1-1-2) with 4.89 t/ha against the best check Purnendu (3.63 t/ha). All these entries had 70-75% survival against the best check variety Purnendu (62.0%).

Initial Variety Trial- Semi deepwater (IVT-SDW)

Thirteen entries including three check varieties (Sabita, Purnendu and Varshadhan) were evaluated in a randomized block design with two replications under semi-deepwater conditions. Among the different entries, Entry No. 609 (Local check Varshadhan) performed the best (4.25 t/ha) followed by Entry No. 612 (IET 23929; MTU 1168) with 4.19 t/ha and Entry No. 613 (IET 23066; CR 2683-45-2-2-3) with 4.12 t/ha.

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

Eight 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. 508 (IET 23503; CR 2687-2-3-1-1-1) performed the best (4.10 t/ha) followed by Entry No. 507 (Local check Varshadhan) with 3.98 t/ha and Entry No. 502 (IET 23052; CR 3607-12-1-2-1-1) with 3.80 t/ha and Entry No. 505 (IET 23055; CR 2437-B-2-1-1-1) with 3.06 t/ha.

Initial Variety Trial- Deepwater (IVT-DW)

IVT-DW was conducted with 12 test entries generated at different deepwater breeding centers of the country with three check varieties. Highest grain yield of 3.93 t/ha was recorded from test Entry IET 24526 (CR 3607-7-5-4-3-1) followed by 3.92 t/ha and 3.92 t/ha from entry IET 24532 (CR 3607-7-4-3-2-2) and IET 24533 (CRL 76-48-1-2-1-1), respectively. The best check was regional check variety, Dinesh which yielded 3.61 t/ha from the trial.

Advance Variety Trial 1- Deepwater (AVT 1-DW)

AVT 1-DW was conducted with six test entries promoted from the initial variety trial of previous year and three check varieties. Highest grain yield of 4.55 t/ha was recorded from the test Entry No. 904 (IET 23599; CR 2682-1-1-5-1-1) followed by 4.34 t/ha and 3.72 t/ha from Entry No. 905 and Local Check variety CR Dhan 505, respectively.

Advance Variety Trial 2- Deepwater (AVT 2-DW)

AVT 2-DW was conducted with seven test entries promoted from the advance variety trial-1 of previous year and three check varieties. Highest grain yield of 5.28 t/ha was recorded from the entry IET 23010 (CR 3604-6-3-1-1-1) followed by 5.03 and 4.95 t/ha from entry IET 23009 (CR3604-5-2-1-1-1) and IET 23004 (CR 3599-3-2-1-1-1), respectively.

(g) Performance of entries nominated in AICRIP trials during 2014

During the year, one entry IET 22302 (CR 2416-12-1-1-1), a cross between Durga/Hatipanjari with short bold grains is identified as promising for deep water areas of Odisha. It had high HRR (67.8%) and intermediate AC (22.79%), 7.0 ASV and 22 mm GC. It had high Zn content of 26.9 and 22.3 ppm and Fe content of 12.5 and 3.6 ppm in brown and polished rice, respectively indicating that this culture has good nutritional value. It was found to be moderately resistant to bacterial blight and sheath rot.

Three entries viz., IET 23594(CR 2687-3-3-1-1-3), IET 23601 (CR 3835-1-7-2-1-1) and IET 23596 (CR 3836-1-7-4-1-1) tested under AVT1-DW have been promoted to AVT2-DW based on yield superiority and other adaptability parameters. Four entries viz., IET 24519 (CR 2439-B-18-1-1-1-1, IET 24513 (CR 2458-72-6), IET 24518 (CR 3612-1-4-2-1) and IET 24522 (CR 3842-3-1-12-1) tested under NSDWSN have been promoted to IVT-SDW. Similarly, another four entries viz., IET 23066 (CR 2683-45-2-2-3), IET 23895 (CR 2593-1-1-1-1), IET 23934 (CR 3838-1-2-1-4-2) and IET 23906 (CR 2789-9-2) tested under IVT-SDW have been promoted to AVT1-SDW on the basis of overall and regional yield basis. Three entries viz., IET 23053 (CR 2687-2-3-1-1-1), IET 23017 (CR 3605-4-2-1-1) and IET 23052 (CR 3607-12-1-2-1) tested under AVT1-SDW have been promoted to AVT2-SDW.

Breeding rice varieties for coastal saline areas

Development and evaluation of salt tolerant elite lines

Hybridization programme

With the aim of achieving elevated level of salt tolerance, F_2 seeds have been generated from the crosses between new salt tolerant varieties such as Binadhan 8 and Binadhan 10 with high yielding salt tolerant genotypes, developed at NRRI. They are as follows.

a. CR 2814-41-2-1-S-B1-B x Binadhan 10

b. CR 2843-1-S-1-6-B-S-2B-1 x Binadhan 10

c. CR 2838-1-6-3B-S-B-6-1-24-1-B x Binadhan 10

d. CR 2838-1-6-3B-S-B-14-1-1-B x Binadhan 10

e. Luna Sankhi x Binadhan 8

Development of mapping population for detection of QTLs for salt-tolerance

- Two BC_2F_2 populations have been generated from Swarna/Chettivirippu (AC 39389) and IR 64 / Pokkali (AC 41585) crosses.
- DH populations were developed using Pokkali (AC 39416) (tolerant to salinity, anaerobic germination and waterlogging).
- Two RIL populations (F_6) from Swarna/Kamini and Naveen/Chettivirippu (AC 39394) were developed.

Evaluation of breeding population developed for wet season for salinity tolerance at seedling stage

In rabi season 97 breeding lines belonging to F_3 and BC_2F_3 generation derived from nine cross combinations have been raised in two replications at salinity microplot. When susceptible check, IR 29 showed susceptibility symptoms (SES score 9) then 968 tolerant and moderately tolerant single plants have been selected (Fig. 1.11) for salt tolerance at seedling stage (at EC=12 dS/m) and planted in field. They were derived from 11 different cross combination using tolerant donors. They belonged to 11 different cross combinations using tolerant donors, Kamini, FL 478, Chettiviripu, Pokkali, etc.

Fig. 1.11. Salt tolerant backcross derived lines from Swarna/Chettiviripu along with tolerant (FL478) and susceptible (IR29) checks in salinity microplot (EC=12 dS/m)

Table 1.12: Evaluation of advanced breeding lines for grain yield under saline and non-saline condition

Sl No	Designation	Parentage	NRRI*			State farm, Gosaba**			SES score
			Grain yield (kg/ha)	50% flowering	Plant height (cm)	Grain yield (kg/ha)	50% flowering	Plant height (cm)	
1	Luna Suvarna/ Jarava	-	4010	119	135	3250	105	145	7.00
2	IR 83421-6-B-3-3-1-1-CR 3364-S-2B-14-2B	IRRI126/IRRI135	3903	100	114	3750	95	120	7.00
3	CR 2839-1-S-10-B2-B-43-2B	Swarna/FL496	4486	125	123	4375	95	135	7.00
4	CR 2851-1-S-7-2B-1	Gayatri/SR26B	4821	120	113.6	2625	104	130	7.00
5	CR 2839-1-S-11-1-B2-B-46-2B	Swarna/FL496				1875	115	150	7.00
6	CR 2218-41-2-1-1-S-B3-B	Savitri/Pateni	5814	122	115	3125	116	125	7.00
7	CR 2218-41-2-1-1-S-B1-1	Savitri/Pateni	3993	124	116	2250	117	138	7.00
8	CR 2459-23-2-1-1-S-B1-1	Gayatri/Rahspunjar	5104	123	140	2750	117	158	7.00
9	CR 2859-S-B-1-1-2B-1	Varshadhan/FL496	4518	127	145	2375	127	155	7.00
10	CR 2859-S-B-2-1-2B-1	Varshadhan/FL496	6148	124	151	3625	119	166	7.00
11	CR 28141-S-1-6-B-S-B-39-B-1	Naveen/FL478	4412	112	124	4275	100	128	5.00
12	CR2843-1-S-1-6-B-S-B-1	Naveen/FL478	4345	108	122	4125	107	131	5.00
13	IR 84649-81-4-B-B-CR 3397-S-B-1-2B-1	IR05F102/IR66946-3R-156-1-2	4030	115	96	3750	110	105	5.00
14	CR 2839-BC-1-1-S-1-2B-35-B-1	Swarna/FL496	5238	115	112	1	107	120	7.00
15	CR 2840 -1-S-4B-31-B-1	IR64/FL496				4250	116	126	5.00

16	CR 2845-S-1-1-2B-1	Swarna *sub1*/SR26B	4907	125	148	3125	121	125	7.00
17	CR 2845-S-3B-1	Swarna *sub1*/SR26B	4945	124	158	3000	121	141	7.00
18	CR 2851-S-1-2-2B-1	Gayatri/SR26B	4237	125	148	4000	114	136	5.00
19	IR 77660-B-9-1-3-2-1-17-4-1-CR3360-S-4B-1	IR 69726-80-1-3/ IR 64680-81-2-2-1-3	2817	90	115	2000	80	125	7.00
20	CR 2838- SR-27	IR64/FL478	2528	107	111	2375	100	115	5.00
	CD at 0.05		267.8			183.7			

*normal condition (EC=0 dS/m) **soil EC= 2.57-5.60 dS/m, pH= 5.78, date of sowing =10.7.14, date of planting=5/8/14

Evaluation for seedling stage salt tolerance and yield under stress and non-stress of elite lines developed for *kharif*

Among 105 breeding lines were evaluated for salt stress (EC=12 dS/m) at salinity micro plot in *kharif* 2014, 26 were detected tolerant or moderately tolerant as compared to tolerant check FL478. Among them a few lines were detected with high yielding ability at coastal saline area (State farm, Gosaba, Sundarbans) as well as in normal situation at NRRI experimental farm. Some of them are CR 2851-S-1-2-2B-1 (4000 kg/ha, 4237 kg/ha), CR 2814-1-S-1-6-B-S-B-39-B-1 (4275 kg/ha, 4412 kg/ha) and IR 84649-81-4-2B-CR 3397-S-B-1-2B-1 (3750 kg/ha, 4030 kg/ha) (Table 1.12).

Evaluation for survibility and yield performance under salinity stress of advanced breeding lines developed for dry season under controlled condition

A set of 150 fixed cultures derived from Naveen x FL 496, Khandagiri x FL 496 and Annapurna x FL 496 crosses along with two checks (Luna Sankhi and FL 478) were evaluated for salinity tolerance (EC 10-12 dS/m during seedling stage and 6-8 dS/m at reproductive stage) under simulated condition (salinity micro plots) during the dry season 2014. Many genotypes which were found tolerant at seedling stage, showed high degree of sensitivity to salinity stress at reproductive stage and did not flower. Only 18 cultures produced some grain yield under salinity stress. Among them, Luna Sankhi produced highest grain yield both under non-saline and saline conditions (Table 1.13).

Bulk segregant analysis and selective genotyping for identification of QTLs associated with salinity tolerance

AC 41585 was identified as tolerant to salt stress both at seedling and at flowering stages. A backcross derived mapping population (BC_3F_5) consisting of 192 lines was developed from tolerant genotype Pokkali (AC 41585) and susceptible elite cultivar IR64 through 3 repeated backcrossings followed by single seed descent method. Salinity stress (EC=8 dS/m) was imposed on plants of BILs before booting stage. Based on plant yield and yield reduction (yield stability index) under stress highly tolerant and susceptible lines were selected. Highly susceptible (SES score 7-9) and tolerant (SES score 1-3) lines with highest and lowest photosynthetic index recorded 10 days after stress (12 dS/m) were selected for bulk segregant analysis.

Bulk segregant analysis - Sixty polymorphic primers showing polymorphism between parents were used in bulk segregation analysis. No marker could differentiate tolerant bulk and donor AC 41585 from susceptible bulk and susceptible cultivar IR64. In most of the cases, the size of bands/alleles from susceptible and tolerant bulks are similar with IR64. Heterozygote banding pattern was observed in resistant bulks at five SSR loci (Fig. 1.12).

Genotyping of mapping population - Ninety one lines including parents with varying level of tolerance were genotyped with 60 primers and association analysis was done. An association (R= -33) was observed between stability index for grain yield under stress and a hyper variable SSR marker, ssr0663 on chromosome 6 while positive association (R= 0.2) was observed with RM122 on chromosome 5 and RM 22143 on chromosome 7 (Fig. 1.13).

Performance of elite breeding lines for coastal region in all India multi locational testing

Three entries, IET 24426 (CR 2218-41-2-1-1-S-B3-B), IET 24430 (CR 2839-1-S-11-1-B2-B-46-2B) and IET 24434 (IR 83421-6-B-3-3-1-1-CR 3364-S-2B-14-2B) were

Table 1.13: Grain yield based on single plant in saline and non-saline condition

	Yield /plant (g)		
Designation	Control	Salinity	% Reduction in grain yield
CR 3881-4-1-3-7-2-4	2.777	0.250	91.0
CR 3881-5-1-10-1-1-1	0.496	0.281	43.3
CR 3882-1-1-11-2-3-1	0.994	0.490	50.7
CR 3882-1-1-8-2-3-1	1.173	0.107	90.9
CR 3882-7-1-6-2-1-2	0.854	0.031	96.4
CR 3882-7-1-6-2-1-4	0.874	0.299	65.8
CR 3882-7-1-6-3-5-1	2.253	0.144	93.6
CR 3882-7-1-16-2-3-1	2.018	0.355	82.4
CR 3884-244-8-1-1-1-1	2.694	0.349	87.0
CR 3884-244-8-5-5-4-1	2.325	0.281	87.9
CR 3884-244-8-5-11-1-2	1.999	0.115	94.2
CR 3884-244-8-5-11-1-3	0.791	0.245	69.0
CR 3884-244-8-5-11-3-1	1.889	0.377	80.0
CR 3884-244-8-5-15-1-2	4.304	0.118	97.3
CR 3884-244-8-5-15-1-4	2.338	0.278	88.1
CR 3884-244-8-5-15-1-5	1.745	0.260	85.1
CR 3884-244-8-7-3-1-2	0.925	0.376	59.4
CR 3884-244-8-11-1-3-1	3.850	0.615	84.0
Luna Sankhi (check)	5.066	1.410	72.2
FL 478 (check)	2.534	0.576	77.3
LSD (P=0.05)	0.35	0.17	

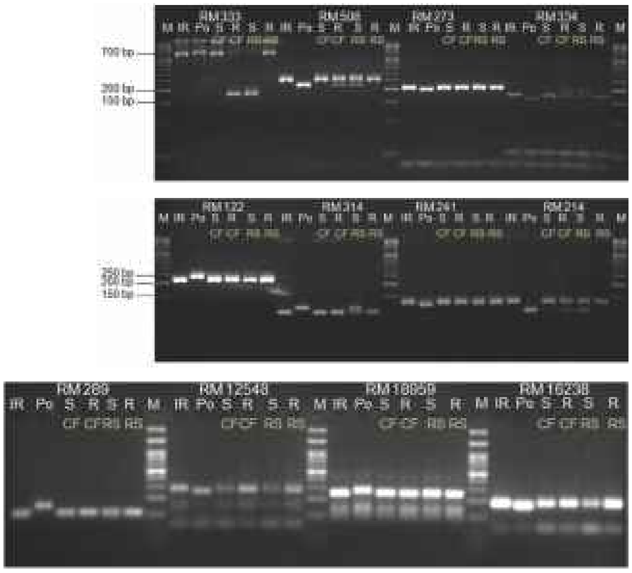


Fig. 1.12. Bulk segregant analysis with 60 polymorphic SSR markers for salinity tolerance at reproductive stage (RS) and chlorophyll florescence (CF) at seedling stage

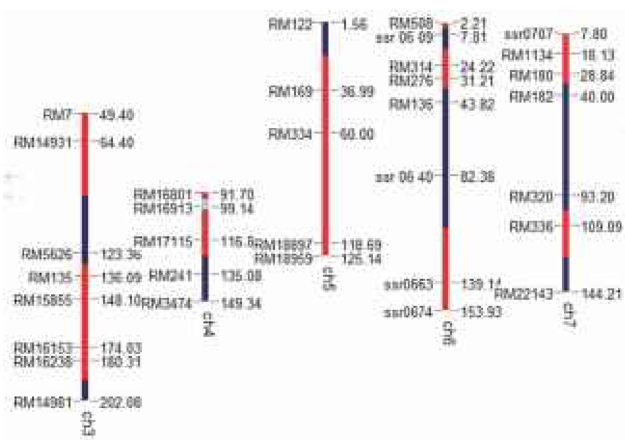


Fig. 1.13. Position of markers on five chromosomes of a salt tolerant line at flowering stage (line-188) from a backcross derived mapping population of IR 64 / Pokkali. Red colour indicates the chromosomal fragments from IR 64 and blue indicates alleles from Pokkali

promoted to second year of testing in CSTVT. IET 24426 (Savitri/Pateni) ranked first in western region with mean yield of 5363 kg/ha. IET 24434 with long slender grain yielded 4288 kg/ha and registered a yield advantage of 21% over the check, CST 7-1 and was promoted for eastern region while IET 24430 was promoted for southern region.

Evaluation of salt tolerant breeding lines in *rabi* 2014 at coastal saline area

Eighteen salt tolerant genotypes were evaluated with two checks (Luna Sankhi and Naveen) in dry season at farmer's field at Dhinkia of Ersama block of Jagatsinghpur district. The experiment was designed in RCBD with three replications. The soil ECe and water EC were measured throughout the crop growth period. The soil ECe ranged from 3.8 to 8.5 dS/m and water EC ranged from 3.8 to 9 dS/m. The highest yield was recorded in CR 3884-244-8-5-11-1-1 (4.27 t/ha) followed by CR 3881-M-3-1-5-3-1-1 (4.26 t/ha) and CR 3881-4-1-5-4-3-1 (4.2t/ha). Luna Sankhi and Naveen (Checks) were recorded with grain yield of 4.15 t/ha and 3.33 t/ha, respectively. The ten best entries are given in Table 1.14.

Evaluation of salt tolerant breeding lines at normal soil in *rabi* 2014

Thirty salt tolerant genotypes with two checks (Luna Sankhi and IR 29) were evaluated in dry season at normal soil. The experiment was designed in RCBD with three replications. One genotype CR 3881-4-1-6-3-4-1 (7.23 t/ha) produced more than 7.0 t/ha grain yield. Eight genotypes CR 3880-10-1-9-2-2-1 (6.74 t/ha), CR 3882-1-1-6-1-4-1 (6.43 t/ha), CR 3881-M-33-1-8-2-3-1 (6.18 t/ha), CR 3881-M-3-1-5-3-5-1(6.12 t/ha), CR 3881-M-3-1-5-1-1-1(6.11 t/ha), CR 3879-3-1-3-1-2-1 (6.1 t/ha) and CR 3879-3-1-6-1-3-1 (6.1 t/ha) recorded with more than 6.0 t/ha and seventeen genotypes were found with more than 5.0 t/ha yield. Luna Sankhi and IR 29 (checks) gave yield of 5.23 and 4.55 t/ha, respectively. The best ten lines are given in Table 1.15.

Evaluating long duration multiples abiotic stress tolerant (saline and submergence) breeding lines in normal soil

Twenty eight long duration multiples crosses (saline and submergence) breeding lines with two checks (Luna Suvarna and SR 26B) were evaluated in normal soil. The experiment was designed in RCBD with three replications. The highest yield was recorded in CR 3900-193-9-9-6 (6.87 t/ha) followed by CR 3878-245-1-1-5 (6.64 t/ha) and CR 3900-193-9-13-2 (6.41 t/ha). 100 grain wt was highest in CR 3900-193-9-13-2 (2.58 gms) followed by CR 3900-193-9-9-6 (2.28 gms) and CR 3887-15-2-2-1 (2.28 gms), whereas checks Luna Suvarna and SR 26B yielded 5.65 t/ha and 5.2 t/ha with 100 grain wt. of 1.92 gms and 2.32 gms, respectively. The best ten lines are as follows (Table 1.16).

Table 1.14: Evaluation of breeding lines at coastal saline areas in *rabi*

Genotypes	Pl ht	Pan len	EBT	DFF	Yld (t/ha)
CR3881-4-1-5-4-3-1	123	27.4	13	95	4.2
CR3884-244-8-5-11-1-4	122	27.8	10	105	3.73
CR3882-1-1-6-1-4-1	123	25.6	9	95	3.66
CR3881-M-3-1-5-3-1-1	121	28.2	11	95	4.26
CR3884-244-8-7-4-1-3	122	26.6	9	96	4.1
CR3884-244-8-5-11-1-1	101	24.4	12	98	4.27
CR3881-M-3-1-5-1-1-1	118	26.8	10	95	3.92
CR3883-3-1-5-2-1-2	115	23.4	9	98	4.18
CR3881-M-34-1-6-2-3-2	106	25.8	11	96	3.77
CR3881-M-3-1-4-5-5-1	117	24.6	9	107	3.62
Luna Sankhi	123	26.8	11	95	4.15
Naveen	115	24.6	9	95	3.33
5% LSD					0.05

Table 1.15: Evaluation of breeding lines under non-stress condition

Genotype	Pl ht	Pan len	EBT	DFF	Yield (t/ha)
CR3881-4-1-6-3-4-1	123	27.4	13	95	7.23
CR3881-M-3-1-5-3-5-1	122	27.8	10	105	6.12
CR3882-1-1-6-1-4-1	122.8	26.6	9	96	6.43
CR3881-M-33-1-8-2-3-1	101	24.4	12	98	6.18
CR3879-3-1-6-1-3-1	118.4	26.8	10	95	6.1
CR3879-3-1-3-1-2-1	120.2	27.4	14	96	6.1
CR3881-M-3-1-5-1-1-1	105.5	28.4	15	98	6.11
CR3881-M-34-1-6-2-2-1	108.2	25.8	12	94	5.96
CR3882-7-1-13-1-3-1	102	28.4	14	95	6.1
CR3880-10-1-9-2-2-1	117.3	28.5	15	90	6.74
Luna Sankhi	112.5	26.2	11	90	5.23
IR 29	105.7	23.5	8	95	4.55
5% LSD					0.11

Table 1.16: Evaluation of breeding lines developed for multiple abiotic stress tolerance

Genotypes	DDF	Plant ht (cm)	Pan len (cm)	EBT	100 grns wt	Yld (t/ha)
CR3890-35-1-3-4	114	125	28	11	1.92	5.50
CR3898-113-4-2-1	115	132	25	10	2.28	5.58
CR3900-135-8-5-4	114	134	26	12	1.8	5.40
CR3900-193-9-5-3	118	123	30	9	2.45	5.98
CR3903-161-1-2-2	120	142	25	11	1.53	6.26
CR3900-193-9-9-6	113	144	31	12	2.28	6.87
CR3900-193-9-13-2	122	128	30	12	2.58	6.41
CR3903-161-1-6-6	121	123	25	10	1.8	5.13
CR3903-161-2-1-7	114	115	26	10	1.62	5.52
CR 3878	122	164	28	11	1.84	6.64
Luna Suvarna	121	147	25	10	1.92	5.65
SR26B	125	155	24	9	2.32	5.2
5% LSD						0.12

Development of super rice for different ecologies

Identification and evaluation of promising elite lines from existing New Plant Types (NPT) and others for irrigated and shallow lowland ecology

In *rabi* 2014, twenty five cultures were shortlisted from 79 elite lines basically derived from second generation NPTs and were tested in AYT for evaluating their grain yield and morpho-physiological traits under higher fertilizer dose (120: 50: 50:: N :P_2O_5 :K_2O). The entries were tested in randomized complete block design (RCBD) with two replications against four checks *viz.*, Naveen, Annada, IR-64 and Swarna. Among the genotypes, CR 3721-11-2-1, CR 3960-1, CR 3728-2, CR 354-7-1-3 and CR 3965-1 recorded high grain yield of 8.7, 7.21, 6.94, 6.51 and 6.4 t/ha, respectively, in small plot experiments. There were yield advantages of 55.36%, 28.92%, 23.89%, 16.19% and 14.24%, respectively, against best check Naveen (5.60 t/ha). It was analyzed that, there were appreciable number of ear bearing tillers, high grain number, long and erect top three leaves along with higher 1000 grain weight contributed to higher grain yield in comparison to checks.

In *kharif* 2014, same set of genotypes was tested under AYT in RCBD. In this season, the crop was affected by which caused seedling damage at very early stage. Under such circumstances, in AYT, highest grain yield was recorded in CR 3623-2 (5.80 t/ha) followed by CR 3727-12-1 (5.62 t/ha) and CR 3961-4 (5.59 t/ha). Significant yield advantages were recorded over best check (Naveen) i.e., 22.4%, 18.5%, and 17.7%, respectively. The high grain yield could be attributed to more tiller number (8-10), moderately long panicle (30-33 cm) moderately long top three leaves and higher number of fertile grains. In this context, these genotypes could be utilized as potential donor/parent in the process of development of super rice.

Moreover, the genotypes, *viz.*, CR 3623-2 and CR 3960-

1 were having highly erect as well as stay green leaves for potential utilization of photosynthesis and ability to accommodate more number of plants per unit area, light penetration to lower leaves, therefore, could be the potential candidates for hybridization (Fig. 1.12).

(a) CR 3623-2 at late dough stage showing stay green and erect top three leaves

(b) CR 3960-1 at late dough stage showing stay green character of top three leaves

Fig. 1.12. Promising selections with ideal ideotype for prospective utilization as parents

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

A set of 19 NPT PSR lines along with two checks were evaluated under transplanted condition during *kharif* 2014. The experiment was laid in RBD with two replications. Highest grain yield was recorded by IR 73930-41-5-3-1 (3819 kg/ha), followed by IR 74714-141-3-3-2-3 (3750 kg/ha) and NDR 1045-2 (3653 kg/ha). These genotypes could be potentially utilised as parents for development of super rice in this ecology.

Critical investigations on morpho-physiological traits for designing super rice for irrigated ecology

A set of 450 different genotypes including *tropical japonicas* (with 'wc' genes), their derivatives and other exotic lines were collected and screened in an augmented block design with five checks (Annada, Naveen, IR-64, Swarna and Varshadhan) for potential morpho-physiological traits, for their prospective use as donor/parental lines for development of super rice.

Grain yield is the ultimate character that is targeted by a breeder for crop improvement. In this context the following genotypes were found to be highly promising as per the following (Table 1.17).

However, other important characters were also identified for prospective utilization in breeding programme.

- Dwarf plant type: Most of the *tropical japonica* genotypes were with tall plant type, however, few were dwarf types with relatively high grain yield *viz.*, EC 497157(86.2 cm), EC 497141(105.6 cm) and EC 491380 (104.0 cm).
- High tiller No: High tiller is desirable in super rice along with heavy panicle and high grain yield. In this context, EC 491471(13.4), EC 497128(12.3), EC 491172(11.6), EC 491254(11.2), and EC 497024(11.2) registered high tiller along with appreciable grain yield.
- No. of fertile grains: One of the major bottlenecks in *indica, tropical japonica* cross is grain sterility. Therefore, number of fertile grains should be taken care of during selection of potential donors. EC 496941(222.1), EC 491180(209), EC 491436(198.3), EC 491350(179) and EC 497189 (177.8) were found with appreciable high grain along with standard grain yield.
- Long and wide top leaves: It has been reported that flag leaf and subsequent leaves were important for synthesis and translocation of assimilate for high grain number and weight. Moreover, the recent strategy for increasing biomass is long, wide and erect top three leaves, rather than tall height of plants. In view of this, EC 491274 (57.8 cm flag leaf; 70.6 cm 2nd leaf and 1.82 flag leaf width), EC 497039 (56.0 cm, 57.0 cm and 1.46 cm), EC 491431 (51.6 cm, 60.6 cm and 1.96 cm) and EC 491347 (50.8 cm, 62.4 cm and 2.12 cm) were recorded with long and broad leaf along with other standard features and could be the potential donors.
- Leaf erectness: EC 491234, EC 491163, EC 491375, EC 491393 and EC 491152, were recorded with highly erect flag leaf architecture and could be useful parents for designing super rice.

However, grain is the product of several component characters. In this context a correct combination of high fertile grain number, 1000 grain weight and tiller number along with other characters have to be taken up for introgression of required traits/ genes for desired improvement.

Physiological efficiency of selected NPT lines for irrigated ecosystem

Five selected super rice lines along with a high yielding check MTU 1010 were grown under field condition in a randomized block design with four replications during *kharif* 2014 with fertilizer dose of N:P:K@100:50:50 kg/ha. LAI at flowering was highest in SR 28 (7.56) followed by SR 14 (6.65) and SR 1 (6.07), while highest photosynthetic rate was observed in SR 2 (33.01 µmol CO_2 m^{-2} s^{-1}) followed by MTU 1010 and SR 14. Grain yield was recorded highest in SR 2 (6.01 t/ha) followed by SR 14 (5.83 t/ha) and SR 27 (5.68 t/ha). Higher grain yield in these genotypes might have been contributed by high photosynthetic rate, high biomass and high 1000 grain wt. Overall yield advantage in these NPT lines was 14.3 % over check variety MTU 1010 and highest yield advantage was obtained in SR 2 (21.3%).

In general, the rate coefficient (γ) of biomass partitioning to leaves was less than in stem during vegetative phase with a slow and decreasing trend from panicle initiation to maturity and almost becoming negligible at maturity. Biomass partitioning to leaf in all the varieties was of similar trend, while variation was recorded in stems. However, rate of partitioning to panicle was highest in SR 2 (2.55 g/day/m^2), which was being reflected in highest grain yield production (Fig. 1.13).

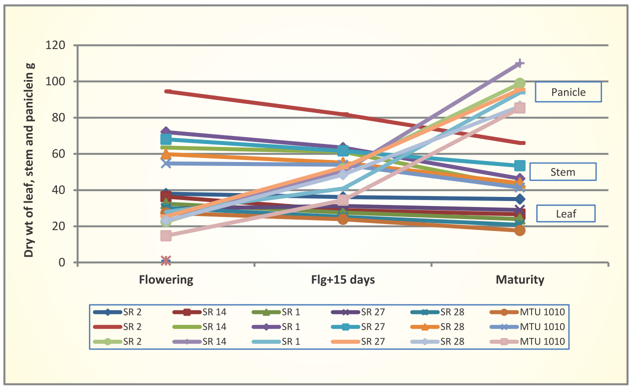


Fig. 1.13. Biomass partitioning of different plant parts during flowering to maturity in selected NPT lines

Table 1.17: Performance of potential *tropical japonica* genotypes with higher yield potential

Genotype	Station code	Plot yield (g/m^2)	No. of fertile grains	1000 grain weight	Tiller no.	Days to Flowering
EC-496935	WC 361	1116	170.8	21.37	5.4	134
EC-491423	WC 242	1033.083	133.2	30.25	4.8	130
EC-491380	WC 201	948.75	140	23.6	8.2	130
EC-496941	WC 366	915.5581	222.1	18.68	6.8	151
EC-497141	WC 546	812.3077	90.7	22.27	8.8	126
EC-497093	WC 501-1	782.1	129.8	30.81	10	109
EC-491313	WC 143	779.0357	146.2	29.07	7.6	141
EC-491233	WC 77	754.6579	96.6	30.53	7.2	128
EC-491438	WC 254	743.2857	87	20	10.5	129
EC-497157	WC 560	739.8947	120.6	26.94	7.2	116
Varshadhan (Check)	-	692.1951	192	22.88	9	149

Hybridization of potential genotypes with promising TJ, TJ derivatives and others in irrigated ecology for yield, ideal plant traits and biotic stresses tolerance

Basically, the 2nd generation NPTs were thought to be the potential candidates for development of new genotypes. In this context, 45 new crosss were attempted involving elite lines(in the back ground of elite varieties *viz.*, CR 3856-44-22-2-1, PAU 201, Pusa 44, COR 50, Tapaswini MAS, Swarna MAS, WITA 12, MTU 1010, IR 64 MAS etc.) along with *tropical japonicas* and aromatic derivatives from Pusa Sugandha 2, Pusa Sugandha 5, PVK Ganesh, HMT PVK etc. Some of the *tropical japonica* and aromatic derivatives did not perform well, therefore the F_1s of wide crosses were again backcrossed to *indica* elite lines for recovery of popular *indica* features along with introgression of super plant type traits.

Hybridization in bunded upland/shallow lowland

A cross between CR Dhan 40/IR 73963-86-1-5-2-2 was raised under transplanted condition and 90 individual plants were selected and advanced to F_3 for prospective selection under favourable upland. Similarly, crosses were made between super rice culture CR 3856-44-22-2-1-11 with lowland varieties *viz.*, Pooja and Reeta for further advancement of generation for shallow lowland.

Selection and generation advancement of segregating generations in cross with super rice traits, biotic stress tolerance and acceptable grain quality with conventional and molecular (BLB) approaches

Irrigated/ shallow lowland: Progeny row of single plant selections in different generations *viz.*, 575 F_3, 55

Table 1.18: Fertility and grain number characteristics of potential heavy panicles

Genotypes	Total no of grains /panicle	Wt of Panicle(g) (Max)	Filled Grains/ Panicle	Chaffs /panicle	% fertility	Potential fertile Grain No.	Grain yield/ha (t/ha)
CR 3856-47-12-1-1-1-1 (SR 46)	410.25	11.17	321.00	89.25	78.25	420.00	4.5
C33967-60-1-2-1-1-1-1(SR 37)	216.62	12.0	144.46	72.15	66.69	195.50	4.69
C3856-76-11-2-2-1-2 (SR 43)	225.72	12.2	179.59	46.13	79.57	228.42	3.98
C3856-44-22-2-1-7-1 (SR 27)	192.91	11.17	151.19	41.71	78.38	225.50	5.03
C3856-29-14-2-1-1-1 (SR 18)	107.05	10.32	64.68	42.36	60.42	215.9	2.98
C3856-80-11-1-1-1-1 (SR 13)	133.43	7.50	86.95	46.48	65.17	200.50	5.36
CR 3939-2-2-1-1-1(SR 48-4)	219.07	4.18	170.37	48.70	77.77	200.40	6.16
C3856-44-22-1-7-5 (SR 38)	197.96	7.60	154.61	43.35	78.10	285.50	5.04
C3966-2-1-2-1-2 (SR 25)	181.47	7.10	129.58	51.89	71.41	246.92	4.89
C3856-44-22-2-1-11-1 (SR1)	400.87	11.38	293.40	107.47	73.19	329.80	8.01
C3856-44-22-2-1-10-1 (SR 14)	191.91	7.93	145.05	46.86	75.58	167.60	6.8
C 3936-11-1-1-1-1-1 (SR 2)	184.70	4.647	148.00	36.70	75.52	168.70	7.94
Swarna (Check)	147.8	3.12	127.4	26.4	86.19	157.80	5.17
LSD(0.05)	10.23	1.64	8.2	4.2	3.42	8.9	0.76

F_4 , 32 F_5 , 31F_6 , 15 F_7 along with 42 F_2 and 45 F_1 were done for developing super rice (NGR). During development of super rice many heavy panicle type genotypes were identified (Fig. 1.14). However, many of them were shy tillering type. Amongst them, SR 46 was found with highest number of fertile grains (321) followed by SR 1(293), SR 43 (179) and SR 48-4(170). In other cases *viz.*, SR 37, SR38 and SR 14 although the total grain number was quite high, the effective grain number was reduced due to less fertility percentage (Table 1.18). In case of SR 1, the grain number compensated the number of effective tillers per meter square. Similarly, in SR 2 the grain yield was compensated by heavier grain number. The heavy panicles of SR 46, SR 37 and SR 43, SR 27 and SR 18 were not compensated either by less number of effective tillers or less number of fertile grains towards grain yield. Therefore, these genotypes could be utilized as potential parents for further development of super rice.

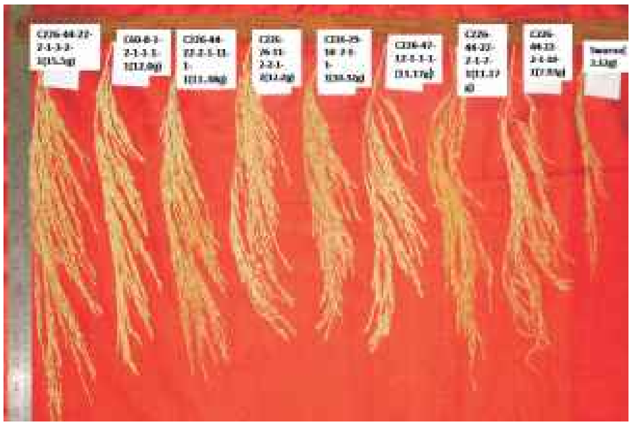


Fig. 1.14. Heavy Panicles and their comparison with checks

Screening super rice for disease resistance

Out of 42 super rice cultures screened for sheath blight resistance, none of the genotypes found to be highly tolerant with score 1 and 22 genotypes were found tolerant with score 3 (highly tolerant). Out of rest 20 genotypes, 10 were recorded with 5-7 score and 10 were found with 9 score (susceptible). Similarly, screening for NPT genotypes against sheath blight, recorded eight genotypes to be tolerant (score 2) including high yielding culture CR 2364-25-2 (N 327), and CR 3727-2-2-1 (N 370). While screening for BLB, Blackgora was found to be highly resistant against BLB (score 1), whereas eight cultures were found to be highly tolerant (score 3) including CR 3624-2(N 305) and CR 3727-2-2-1(N 370).

Screening super rice for pest resistance

Preliminary screening of sixty *tropical japonica* lines including susceptible check TN 1 were done against yellow stem borer, *Scirpophaga incertulas* in field under natural condition during *kharif* 2014. The observation was recorded both in vegetative and reproductive stage. However, in vegetative stage the dead heart formation was significantly low both in test entries as well as standard susceptible check. In reproductive stage, the entries *viz.*, EC 491187 (WC 35) and EC 496863 (WC 297) didn't show any white ear head (WEH) formation due to stem borer, while TN 1 registered highest WEH (8.3%).

Introgression of BLB resistance through molecular approach

In order to develop breeding materials with super rice plant type and super agronomic traits *viz.*, heavy panicle, high fertile grain number, semi-dwarf height, strong culm, erect long and wide top three leaves along with field tolerance to major diseases and pests in the background of acceptable grain quality, twenty five three way crosses and fifteen new crosses were made involving *tropical japonica* and their derivatives in the back ground of second generation NPTs and elite varieties. One prominent genotype with above desirable traits was developed. However, it was infested with BLB and subsequently found to be susceptible to major strains of BLB. In this context, backcross breeding programme was initiated along with marker assisted backcrossing. During 2014-15 backcross BC_3F_1 was made using heavy panicle genotype CR 3856-44-22-2-1-11-1 as recipient and Swarna MAS containing *Xa21, xa13* and *xa5* resistant genes as donor.

Preliminary yield trial for irrigated and shallow lowlands (PYT)

In the process of development of super rice the promising crosses were advanced in progeny row method with single plant selection different cross combinations were tried. Few cross combinations were found to be having promising performance along with other super quantitative traits. In this context, 47 fixed lines were tested for their performance in preliminary yield trial for super rice traits that contributes towards higher grain yield. These genotypes were taken up in PYT. The experiment was laid out in randomized block design

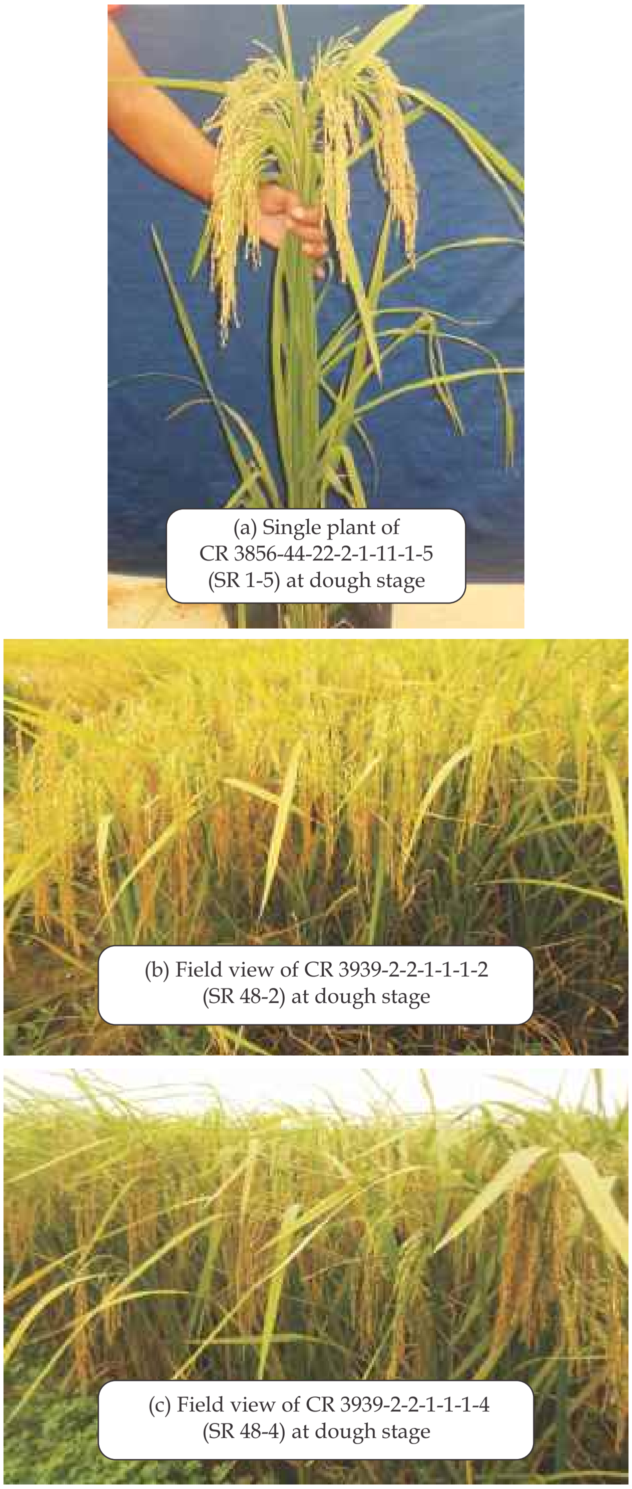


Fig. 1.15. Promising stable genotypes of super rice

with two replications and the released varieties *viz.*, Annada, IR 64, Naveen, MTU 1010 and Swarna were taken as checks. Highest yield was recorded in genotype, SR 1 (8.01 t/ha) followed by SR 2 (7.94 t/ha) and SR 14 (6.83 t/ha) having 54.93%, 53.60% and 32.09% yield superiority over checks. Higher grain yield was attributed basically due to heavy panicles (7.58 g in SR 1; 5.32 g in SR 2 and SR 27 as in (Table 1.19), higher number of fertile grains per panicle (196 in SR 1, 192.6 in SR 45 and 166.05 in SR 4) although less number of tillers (5-6 in high yielders) were there. The higher yield basically comes from higher biomass. The biomass basically came from slightly raised height and long and wide leaves particularly in SR 1, SR 2, SR 14, SR 4 and SR 7.

Similarly, in *kharif* 2014, the same set of genotypes were taken up in PYT. The experiment was laid out in randomized block design with two replications (Table 1.20). The genotypes SR 40-1 was found to be the highest yielder (6.52 t/ha), followed by SR 10-1 (6.12 t/ha), SR 15-1-1 (6.06 t/ha) and SR 33-1 (5.97 t/ha). These genotypes were recorded with yield increment to the tune of 47.51%, 38.46%, 37.10% and 35.07% yield increment over the best check i.e., Swarna with grain yield of 4.42 t/ha. The higher grain yield attributed to high number of fertile grains, bolder grains, higher number of effective tillers etc.

Considering both the seasons, SR 48-2, SR 48-4, SR 14-5 and SR 1-5 were found to be stable. The super rice genotypes developed were mostly of heavy panicle type with more number of grains per panicle, however, most of them were of shy tillering type, resulting in less number of effective panicles per m^2. In this context, more work on agronomy of super rice is needed.

Nomination to AICRIP

Out of four lines nominated for multi-locational trial under AICRIP, CR 3624-1 was promoted to AVT1-IM. Ten new entries have been nominated to AICRIP testing *viz.*, CR 3856-44-22-2-1-11-1, CR 3936-11-1-1-1-1-1, under IVT NPT; CR 3721-11-2-1, CR 3960-1, CR 3623-2 and CR 3954-7-1-3 under IVT IM; CR 3961-4 under IVT IME ; CR 3962-4 under IVT-L and CR 3856-44-22-2-1-10-5 and CR 2463-2 under aerobic situation.

Standardization of agronomy for super rice

In order to optimize the nitrogen doses and identify the best super rice across nitrogen doses and spacing, one agronomic trial was undertaken. The soil in which the experiment was conducted was sandy clay loam texture with pH 6.8 and electrical conductivity 0.5 dS/m, organic C 0.65%, available N 189 kg/ha. The

Table 1.19: Grain yield and other quantitative parameters of super rice strains during *rabi* 2014

Genotype	Code	Days to 50% flowering	Plant height	Flag leaf length	Flag leaf width	Fertile grains/ panicle	Sterile grains/ panicle	Total grains/ panicle	1000 grain wt.	Pan icle wt.	Tiller No.	Panicle length	Grain yield (t/ha)	% increase of gr. yield over check
CR 3856-44-22-2-1-11	SR 1	102.00	117.00	39.0	2.40	196.30	48.60	244.90	22.46	7.58	5.80	34.60	8.010	54.93
CR 3936-11-1-1-1-1-1	SR 2	109.00	127.00	36.2	2.60	130.00	25.60	155.60	29.81	5.32	6.90	23.10	7.941	53.60
CR 3856-44-22-2-1-10	Sr 14	95.00	112.00	42.0	1.44	145.05	46.86	191.90	22.74	4.39	8.80	33.00	6.827	32.05
CR 3939-2-2-1-1-1	SR 48	110.00	117.20	41.4	1.44	143.10	16.00	159.10	22.01	4.14	6.80	33.10	6.161	19.17
CR 3939-2-2-1-1-1-2)	SR 4	101.00	115.00	42.4	2.20	166.05	42.00	208.05	21.21	4.25	5.40	30.80	5.572	7.78
CR 3960-21-11-1-1-2-1	SR 42	92.00	96.40	30.1	1.56	160.60	40.35	200.95	23.82	4.50	5.90	30.60	5.540	7.16
CR 3960-51-2-1-1-1	SR 39	98.00	110.40	39.2	1.50	135.20	14.60	149.80	23.01	3.76	6.40	30.60	5.200	0.58
CR 3856-76-11-2-2-1	SR 45	98.00	112.80	42.8	1.90	192.60	21.20	213.80	22.04	4.73	7.20	31.40	5.170	0.00
CR 3938- 6-2-1-1-1	SR 7	104.00	122.60	43.4	2.06	158.20	14.30	172.50	21.66	4.18	8.20	27.60	5.179	0.17
Naveen		99.00	115.40	33.9	1.40	132.50	23.30	155.80	18.57	3.46	6.80	24.60	4.910	0.00
Swarna		121.00	87.30	31.5	1.45	134.10	15.40	149.50	17.03	3.17	7.20	25.10	5.170	0.00
LSD(5%)		3.6	2.58	3.08	0.40	10.2	4.6	11.6	3.20	0.85	1.67	2.66	0.79	-

Table 1.20: Grain yield and other quantitative parameters of super rice strains during *kharif* 2014

Genotypes	Station Code	Days to 50% Flowering	Tiller No.	Plant height (cm)	Panicle length (cm)	Flag leaf length (cm)	Flag leaf width (cm)	2nd leaf length (cm)	2nd leaf width (cm)	Fertile grains/ panicle	Sterile grains/ panicle	Total grain wt. (g)	Panicle wt. (g)	1000 grain wt. (g)	Grain yield (t/ha)	% increase of gr. yield over check
CR 3938-2-1-1-2-1	SR-40-1	100	6.2	130.5	35.2	35.4	1.41	50	1.14	126.7	31.9	158.6	3.95	27.99	6.52	47.51
CR 3960-8-3-2-2-1	SR-10-1	130	6.8	107.4	33.8	31.4	1.43	56.4	1.54	130.2	25.4	155.4	3.9	18.78	6.12	38.46
CR 3960-40-3-1-1-1-1-2	SR-15-2	109	6	106.2	25	22.5	0.81	37.2	1.41	145.1	53.2	198.3	3.95	25.78	6.06	37.10
CR 3856-50-2-1-1-1-1	SR-33-1	92.5	6.2	134	24.4	42.2	1.04	45.1	1.48	100.4	46.6	147	4.4	22.10	5.97	35.07
CR 3939-2-2-1-1-1-4	SR-48-4	120.5	5.2	137	32	46.4	1.61	54.4	1.35	144.2	24.2	168.4	3.05	21.13	5.82	31.67
CR 3856-44-22-2-10-5	SR-14-5	107.5	8.2	141	32.8	37.3	1.71	45.8	1.35	136.3	19.4	155.7	3.2	22.55	5.78	30.77
CR 3939-2-2-1-1-1-2	SR-48-2	108	7.0	126	29.4	42.2	1.28	52.7	1.12	136.0	28.6	179.9	3.48	20.50	5.71	29.19
CR 3856-44-22-2-11-1-5	SR-1-5	99	5.6	140.6	29.8	33.4	2.24	47	2	164	48.3	222.3	5.6	21.49	5.55	25.57
CR 3960-10-1-1-1-1	SR-36-2	106.5	5.7	113	30.6	38	1.51	55.3	1.28	145.3	39.5	184.8	4.8	17.39	5.55	25.57
CR 3856-64-1-3-1-1	SR-8-2	95.5	5.4	133.8	30.3	35	1.75	45	0.93	110	20.3	120.3	2.98	21.47	5.519	24.86
Naveen		98	7.0	119.8	26.6	33.2	1.45	37.2	1.37	92.5	11.8	104.3	2.822	19.74	4.21	-4.75
Swarna		120	6.0	91.8	23.3	29.6	1.23	37.2	1.26	127.4	20.4	147.8	2.36	17.82	4.42	0.00
LSD(5%)		3.6	2.58	3.08	0.40	10.2	4.6	11.6	3.20	0.85	1.67	2.66	0.79	3.11	0.76	-

main plot (MP) consisted of three nitrogen levels i.e. 80, 120 and 160 kg/ha. The main plots were divided into three sub plots (SP) which consisted of spacings, 15 cm X 15 cm, 20 cm X 15 cm and 20 cm X 20 cm. The subplots were further divided into three genotypes (sub-sub plots, SSP) i.e. SR 1 (CR 3856-44-22-1-11), SR 2 (CR 3936-11-1-1-1-1) and rice var. Swarna (check).

Significant difference in number of panicles m^{-2}, panicle weight and yield (g m^{-2}) was recorded in sub-sub plots (genotypes) (Table 1.21). However, no such difference was observed due to nitrogen doses. The interaction between main plot and sub plot were statistically significant. Highest grain yield was obtained in case of SR2 (654.1 g/m^2) followed by SR 1(590.3 g/m^2). The check variety was recorded with grain yield of 493.7 g/m^2. Among the N doses, 120 kg N/ha recorded maximum grain yield (599.3 g/m^2). Among the planting geometries, 15 cm x 15 cm (SP 1) spacing recorded highest plant population as well as grain yield. This was because of shy tillering of the super rice genotypes. The closer spacing resulted into higher number of effective tillers and in turn significantly higher grain yield than SP 2 (20 cm X 15 cm) and SP 3 (20 cm X 20 cm),

Selection and generation advancement of segregating generations for bunded upland

Ten different crosses in F_4 were taken up involving Sahabhagidhan, Naveen, Annada, Vandana, Swarna *Sub-1*, Anjali, NPT PSR 14, CR Dhan 40, NPT PSR 18, Sadabahar and NPT PSR 16. Selection was made in 161 lines and a total of 805 individual plant progenies were selected and harvested separately. Due to unfavourable climate these were harvested in bulk.

Preliminary yield trial and seed multiplication for various trials and nomination to AICRIP in bunded upland

Fifteen promising advance breeding lines of super rice genotypes were evaluated in a randomized block design with three replications under aerobic conditions. Four entries performed better than check CR Dhan 200. Among the different entries, CR 3300-2 performed best with an average yield of 5.42 t/ha followed by CR 3624-1, CR 3961-4 and CR 2721-11 with an average yield of 5.08 t/ha.

Evaluation of irrigated cultures in national trials at NRRI, Cuttack

Advance Variety Trial 1- Rice IME

Thirtyone entries including checks IR 64 (NC), Lalat (RC), Naveen (LC) and hybrid check were evaluated in a replicated trial under irrigated conditions (IME).

Advance Variety Trial II- Rice IME

Seven entries including checks IR 64 (NC), Lalat (RC) and Naveen (LC) were evaluated in a replicated trial under irrigated conditions (IME).

Variety released by SVRC

CR Dhan 307 (Maudamani)

CR Dhan 307 (Maudamani) was released by SVRC, for well managed favourable rainfed lowland / irrigated condition of Odisha. The elite breeding line CR 2599

Table 1.21. Grain yield of different treatment w.r.t. nitrogen, spacing and genotypes in super rice cultures

	MP_1				MP_2				MP_3				
Main_sub_sub_sub	SP_1	SP_2	SP_3	Mean	SP_1	SP_2	SP_3	Mean	SP_1	SP_2	SP_3	Mean	Sub-Sub Plot Mean
SSP_1	557.3	561.6	560.0	559.6	653.3	618.3	587.6	619.7	655.3	571.6	547.6	591.5	590.33
SSP_2	586.6	627.0	622.0	611.8	734.3	666.3	630.3	677.0	718.0	662.0	640.3	673.4	654.11
SSP_3	481.7	477.3	489.3	482.8	547.0	478.3	478.3	501.2	507.0	506.7	477.3	497.0	493.67
Mean	541.9	555.3	557.1	551.4	644.9	587.7	565.4	599.3	626.8	580.1	555.1	587.3	Gmean= 579.37

MP - Main Plot, SP - Sub Plot, SSP - Sub-Sub Plot
Mp1= 80 kg N/ha, MP2=120 kg N/ha, MP3=160 kg N/ha
SP1= 15 cm X 15 cm, SP2= 20 cm X 15 cm and SP3= 20cmX 20 cm
SSP1=SR1 (CR 3856-44-22-1-11), SSP2=SR2 (CR 3936-11-1-1-1-1) and SSP3= Swarna (check)

was developed from the segregating materials of the cross Dandi/Naveen//Dandi for with high grain yield and resistance to major diseases and insect pests. The days to 50% flowering of the variety is 100-105 days, semidwarf (100-105 cm), non-lodging genotype with an average yield of 4.8 t/ha. It produces short bold grain (l/b ratio-2.15), 278 panicles per m^2, good tillering (7-10) with high grain number/ panicle. CR Dhan 307 possess all desirable quality characters like high milling % (72%), intermediate alkali spreading value (7.0), intermediate amylose content (23.73%) and gel consistency of 26.0. It exhibited moderate resistance reaction against the pests stem borer, leaf folder, rice whorl maggot, green leaf hopper and and gall midge biotype 6 attack. While it showed moderate reaction to white backed plant hopper, gallmidge biotype 5, rice hispa and rice thrips. It exhibited moderately tolerance reaction to diseases like leaf blast, neck blast and brown spot.

CR Dhan 206 (Gopinath)

CR Dhan 206 (Gopinath) was released for the state of Odisha for aerobic situations. It was developed from cross of parents Brahmannakhi and NDR 9930077 through pedigree method of selection. It had yield advantage of 37.45%, 28.6% and 10.2% over national check (IR 64), regional check (MAS 946) and local checks, respectively in the state. The culture is semi-dwarf type (105 cm), early maturing (110-115 days), non-lodging possessing high panicles/m^2 (300), moderately long and dense panicle with medium test weight with better fertilizer response. It is moderately resistant to leaf blast, brown spot, sheath rot, stem borer, leaf folder and whorl maggot. It possessed good grain quality parameters with intermediate amylose content, short bold grain, good hulling, milling and head rice recovery(Fig. 1.16).

Fig. 1.16. CR Dhan 206 at maturity stage

Resistance breeding for multiple insect-pests and diseases

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

Introgression of BLB resistance gene *xa5, xa13, Xa21* and blast resistance gene *Pi2, Pi9* into Naveen variety

During *rabi* 2014, double cross F_1 (Naveen/ CRMAS 2231-37 // Naveen/ CRMAS 2620-1) seeds along with recurrent and donor parents were grown. Using molecular markers, double cross F_1 plants were identified with all the five genes targeted *(xa5, xa13, Xa21, Pi2 and Pi9)*. Selected plants were used to backcross with the recurrent parent to get BC_1F_1 seeds. During *kharif* 2014, these BC_1F_1 seeds were planted in net house in a staggered manner. Fourteen BC_1F_1 plants were screened using molecular markers and the selected plants with all the target genes were used for back crossing. Forty five BC_2F_1 seeds were harvested.

Introgression of BLB resistance gene *xa5, xa13, Xa21* and blast resistance gene *Pi2, Pi9* into Pooja variety

During *rabi* 2014, twenty F_1 (Pooja / CRMAS 2232-71 plants along with another donor CRMAS 2619-9 (*Pi2* and *Pi9* gene) were planted in the net house in a staggered manner. Five plants screened for the presence of three bacterial blight resistance genes *(xa5, xa13, Xa21)* were used for crossing with CRMAS 2619-9. During *kharif* 2014, eleven three-way cross F_1's (Pooja/ CRMAS 2232-71/// CRMAS 2619-9) plants along with recurrent parent Pooja were planted in the net house in a staggered manner. Six F_1 plants found positive for all the five genes were used for backcrossing with the recurrent parent Pooja. One hundred and forty two BC_1 F_1 seeds were harvested.

Improvement of promising varieties for sheath blight and RTD disease resistance

Fifteen new crosses and six backcrosses were made taking elite varieties Naveen, Pooja, Swana *sub*1, Tapaswini, Gayatri and promising donors for tungro and sheath blight diseases. For tungro disease IET 16952, Vikramarya and Kataribhog were taken as the resistant donors and for sheath blight CR 1014, Tetep, IET 19346, IET 20230, ADT 39 and Jogen were used.

Improvement of Naveen and Pooja varieties for BPH resistance

Four new crosses were made involving Naveen, Pooja and donors for BPH resistance *viz.*, IR 65482-7-216-1-2 (*Bph 18*) and IR 71033-121-15-B (*Bph 20* and *Bph 21*). Four back crosses were also made using Naveen and Pooja as the recurrent parent and F_1s of Naveen and Pooja with BPH tolerant donors CR 3006-8-2 (derived from a cross combination of Pusa 44 / Salkathi) and CR 2711- 76 (derived from a cross combination of Tapaswini / Dhobanumberi).

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

One hundred and fourty seven germplasm and breeding lines were screened against sheath blight under artificial inoculation. Three hundred and two breeding lines were screened against tungro disease and 29 lines showed high degree of resistance with score 1. Twenty one lines showed high degree of tolerance with score 3.

Thirty IRBB lines and 45 introgression lines from IRRI developed through wide hybridization were screened against BLB under artificial innoculation. Three lines *viz.*, IRBB 58, IRBB 66 and IR 75084-74 -8-B-B-B (from *O. officinalis* AC 100896) showed high degree of resistance with score 1. Another 20 genotypes including nine wide cross derivatives were recorded with score 3 (highly tolerant).

The same set of 45 introgression lines developed through wide hybridization were also screened against BPH. Three lines IR 73382-80-9-3-13-2-2-1-3-B (derived from IR 64/ *O. rufipogon* AC 106412), IR 75870-8-1-2-B-6-1-1-B (derived from IR 64/ *O. glaberrima*) and IR 77390-6-2-18-2-B (derived from IR 69502-6/ *O. glaberrima*) showed high degree of resistance with score 1. These donors can be revalidated and used in the resistance breeding programme.

Advance variety trial 2-Near Isogenic Lines (AVT 2-NIL)

The trial was conducted with four introgressed lines along with four check varieties to study the comparative performance of introgressed lines in the background of Samba Mahsuri and Improved Samba Mahsuri possessing blast and bacterial blight resistance genes in a randomized block design with three replications. Among the eight entries, Entry No. 4408 (Improved Samba Mahsuri) performed best with an average yield of 3857 kg/ha followed by Entry No. 4404 (RP 5863-Patho-3-56-11) (3411 kg/ha) and Entry No. 4402 (Samba Mahsuri) (3353 kg/ha).

Entries promoted and new nominations for AICRIP trials

CR 2647-5-2 derived from a cross combination of Swarna/Vikramarya was promoted to AVT-1-IM based on its performance.

CR 3941-4 and CR 2920-15 for IVT-IME, CR 3808-13, CR 3807-42, CR 3939-18 and CR 3943-1 for IVT-IM, CR 3942-2, CR 2921-6 and CR 3940-21 for IVT-L, CR 3941-7, CR 3941-10, CR 3808-60-13 and CR 3808-57 for IVT-RSL were nominated for AICRIP trials of 2015.

Breeding for higher resource use efficiency

Evaluation of rice germplasm for aerobic condition, early seedling vigour and anaerobic germination

A panel of 631 germplasm lines was evaluated under aerobic condition along with checks (CR Dhan 201, Dular, N22, Vandana and CR 143-2-2) during dry season. Genotypes AC 44091 and AC 43935 exhibited grain yield on par with check CR Dhan 201 under soil moisture tension of (-)35 to (-)40 kPa maintained throughout the growth period (Table 1.22). Further, ARC 10493, AC 44100, IR 65192-4B-10-3, AC 43949 and AC 44055 recorded higher grain yield per plant than the general mean of 19.74 g.

A set of 636 germplasm accessions were evaluated in augmented design for early seedling vigour with five checks *viz.*, Brown gora, Salempikit, Vandana, Apo and Sabita during dry season. Shoot and root length and dry weight of shoot and root were assessed on 14th and 28th day after sowing. Based on relative growth rate (g/day) and crop growth rate (m^2) at 14 and 28 days after sowing, 106 lines were selected. Among them, genotypes AG 61, AC 4148, ARC 10840, ARC 10873, AC 35633 and ARC 10714 excelled than the checks (Table 1.23; Fig. 1.17)

Table 1.22. Performance of germplasm lines under aerobic condition

Sl.No.	Genotype	Filled grains/plant	Spikelet Fertility %	Grain yield/plant (g)
1	AC 43801	343.33	42.28	12.38
2	AC 44091	802.33	87.18	26.03
3	Dular	517.33	86.54	19.12
4	N22	558.67	87.34	11.55
5	Vandana	813.00	79.52	17.33
6	ARC 10493	873.00	85.84	24.27
7	AC 44100	876.67	83.66	22.40
8	Fortuna	593.00	50.97	16.61
9	CR Dhan 201	721.33	76.89	26.28
10	AC 43935	723.00	74.30	26.11
11	IR 65192-4B-10-3	595.00	82.87	22.95
12	AC 43949	574.67	70.98	20.21
13	AC 44055	683.50	77.77	21.18
14	CR 143-2-2	660.33	84.73	14.95
	Mean (n=631)	645.23	75.06	19.74
	CD 5%	78.27	7.18	2.40

Fig. 1.17. (a) Twenty eight days old vigorous (ARC 10873) and (b) weak seedling (ARC 6591)

Six hundred and thirty six germplasm lines were tested for anaerobic germination. Among them, genotypes ARC 6648, ARC 7126 and ARC 7110 had registered 81.54%, 73.08% and 77.69% germination under anaerobic condition, respectively. Whereas, ARC 6648 exhibited 12.34% superiority over the positive checks *viz.*, EC 516602 and AC 34245.

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 situation, 20 F_1s were obtained by cross combination of one upland drought tolerant parent with high yielding irrigated/lowland variety with good grain quality during *rabi* 2014. Again, the 20 F_1s were crossed with irrigated high yielding third parent in a three way cross during *kharif* 2014 to reduce the non-responsiveness trait of upland genotype.

Table 1.23: Shoot weight and root weight of selected genotypes

Genotype	14 DAS		Genotype	28 DAS	
	Shoot dry wt/pl. (g)	Root dry wt/pl. (g)		Shoot dry wt/pl (g)	Root dry wt/pl. (g)
AG 20	0.087	0.010	AG 61	0.477	0.077
AC 44107	0.073	0.006	AC 35633	0.386	0.036
AG 14	0.067	0.008	AC 4148	0.346	0.043
ARC 10840	0.063	0.006	AC 43967	0.338	0.055
AG 61	0.060	0.008	CO 51	0.322	0.040
ARC 10714	0.060	0.005	ARC 10873	0.313	0.037
Sabita	0.054	0.007	ARC 10840	0.311	0.034
ARC 10954	0.053	0.008	AG 53	0.299	0.074
ARC 10873	0.054	0.009	ARC 10714	0.284	0.024
AC 35633	0.048	0.005	ARC 10797	0.279	0.021
AC 43967	0.049	0.006	AC 35119	0.266	0.061
Apo	0.054	0.008	Apo	0.203	0.055
Mean (n=636)	0.058	0.005	Mean (n=636)	0.201	0.022

F_1s generated through three way cross of Pyari / Sattari // CR 143-2-2 has recorded partial male sterility of more than 85% (Fig. 1.18). Further segregation from this F_1 and backcrossing F_1 with corresponding recurrent parent will bring out the possibility of new source of male sterile cytoplasm.

From the ongoing 263 lines of F_2 generation, single plant progenies were selected and 141 lines were advanced to F_3 generation. Twenty one promising lines of F_7 generation were bulked for next season initial yield evaluation trial.

Fig. 1.18. (a) View of F_1 (Pyari / Satari // CR 143-2-2) plant, (b) sterile panicles

Table 1.24: Performance of *Oryza nivara* derivatives under aerobic condition

Derivatives	Days to 50% flowering	Plant height (cm)	No. of panicles/plant	Panicle length (cm)	Grain yield (t/ha)
KB-21	88	97.50	16.25	20.50	3.37
KB-22	91	105.00	12.50	25.00	5.40
KB-23	90	102.50	6.50	26.75	3.11
KB-24	92	110.00	9.75	24.00	2.84
KB-25	90	100.75	7.25	23.75	1.62
KB-26	92	121.25	8.75	26.00	4.15
KB-27	91	105.50	7.75	24.75	5.04
KB-28	89	86.75	15.25	22.25	2.19
KB-29	90	93.75	11.75	23.25	2.86
KB-30	95	147.00	9.75	26.25	5.54
KB-31	90	105.00	6.75	25.00	2.60
KB-32	89	90.75	11.00	21.25	2.34
KB-33	91	105.75	14.00	23.75	4.18
KB-34	93	102.75	11.75	23.75	4.28
KB-35	90	101.25	6.00	20.00	5.05
KB-36	95	106.75	3.75	24.75	2.67
KB-37	92	103.25	7.50	21.50	4.70
KB-38	92	103.25	10.75	25.25	2.68
KB-39	91	101.50	12.25	22.25	4.92
KB-40	94	106.25	11.00	23.00	3.66
KB-41	88	97.25	8.50	24.25	4.09
KB-42	92	110.50	5.75	20.75	4.10
KB-43	90	106.50	11.00	24.50	4.51
KB-44	95	117.00	8.25	22.00	4.28
KB-45	92	115.00	10.25	22.00	5.06
KB-46	94	104.75	7.75	22.00	2.89
CR Dhan 200	92	90.12	6.21	24.04	5.22
Mean	91.40	105.67	9.68	23.40	3.90
CD5%	0.75	4.32	1.16	0.71	0.53

In order to introgress anaerobic germination tolerance in Naveen, anaerobic germination tolerant AC 34245 was crossed with Naveen during *rabi* 2014 and F_1 was backcrossed with recurrent parent Naveen during *kharif*, 2014.

Evaluation of advance breeding lines of wide cross derivatives for yield and other traits under aerobic condition

Twenty six fixed lines of *Oryza nivara* derivatives were evaluated in a randomized block design with three replications under aerobic conditions during *kharif* 2014 at NRRI, Cuttack. The performance of five lines were found promising as compared to the check CR Dhan 200. The promising genotypes were KB 22 (CR 143-2-2/*O. nivara* (AC 100374)) (5.4 t/ha), KB 27 (IR 64/*O. nivara*)(AC 100476)(5.04 t/ha), KB 30 (Lalat/*O. nivara* (AC 100476) (5.5 t/ha), KB 35 (Apo/*O. nivara)* (AC 100476) (5.05 t/ha) and KB 45 (Lalat/*O. nivara)* (AC 100476) (5.06 t/ha) (Table 1.24).

Evaluation of DTY and *Sub1* introgressed lines of Swarna NILs under transplanted situation

One hundred and thirty four fixed lines of Swarna NILs belonging to different duration categories were evaluated in a randomized block design with three replications during *kharif*, 2014. Based on maturity, phenotypic acceptability and grain yield, entries IR 96321-1686-62-B-3-1-3 (6.84 t/ha), IR 96321-1686-140-B-2 (5.42 t/ha), IR 96321-213-120-B-1-1 (4.41 t/ha), IR 96321-327-128-B (5.39 t/ha) and IR 91648-B-89-B-5-2 (5.97 t/ha) belonging to late, medium, early, late and medium, respectively were selected for next stage of evaluation.

Development of genotypes with drought tolerance

The objective was to develop high yielding cultivars with good grain yield under intermittent drought stress either for vegetative stage or for reproductive stage for both. With this objective, 22 crosses were made and generation advance was carried out for another 20 crosses with single plant selection followed by progeny row. Biparental as well as multi-parental crosses were included for better combination of other biotic stress tolerance. The initial selections were done entirely for grain yield, whereas advanced generations would be taken up for drought screening after F_4. The purpose was introgression of multiple tolerant genes in the background of high yielding varieties. The crosses were made involving drought tolerant donors with potential high yielding varieties *viz*., Sahabhagidhan, Vandana, Vanaprabha, Salempikit, CR 143-2-2, Dagadesi, Brahman nakhi, Mahulata, ZHU and BVD 9. The genotypes selected in advanced generation showed at least 10 % yield increment over irrigated checks.

Validation and marker assisted selection for drought tolerance QTLs

The aim of the current study is to pyramid a major QTL *qDTY12.1* and blast resistance gene *Pi9* into an upland variety which already had the major QTL *qDTY2.3* and *qDTY3.2*. Thus a parental polymorphism was carried out to find the parents which may be polymorphic to Way Rarem (*qDTY12.1* donor). RM28166 is an SSR marker which is tightly linked to the QTL qDTY12.1. Similarly, RM517 and RM 573 were also reported to be tightly linked to the QTLs qDTY3.2 and qDTY2.3, respectively. This parental polymorphism study was also done as an indication for the probable presence of the above mentioned QTLs. Way Rarem was used as check for *qDTY12.1* and Vandana as check for *qDTY2.3* and *qDTY3.2* (Table 1.25).

Based on the gel banding pattern with respect to the positive check Way Rarem, it was found that the following genotypes may contain qDTY12.1 (Fig. 1.19): Sahabhagidhan, Satyabhama, Sidhant, Salempikit, Anjali, Curinga, CR2702, Mahulata and CRMAS 2620-1.

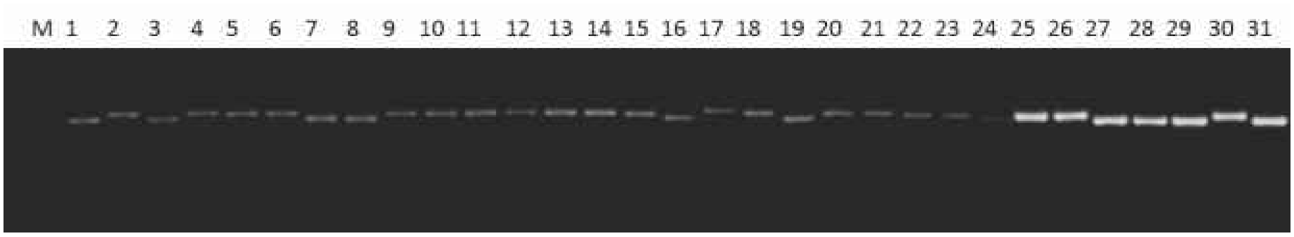


Fig. 1.19. Parental Polymorphism study of the 31 genotypes using SSR marker Rm28166 (specific for qDTY12.1)

Table 1.25: List of genotypes used for MAS

Sl No	Variety	Sl No	Variety	Sl No	Variety	Sl No	Variety
1	Way Rarem	9	Sadabahar	17	Poornima	25	IR 64
2	Vandana	10	Hazaridhan	18	Annada	26	Azucena
3	Sahabhagidhan	11	Annapurna	19	Anjali	27	Curinga
4	Browngora	12	Kalinga III	20	Vanaprava	28	CR 2702
5	Kalyani 2	13	HND 15	21	Blackgora	29	Mahulata
6	NDR 1045	14	Khandagiri	22	Heera	30	CR 143-2-2
7	Satyabhama	15	N 22	23	Pathara	31	CRMAS 2620-1
8	Sidhant	16	Salempikit	24	Dular		

Similarly, RM517 and RM573 were used for the parental polymorphism study among the 31 genotypes for the QTLs *qDTY3.2* and *qDTY2.3*, respectively and on the basis of gel banding pattern it can be said that the following genotypes contain these two QTLs:

- *qDTY3.2:* Kalyani 2, NDR 1045, Satyabhama, Sidhant, Hazaridhan, Kalinga III, Khandagiri, Salempikit, Poornima, N 22 and Dular.
- *qDTY2.3:* Browngora, NDR 1045, Annapurna, Kalinga III, N 22, Salempikit, Poornima and Annada.

This genotype was studied extensively and farmers were quite happy about the performance of N 22 (i.e., Grain yield under drought). Thus based on these findings it was decided that N 22 will be taken as recurrent parent in this study for introgression of another major QTL i.e., *qDTY12.1*.

In *kharif* 2014, a hybridization was made between Way Rarem (an upland cultivar of Indonesia and *qDTY12.1* donor) and N 22 (an upland variety, also contains *qDTY2.3* and *qDTY3.2*), in an attempt to pyramid the three QTLs together. A total of 20 F_1 seeds were obtained which were planted in *rabi* 2015 using standard agricultural practices. Leaves were collected from each of these F_1 plants along with the parents for DNA isolation. The DNA obtained from these F_1 plants were then subjected to PCR amplification using SSR primers linked to QTLs *viz.*, *qDTY12.1* (RM28166), *qDTY2.3* (RM 573) and *qDTY3.2* (RM 517). These PCR products were then electrophoresed using 4% agarose gels and 110V for 5 hours. Out of the 20 F_1 plants, 19 true F_1 hybrids were obtained.

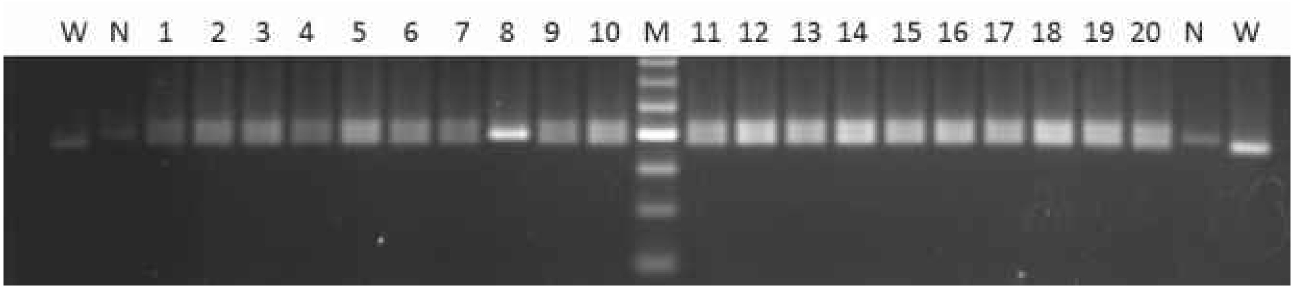


Fig. 1.20. PCR amplification of F_1 plants and the two parents Way Rarem (W) and N-22 (N) using SSR marker RM28166 for testing the presence of qDTY12.1. (M= 50 bp ladder)

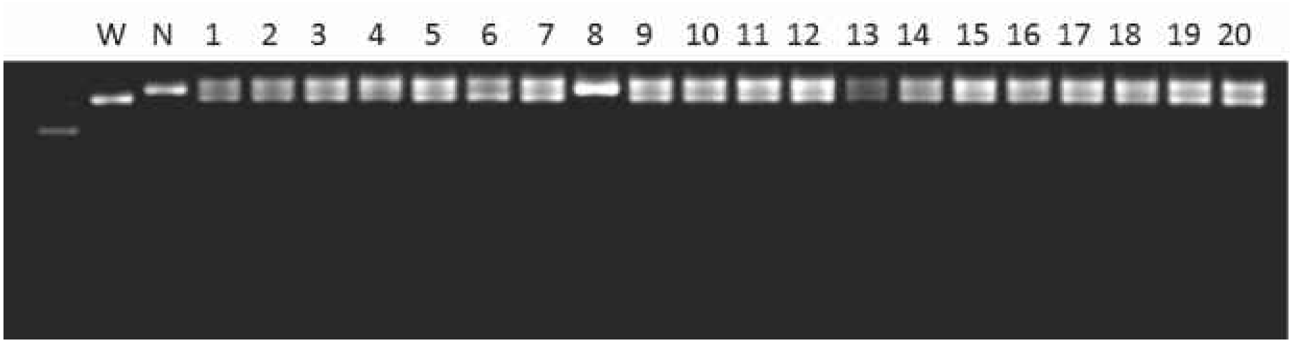


Fig. 1.21. PCR amplification of F_1 plants and the two parents Way Rarem (W) and N 22 (N) using SSR marker Rm517 for testing the presence of qDTY3.2 (M= 50 bp ladder)

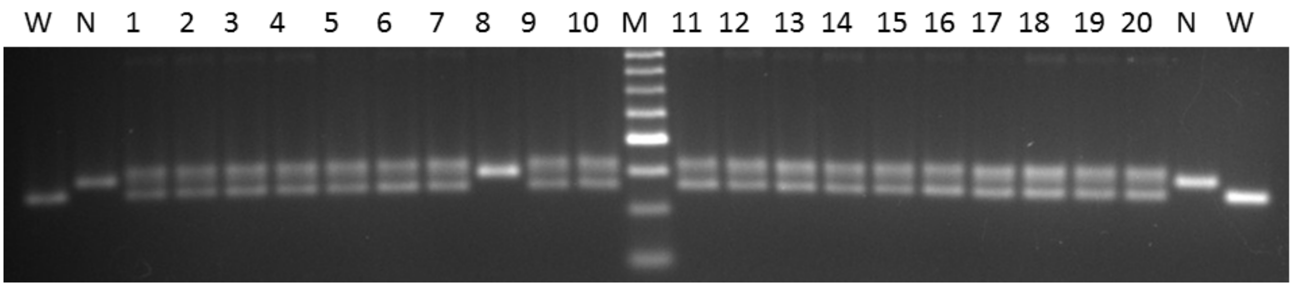


Fig 1.22. PCR amplification of F_1 plants and the two parents Way Rarem (W) and N 22 (N) using SSR marker Rm573 for testing the presence of qDTY2.3 (M= 50 bp ladder)

Variety released by SVRC

CR Dhan 101 (Ankit)

CR Dhan 101 (Ankit; IET 21627) was released by SVRC, Odisha for direct seeded upland ecology of the state. The maturity duration of the variety was 105-110 days along with semi-dwarf plant height, non-lodging plant type with an average of 250 panicles/m^2. It produces medium slender grain, moderate tillering (6-8), more grains/panicle and compact panicle with test weight of 22g. The genotype was moderately resistant to leaf blast, neck blast, brown spot, sheath rot, stem borer dead heart & white ear head damage, green leaf hopper, leaf folder and whorl maggot. The variety has high response to fertilizer application as compared to checks and qualifying varieties. The grains were medium slender, white kernel and possess good hulling and milling character along with desirable alkali spreading value.

CR Dhan 203 (Sachala)

CR Dhan 203 (Sachala; IET 21920) was released by SVRC, Odisha for aerobic cultivation in the state. Maturity duration of the variety is 110-115 days with semi-dwarf, non-lodging plant type (100 cm). It possesses long slender grain, more panicles per m^2 (255) with 85-90 days to 50% floweirng, normal tillering (7-9), medium and dense panicle with moderate test weight. It is moderately resistant to leaf blast, brown spot, sheath rot, stem borer (both dead heart and white ear heads), leaf folder, whorl maggot and rice thrips. As compared to the checks and qualifying varieties, variety Sachala was found to response to higher dose of fertilizer application.

Generation of breeding material for cold tolerance

A cross was attempted between cold tolerant Geetanjali and cold susceptible-drought tolerant Sahabhagidhan in *kharif* 2013. The F_1 was again crossed with MTU 1010 as three way cross in *rabi* 2014. Two hundred and twenty F_2 plants obtained from three way cross were raised in field during *rabi* 2015 to screen against cold under natural condition.

Trials under All India Coordinated Rice Improvement Programme (AICRIP)

Initial Variety Trial-Early Direct Seed (IVT E(DS))

Twenty seven entries including three check varieties were evaluated.

Initial Variety Trial-Aerob (IVT aerob)

Forty nine entries including four checks were evaluated in a randomized block design with three replications under aerobic situation.

Advance Variety Trial - Early Direct Seed (AVT 1 E(DS))

Advance variety trial for early direct Seed was conducted with 10 test entries along with three check varieties.

Advance Variety Trial 1 – Aerob (AVT 1-AEROB)

Eighteen entries including four checks were evaluated in a randomized block design with three replications under aerobic situation.

Advance Variety Trial 2 – Aerob (AVT 2-AEROB)

Advance variety trial for aerobic situation was conducted with 12 test entries generated at different breeding centers of the country and four check varieties.

Breeding for aromatic rice and grain quality improvement

Development of high yielding good grain quality aromatic genotypes with short/ long slender grain and biotic resistance

In order to develop high yielding aromatic genotypes eight new crosses were made involving elite varieties Pooja, Naveen, Tapaswini MAS, Pusa 44 MAS with aromatic donors Pusa 1121, Pusa 1509, Gobindabhog and Kalanamak. Three hundred and twenty six lines belonging to forty eight cross combinations in F_3 to F_7 generations were evaluated in irrigated condition and three hundred and nineteen single plant selections were made and 45 bulks were harvested based on their uniformity, agro-morphological characters and aroma. In an un-replicated observational yield trial sixty five uniform lines were evaluated. The promising genotypes were CR 2969-28, CR 2976-15-2, CR 3705-3-2, CR 2616-7-4 with more than 5.0 t/ha yield capacity and aroma. In an advanced yield trial twenty one aromatic, promising breeding lines were evaluated in which three genotypes CR 2938-46 (4.73 t/ha), CR 2713-6-2 (4.32 t/ha) and CR 3660-28 (4.22 t/ha) were found to be more promising in comparison with the aromatic check Ketekijoha (3.52 t/ha).

Maintenance and collection of aromatic short grain rice

One hundred and twenty six aromatic short grain landraces of Odisha and one hundred twenty four Kalanamak genotypes collected from different regions of eastern Uttar Pradesh were evaluated for their uniformity and maintained for their use as donors. Another set of 226 short grain aromatic rice germplasm belonging to different states of India were acquired from IIRR, Hyderabad for evaluation and conservation purpose.

Evaluation of breeding material with slender grain and desirable grain quality

Four hundred and thirty six lines belonging to fifteen cross combinations involving Samba Mahsuri, Padmakesari, HMT, IR 64 MAS, Banskathi, Swarna, Katrani, Chinikamini, Kalajeera and Basmati 370 in F_4 to F_7 generations were evaluated in irrigated condition and two hundred and eighty five single plant progenies and 46 bulks were made based on their agro-morphological and grain characters. In an un-replicated observational yield trial, forty two uniform lines were evaluated and five promising genotypes (CR 3694-8-2, CR 3648-14, CR 2711-3, CR 3712-23 and CR 3713-8-2) were with more than 5.0 t/ha yield capacity with slender grain.

Identification and mapping of genes/QTLs associated with grain aroma

Four hundred and ninety eight single plant selections of F_7 generation mapping populations belonging to two cross combinations Pusa 44/ Kalajeera and Gayatri/ Kalajeera were collected for phenotyping.

Biofortification of popular high yielding rice varieties with additional levels of iron and zinc through conventional approach

In order to develop genotypes with higher level of micronutrient (Iron and Zinc), 345 lines belonging to twenty five crosses involving Pusa 44, Gayatri, NDR 359, PR 118, PR 111, Samba Mahsuri, Sarala, Swarna and MTU 1071, Azucena, Jalamagna, Basmati-370, Dhusara and Chinikamini were advanced and two hundred and thirty six, two single plant selections and forty two bulks were made based on agro morphological characters and uniformity. Ten new cross combinations were attempted involving elite varieties Naveen, Swarna and newly identified donors Samalei, Khira, Upahar, IR 50 and Kalanamak.

Evaluation of elite aromatic cultures in national trials at NRRI, Cuttack

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

The IVT- ASG trial was conducted with 25 test entries along with three check varieties (Badshabhog (NC), Kalanamak (RC) and Ketekijoha (LC).

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

Seven entries including three check varieties (Badshabhog (NC), Kalanamak (RC) and CR Dhan 907 (LC) were evaluated in a randomized block design with three replications under irrigated conditions.

Advance Variety Trial 2- Aromatic Short Grain (AVT 2 - ASG)

Nine entries including three check varieties were evaluated in a replicated trial.

Initial Variety Trial- Basmati (IVT - BT)

Thirty entries including five checks: Pusa Basmati-1, Taroari Basmati, Pusa Basmati 1121, Pusa RH 10 and local check Geetanjali were evaluated in a replicated trial under irrigated conditions.

Evaluation of biofortfied cultures in national trials at NRRI, Cuttack

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

Ten entries including checks Kalanamak, Chittimuthyalu and Samba Mahsuri were evaluated in a replicated trial under irrigated conditions.

Initial Variety Trial- Rice Biofortification (IVT - Biofort)

Forty eight entries including checks Kalanamak, Chittimuthyalu and Samba Mahsuri were evaluated in a replicated trial under irrigated conditions.

Performance of entries nominated in AICRIP trials during 2014

During the year in the final year of testing IET 23189 (CR 2713-35), with yield of 4.89 t/ha recorded superiority over the best check at 13 locations with yields varying from 3.60 t/ha at Chinsurah to 7.65 t/ha at Raipur. It out yielded the best check in Chhattisgarh (80%), Odisha (59%), Bihar (58%), Maharashtra (42%), Gujarat (35%), Uttar Pradesh (22%), West Bengal (14%) and Assam (11%). Possessing aromatic, translucent and medium slender grains, this entry showed high HRR (70.7%), intermediate AC (22.58%) and medium GC (58 mm). Other promising entries include IET 22648 (CR 2713-179), IET 22649 (CR 2713- 180), IET 23203 (CR 2947-1) which showed improved yield over the best check on overall basis. IET 24614 (CR 3648-22-4) from the cross Gayatri/Chinikamini was promising with 17% yield advantage over best check and was promoted for second year of testing.

Fig. 1.23. Promising short grain aromatic genotype CR 2713-35

New nominations for AICRIP trials

Three promising high yielding, semi dwarf aromatic cultures CR 2939-23-8-3, CR 3660-22-9-4, CR 3648-26-2, having grain yield potential of more than 4.5 t/ha were nominated for AICRIP trial IVT-ASG. Four promising cultures with high protein such as CR2829-PLN-114, CR 2826-1-1-1-2B-1-2B-1, CR 2826-1-1-2-4B-10-1, CR 2915-1-1-3-1-B-6-2B-1, and CR 2829-PLN-23 were nominated to IVT –Biofort.

Breeding for high protein rice

QTLs for protein content in rice

Normal distribution was observed for GPC and SGPC in a mapping population from ARC 10075/Naveen, developed through backcrossing followed by and evaluated in three seasons. SNP genotyping of this population (190 lines) has been done using a 40894 SNP chip. Around 13% markers (5492) were found polymorphic in homozygous condition between ARC10075 and Naveen. All markers including segregation distortion loci have been mapped using sdl (segregation distortion locus mapping) taking inclusive composite interval mapping (ICIM) implemented in QTIciMapping V3.1 and putative QTLs in each environment have been detected. Two QTLs for GPC has been detected located on chromosome 1 and 2 and are explaining 13% and 17% phenotypic variances with LOD value of 3-4. Two common QTLs have been detected for single grain protein content located on chromosome 2 and 7. They explain 7-14% phenotypic variance (Table 1.26).

Performance of beeding lines in multilocational testing under biofortification trial

IET 24780 (CR 2829-PLN-37) (Fig. 1.24) with mean grain yield of 4.48 t/ha and mean protein content of 10.3% in polished rice was identified by varietal identification committee for release by CVRC for Odisha, UP and MP on the basis of yield advantage over the checks, IR 64 and Samba Mahsuri. This variety had medium slender grain and high HRR (69%) with moderate Zn content (15 ppm).

Among the other lines, IET 24783 (CR 2829-PLN-32) with high grain yield (4.48 t/ha), 6.81% yield advantage over Samba Mahsuri, 10% grain protein content and 16.43 ppm Zn content in polished rice and high HRR (68.2%) was promoted to AVT-1 Biofortification trial. In adition, IET 24777 (CR 2829-PLN-109) and IET 24772 (CR 2829-PLN-100) with 4.48 t/ha and 4.38 t/ha grain yield and 16.29 ppm and 16.75 ppm Zn and more than 10% protein content in polished rice, respectively, have also been promoted to AVT-1 Biofortification trial.

Fig.1.24. High protein content rice variety CR Dhan 310

High throughput phenotyping of mapping population

Calibration and validation (r=0.86) of NIR spectroscopy has been done for GPC using dehusked grain of 250 lines. Around 190 and 162 lines of two backcross derived mapping populations from ARC 10075/ Naveen and ARC 10075/Swarna, respectively, have been evaluated in *kharif* 2014.

Table 1.26: QTLs for grain protein content (GPC) and single grain protein content (SGPC)

Year/season	Trait/QTL	Chromosome	Position (cM)	Left marker	Right marker	LOD	PVE (%)	Add
kharif 2013	qGPC1.1	1	11	Affx-93237905	Affx-93229368	3.1269	12.1762	-0.468
kharif 2014	qGPC1.1	1	10	Affx-93237905	Affx-93229368	3.8318	13.855	-0.4261
rabi 2014	qGPC1.1	1	10	Affx-93237905	Affx-93229368	4.017	13.8505	-0.5806
	qGPC2.1	2	284	Affx-93221488	Affx-93245529	3.1857	17.3534	0.9234
kharif 2014	qSGPC1.1	1	12	Affx-93237905	Affx-93229368	2.8974	10.3696	-0.083
	qSGPC2.1	2	427	Affx-93260438	Affx-93236905	3.3156	6.7025	0.0586
	qSGPC7.1	7	60	Affx-93225742	Affx-93256949	3.5095	7.6782	0.0671
	qSGPC11.1	11	31	Affx-93232878	Affx-93212320	2.8732	6.4237	0.0759
rabi 2014	qSGPC1.2	1	240	Affx-93230672	Affx-93212941	3.3089	18.4627	0.4922
	qSGPC2.1	2	426	Affx-93228464	Affx-93256429	3.5278	14.6356	0.5401
	qSGPC3.1	3	219	Affx-93253793	Affx-93260929	4.1154	14.6526	0.5416
	qSGPC7.1	7	60	Affx-93225742	Affx-93256949	3.3281	7.8131	0.091
	qSGPC8.1	8	115	Affx-93259293	Affx-93258892	4.5477	23.5471	0.3364
	qSGPC12.1	12	128	Affx-93257146	Affx-93240174	2.9661	14.4859	0.5305

Apparent grain protein content of these lines was estimated using calibrated NIR spectroscopy. Average grain protein content in brown rice of BC_3F_5 population from ARC 10075/Swarna was recorded 9.36% with a range of 5.61-14.62%. On the other hand mean GPC in brown rice of BC_3F_5 population from ARC 10075/Naveen was 9.91 and range was 6.39-13.56%.

Improvement of rice through *in vitro* and transgenic approaches

Evaluation of doubled haploids derived from hybrid BS 6444G for BLB resistance

A rice hybrid, BS6444G developed by Bayer Crop Science India Pvt. Ltd. popularly known for its high yielding potential and BLB resistance was used as the donor from which 200 doubled haploids were generated through anther culture technique. These 200 lines were screened for three BLB resistance genes *(viz., Xa4, xa5, Xa21)* using gene based linked markers. Out of them , 14, 17 and 46 DH lines were found to be positive for *Xa21, xa5* and *Xa4* genes, respectively (Fig. 1.25). Besides, nine DHs showed a combination of two genes {such as *Xa4+xa5 (4 lines), Xa21+Xa4 (3 lines) and xa5+ Xa21 (7 lines)*}, while two DHs were found positive for all the three BLB resistance genes *(Xa4, xa5 and Xa21)*. Subsequently, all the identified lines showing positive for different genes were evaluated in the field under heavy BLB pressure during *kharif*, 2014, which showed substantial resistance to BLB (Fig. 1.26). Moreover, two lines carrying all the three genes showed very high level of field tolerance to BLB. These DH lines are being further evaluated for their agronomic and grain quality traits to determine their utility as new varieties.

Screening of DH populations of BS 6444G for aroma

Aroma is the most important quality trait of aromatic rice which commands a higher price than non-aromatic rice and this special trait has huge economic importance that determines the premium price in global trade. Fragrance in rice has been shown to result from an eight base pair deletion and three SNPs in 7[th] exon of the gene encoding Betaine aldehyde dehydrogenase 2 (BADH2) on chromosome 8 of *Oryza sativa* that causes the loss of function of BADH2. A functional BADH2 enzyme inhibits biosynthesis 2-acetyl 1-pyrroline (2-AP) which is a major component of aroma, whereas loss of function leads to the accumulation of the major aromatic compound, 2-AP in aromatic rice.

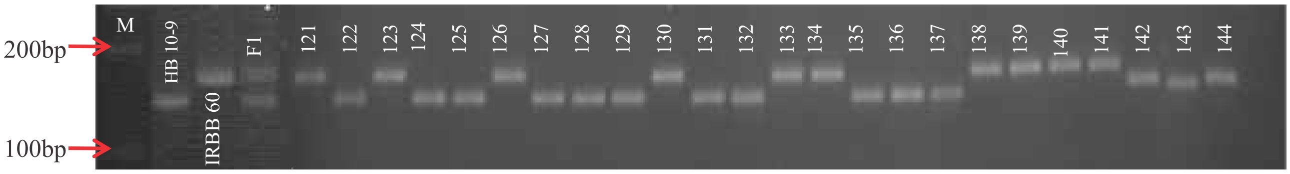


Fig. 1.25. Screening of DHs (121 – 144) along with F_1, IRBB60 (+Ve) and HB-10-9 (-Ve) using MP-STS primer forXa4 gene

Fig. 1.26. DHs showing high and moderate BLB resistance in the field

A total of 200 DH lines derived from BS 6444G developed through anther culture were evaluated using Allele Specific Amplication (ASA) of BADH2 and grain cooking parameters. A panel of analysts evaluated the lines for presence of aroma categorizing them into strong (43), medium (69), low (62) and absent (26). ASA was conducted using four primers developed by Bradbury, *et al.*, 2005 for discrimination of fragrant and non-fragrant individuals, where Kalajeera and Swarna were included as positive and negative controls, respectively. A total of three bands were obtained from which 257 bp, 355 bp and both the two amplicans (257 bp and 355 bp) indicate homozygous fragrant, homozygous non-fragrant and heterozygous non-fragrant, respectively. The upper fragment (~600 bp) act as positive control. Out of 200 lines screened in *rabi* 2014, 186 DH lines amplifying 257 bp band were found to be positive for aroma and four DH lines were heterozygotes for the trait (Fig. 1.27).

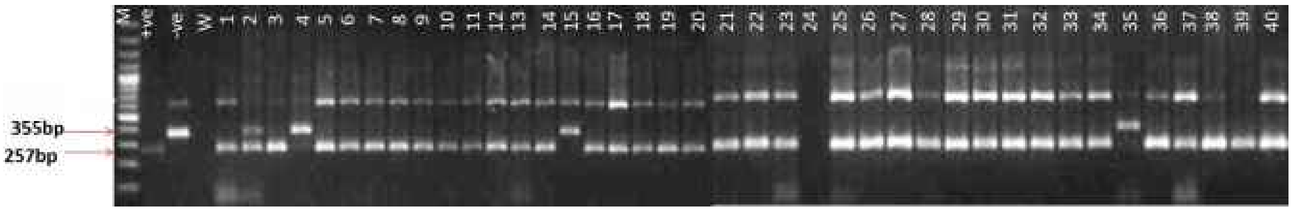


Fig. 1.27. Gel separation showing 40 DHs derived from rice hybrid, BS 6444G for aroma analysed using single tube ASA. M: 100 bp DNA ladder, +ve control: Kalajeera, -ve control: Swarna, W: blank and 1-40: DHs

Field evaluation for selection of promising DHs derived from elite hybrid rice varieties

Morpho-agronomic characters of the 200 doubled haploid lines derived from BS 6444G in *kharif* 2014 were recorded at A_1 generation in the field. Date of flowering, plant height, ear bearing tiller, length of flag leaf, panicle length, fertility%, test weight and grain length : breadth ratio varied from 127-150, 56-100.3 cm, 9-24, 25-39.8 cm, 21.9-32.2 cm, 64.5-96, 15.8-37 gm and 2.8-6.3, respectively. On the basis of these characters, 13 promising DH lines were selected and advanced for yield evaluation. Rest 187 DHs were maintained for further evaluation.

Yield evaluation of promising DHs derived from elite rice hybrid varieties

After evaluation through morpho-agronomic characters, 46 promising DH lines derived from rice hybrids were selected at A_2 generation in field on the basis of duration, test weight and yield in *rabi* 2014. These include 20,5,16,1,1,2 and 1 DHs from CRHR 32, PA 6201, CRHR 5, DRRH 1, KRH 2, Pusa RH 10 and CRHR 7, respectively which were advanced for further field evaluation. Subsequently, all the 46 selected DH lines were evaluated in *kharif* 2014 in randomized block design on the basis of the morpho-agronomic characters like plant height, days to 50% flowering, number of ear bearing tillers, panicle length, grain yield, spikelet fertility and test weight. A comparison was made between CRHR 32 and its DH derivatives (20 selected DH lines) where the parent showed grain yield of 2.55 t/ha and 20 DH lines varied from 2.12 – 4.22 t/ha. The highest grain yield was recorded as 4.22 t/ha followed by 4.02 t/ha, 4.0 t/ha and 3.92 t/ha. The average duration was recorded as 140 days in parent while it varied from 126-135 days in the DH lines. Besides, the grain test weight of donor was noted as 24.4 gm and ranged from 19.96 - 25.1 gm in the promising DH lines. Similarly, a DH line derived from PA 6201 showed the highest grain yield (3.75 t/ha) among the other DHs derived from the elite rice hybrids, CRHR 5, DRRH 1, KRH 2, Pusa RH 10 and CRHR 7.

Assessment of genetic fidelity in 20 selected DHs of CRHR 32 using SSR markers

A total of 20 randomly selected lines from twenty individual DHs were evaluated for their genetic fidelity using 12 set of SSR markers with 1 marker from each chromosome. All the markers amplified scorable bands between 100 bp to 300 bp molecular size range. The banding profile obtained in the progenies derived from DHs was completely uniform suggesting a high level of genetic fidelity among them along with the respective parent (Fig. 1.28). There was no variation among them.

Grain quality characteristics of DH lines derived from CRHR 32

Rice is consumed as a whole cooked milled grain. Amylose content, alkali spreading value, volume expansion, elongation ratio and water uptake value are the major characteristics which influences the cooking quality. The present study was conducted to determine the biochemical composition of 20 selected anther derived DH lines.

The hulling percentage varied from 74 to 78% in 16 DH lines showing higher hulling value than the parent. Similarly, 17 DH lines showed the milling percentage (68-74%) higher as compared to their parent, CRHR 32. The kernel elongation after cooking was found almost double in one DH line (CR-3-1). The head rice recovery showed the range between 53-64%.

The amylose content varied from 19.19% to 26.54%. Out of 20 DHs, four lines (CR 3-1, CR 7-6, CR 7-7 and CR 9-11) were found in grade 4, while rest showed grade 3 in the alkali spread value. The water uptake ranged from 90 ml to 165 ml. Based on the physico-chemical parameters, CR 3-1, CR 7-4 and CR 7-7 showed superior quality over the parent (CRHR 32) (Table 1. 27).

Evaluation of ploidy status of green plants derived from F_1s of Savitri x Pokkali

A total of 162 green plants developed through anther culture were evaluated to confirm the ploidy status after seed set, out of which 115 plants were found to be diploids while 21 green plants were haploids. Though

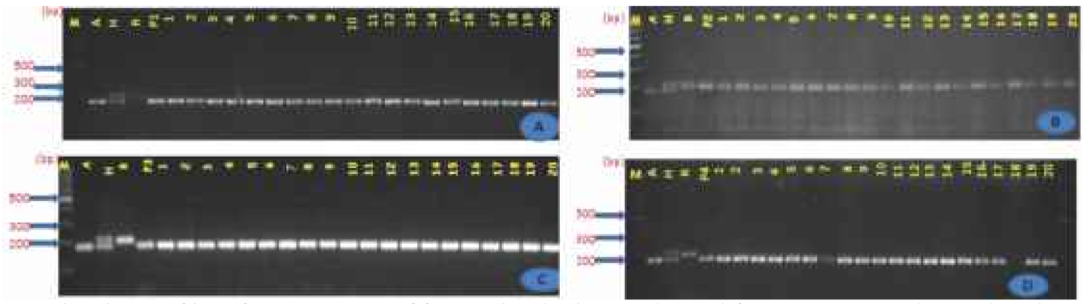


Fig. 1.28. Molecular profiles of 20 progenies of four individual DHs derived from CRHR 32 obtained with A: Rm480; B: Rm481; C: Rm263; D: Rm163. M: marker (100 bp DNA ladder); A: CRMS 31A; H: CRHR 32; R: CRL 22R; P1, P2, P3, P4 : individual parents; 1-20: progenies derived from individual DHs.

Table 1.27: Grain quality characteristics of 20 selected DHs with donor CRHR 32

Genotype	Moisture content (%)	Hulling (%)	Milling (%)	KL (mm)	KB (mm)	L/B	ER	HRR (%)	Amylose (%)	ASV	VER	KLAC	WU (ml)
CRHR 32	12.18	74	65	5.87	2.05	2.86	1.41	56	23.54	3	3.75	8.27	100
CR 1-1	12.00	76	68	5.71	2.1	2.71	1.31	58	21.23	3	3.75	7.48	110
CR 1-4	12.25	76	70	5.48	1.91	2.86	1.55	63	24.23	3	4.00	8.49	105
CR 2-1	12.12	77	72	5.10	1.76	2.89	1.72	65	20.97	3	3.75	8.77	100
CR 2-2	12.02	76	69	6.14	1.64	3.74	1.40	63	26.25	3	3.75	8.59	110
CR 2-3	12.15	74	69	5.84	2.06	2.83	1.62	63	25.08	3	3.75	9.46	120
CR 2-5	12.66	76	68	5.21	2.16	2.41	1.82	60	23.15	3	3.75	9.48	110
CR 3-1	12.72	76	68	5.13	1.79	2.86	1.91	61	21.82	4	3.75	9.8	132.5
CR 3-2	12.31	75	67	5.74	1.94	2.95	1.39	59	19.19	3	3.75	7.97	130
CR 4-1	12.44	74	62	5.78	2.14	2.70	1.30	57	24.49	3	3.75	7.51	122.5
CR 4-2	12.24	74	64	5.83	2.30	2.53	1.41	59	26.54	3	3.75	8.22	90
CR 6-1	12.65	74	66	5.14	1.98	2.59	1.86	60	22.42	3	3.75	9.56	142.5
CR 7-4	12.15	78	70	6.16	1.59	3.87	1.50	62	20.28	3	3.75	9.24	127.5
CR 7-6	12.28	77	69	6.34	1.74	3.64	1.49	58	24.60	4	3.75	9.44	165
CR 7-7	12.34	77	70	6.20	1.64	3.78	1.53	60	22.69	4	4.00	9.48	115
CR 7-8	12.45	76	71	5.54	1.52	3.64	1.29	64	21.54	3	3.75	7.14	150
CR 9-1	12.58	77	71	6.32	1.74	3.63	1.50	62	23.34	3	3.75	9.48	152.5
CR 9-2	12.31	78	70	6.06	1.87	3.24	1.53	63	21.67	3	3.75	9.27	162.5
CR 9-9	12.08	78	74	6.32	1.73	3.65	1.37	62	24.56	3	3.75	8.65	120
CR 9-11	12.25	76	64	5.78	2.16	2.67	1.45	53	25.11	4	3.75	8.38	130
CR 9-12	12.18	77	73	6.35	2.05	3.09	1.52	61	22.25	3	3.75	9.65	125

KL-Kernel length, **KB-**Kernel breadth, **ER-**Elongation ratio, **HRR-**Head rice recovery, **ASV-**Alkali spreading value, **VER-**Volume expansion ratio, **KLAC-**Kernel length after cooking, **WU-**Water uptake other 26 green plants showed normal morphological stature like parents; however, there was no seed set on maturity. A large range of variability in morpho-agronomic characters like days of flowering (138-142), plant height (127-130 cm), ear bearing tiller (5-7) and panicle length (21-23 cm) were noticed. On the other hand, the SSR markers could distinguish two heterozygotes (like parent) out of 115 diploid lines; rest 113 plants were found to be doubled haploids.

Assessment of parental allelic contribution in doubled haploids, derivatives of CRHR 32

A total of 650 SSR markers were screened to survey the parental polymorphism out of which 40 showed polymorphism between CRMS 31A and CRL 22R. Further, all 40 markers were used in characterizing 151 DH lines generated from CRHR 32. Simple sequence repeat analysis revealed homogeneity for 99.34% of the total marker evaluated in 151 DH lines. Out of these lines, 150 showed complete homogeneity for alleles of either parent, suggesting that DH lines were true representatives of the gametic constitution and were derived from the F_1 pollen. However, variation was detected in one line that is heterozygous for the parental alleles which might be generated from somatic tissues. From a total of 6000 loci amplified from 150 DH lines, 53.12% of the alleles were CMS (CRMS 31A) while 46.88% were restorer type (CRL 22R) (Table 1.28). Out of all the 40 markers tested, nine markers deviating from the expected 1:1 ratio was determined based on the χ^2 test at $p < 0.01$ and 0.05. In the DH population, four markers (10.0%) and five markers (12.5%) at $p < 0.05$, respectively showed distorted segregation. However, 31 markers skewed favoring parental alleles which revealed the expected 1:1 ratio for the alleles of CRMS 31A and CRL 22R used for development of CRHR 32 (Fig. 1.29).

Fig. 1.29. SSR marker (RM584) showing allelic frequency in 20 DH lines derived from CRHR 32, M- marker (100bp DNA ladder); 1: Nipponbare; 2: CRMS 31A; 3: CRHR 32; 4: CRL 22R; 5-24: DH lines derived from CRHR 32

Table 1.28: SSR analysis showing allelic frequencies of parental lines in 150 doubled haploids of CRHR 32 using χ^2-test

Sl. No.	Chromosome No.	SSR Marker	SSR repeat motif	DH population (1:1 expected ratio)		
				F_a	F_b	χ^2 -test
1	1	RM529	(CT)12	0.50	0.50	0
2	1	RM495(1)	(CTG)7	0.49	0.51	0.01
3	1	RM10992(1)	(AT)10	0.25	0.75	5.43*
4	1	RM490(1)	(CT)13	0.21	0.79	6.54*
5	2	RM71	(ATT)10T(ATT)4	0.50	0.50	0
6	2	RM279(1)	(GA)16	0.35	0.65	2.05
7	2	RM211(1)	(TC)3A(TC)18	0.39	0.61	3.24

8	2	RM13562(1)	(CT)10	0.20	0.80	7.34**
9	3	RM545(1)	(GA)30	0.25	0.75	5.67*
10	3	RM520(2)	(AG)10	0.54	0.46	0.32
11	3	RM3117(1)	(CA)12	0.31	0.69	2.87
12	4	RM16284(2)	(AT)28	0.52	0.48	0.04
13	4	RM280(2)	(GA)16	0.65	0.35	2.71
14	4	RM17111(2)	(AG)28	0.85	0.15	9.8**
15	4	RM17008(1)	(GA)26	0.1	0.90	12.8**
16	5	RM13(1)	(GA)6-(GA)16	0.29	0.71	5.87*
17	5	RM480 (1)	(AC)30	0.45	0.55	0.21
18	5	RM163(1)	(AG)15	0.44	0.56	0.32
19	6	RM584	(CT)14	0.50	0.50	0
20	6	RM204(1)	(CT)44	0.38	0.62	3.15
21	6	RM19422(2)	(AG)45	0.52	0.48	0.08
22	7	RM21559(1)	(AG)12	0.14	0.86	8.75**
23	7	RM336(1)	(CTT)18	0.30	0.70	3.03
24	7	RM481(2)	(CAA)12	0.62	0.38	2.52
25	8	RM23076(1)	(AG)24	0.39	0.61	3.21
26	8	RM22633(2)	(CT)16	0.60	0.40	1.67
27	8	RM22252	(CCG)10	0.50	0.50	0
28	9	RM205(2)	(CT)25	0.55	0.45	0.43
29	9	RM219(1)	(CT)17	0.44	0.56	0.03
30	9	RM316(1)	(AC)10	0.36	0.64	2.40
31	9	RM23744(1)	(CT)37	0.21	0.79	6.13*
32	10	RM25735 (1)	(AAG)25	0.30	0.70	2.12
33	10	RM216(1)	(CT)18	0.46	0.54	0.13
34	10	RM25712(2)	(AG)12	0.55	0.45	0.47
35	11	RM26269	(TG)11	0.50	0.50	0
36	11	RM26652	(TTC)9	0.50	0.50	0
37	11	RM224(2)	(AAG)7	0.57	0.43	0.83
38	12	RM27574(1)	(AAT)23	0.40	0.60	2.11
39	12	RM28424	(ATA)34	0.50	0.50	0
40	12	RM28157	(TTA)36	0.50	0.50	0

Development and use of genomic resources for genetic improvement of rice

Whole genome re-sequencing of ten high yielding mega rice varieties of India

Whole genome sequencing is a major step towards revealing the genomic diversity and its efficient utilization in crop breeding. Millions of DNA polymorphisms, including single nucleotide polymorphisms (SNPs), structural variants and insertion-and-deletion polymorphisms (InDels) have been identified in rice germplasm by using high throughput sequencing methods and bio-informatic tools. These DNA sequence level variations can be associated with trait variation and thus used indirect selection of trait of interest. Ten high yielding mega rice varieties of India namely, Swarna, Samba Mahsuri, MTU 1010, MTU 1001, PKM-HMT, PR 113, Pusa 1121, Pooja, Shatabdi and Sahabhagidhan were re-sequenced using NGS technology. Short-reads from the genome of each of 10 varieties were mapped to the 93-11 *(indica)* and Nipponbare *(japonica)* reference genomes. The sequencing depths of the uniquely mapped reads varied from 23.2X (Pooja) to 57.7X (PR113) with an average coverage of 39.62X. The genome coverage varied from 91.49% (MTU 1001) to 96.55% (Samba Mahsuri) with an average of 94.49% with 93-11 genome. Similarly, genome coverage varied from 91.38% (MTU 1001) to 95.69% (Samba Mahsuri) with an average of 93.97% with Nipponbare genome (Fig. 1.30). Thus, more than 91% of the whole genome sequences of mega rice varieties were covered using NGS with either 93-11 or Nipponbare reference genomes. The total number of SNPs and InDels varied from 571,396 (Samba Mahsuri) to 2,158,680 (Pusa 1121) with 93-11 genome. As against the Nipponbare genome, the total number of SNPs and InDels varied from 2,323,140 (Samba Mahsuri) to 3,127,894 (Swarna) (Fig. 1.31).

The identification of genomic structural variations (SVs) is a key step in understanding genetic diversity and evolution as well as disease etiology. All SVs classified based on inter and intra chromosomal with sub-division of inversion, translocation, duplication and singleton for *indica* and *japonica* genomes. A total of 37,500 and 54,676 genes were compared with 93-11 and Nipponbare genomes, respectively. Number of genes showing 100% sequence similarity varied from 25,722 (Shatabdi) to 32,514 (Samba Mahsuri) with 93-11 genome. Similarly, number of genes showing 100% sequence similarity varied from 29,995 (Shatabdi) to 40,288 (Samba Mahsuri) with Nipponbare genome. Forty one cloned yield related trait specific genes were annotated using GATK (version 2.8-1) package. Eleven genes controlling traits like grain size, panicle number, panicle branching pattern and grain number showed 100% identity in all 10 varieties. A total of 6,553 SNPs and 1,083 InDels shared by all varieties among all 41 yield specific genes. Unaligned reads with nuclear reference genomes were compared with mitochondrial and chloroplast genomes to get pure unaligned reads. These pure unmapped reads were assembled, annoted using BLASTn algorithm against plant genome nucleotide database to get evidence of genes. A total of 2,072 genes with greater than 90% identity were identified.

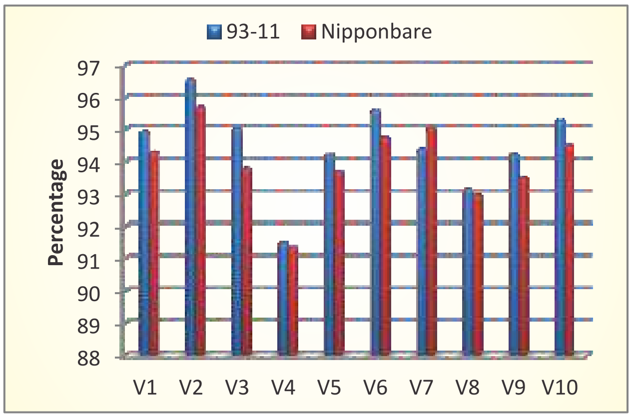


Fig. 1.30. Genome coverage

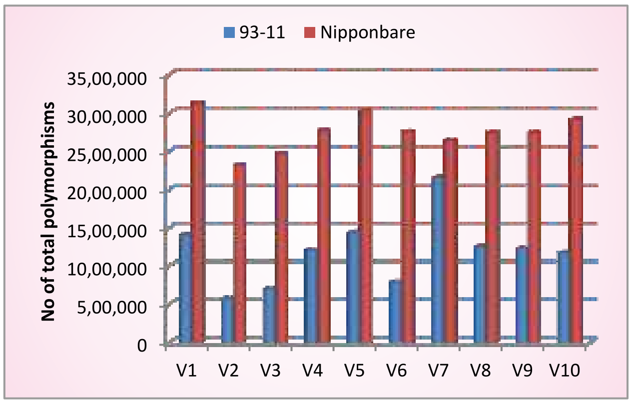


Fig. 1.31. Total number of SNPs and InDels

Legend: V1- Swarna, V2- Samba Mahsuri, V3- MTU 1010, V4- MTU 1001, V5- PKM-HMT, V6- PR 113, V7- Pusa 1121, V8- Pooja, V9- Shatabdi, V10- Sahabhagidhan

Phenotyping of mapping populations (RILs) for identification of QTLs associated with yield related traits

The RIL mapping populations from the crosses CR 662-2211-2-1/ WAB 50-56 and PDKV Shriram/ Heera were grown in the field following Alpha Lattice design, each with two replications. Different agro-morphological, yield related traits were recorded for identification of QTLs associated with yield and its component traits. The RIL population of the cross CR 662-2211-2-1 / WAB 50-56 showed normal distribution for yield related traits like grain number, 100 grain weight, per se yield, panicle length, etc. All the traits showed transgressive segregation.

Identification of QTLs for biotic stresses

Identification of QTLs for BPH resistance

One hundred and ninety RILs along with parents TN1 and Salkathi were genotyped with 40,894 SNP markers. Out of which 4,638 (11.34%) markers were found to be polymorphic between TN1 and Salkathi. The average proportion genome of Salkathi and TN1 in RILs was found to be 54.49% and 43.26%, respectively based on 4,638 polymorphic markers. 3,349 SNP marker loci followed expected Mendelian segregation (1:1) in the RIL mapping population at P<0.01. The linkage map was constructed with 3,349 polymorphic markers using integrated QTL IcMapping (v.4.0) software (www.isbreeding.net). The composite interval mapping (CIM) analysis using integrated QTL IcMapping (v.4.0) software identified two QTLs, *Qbph4.3* and *Qbph4.4* on chromosome 4. *Qbph4.3* with LOD score 4.77 and *Qbph4.4* with LOD score 7.22 explained phenotypic variance (PV) of 9.7% and 15.7%, respectively towards resistance to BPH. The RIL mapping populations from the cross TN1/Dhobanumbari were grown in the field during *kharif* for further generation advancement, phenotyping and identification of QTLs for BPH resistance.

Identification of QTLs for blast and brown spot resistance

One hundred ninety RILs along parents Kalinga III and Moroberekan were genotyped with 40,894 SNP markers, out of which 14,770 (36.12%) markers were found to be polymorphic between Kalinga III and Moroberekan. The average genome proportion of Kalinga III and Moroberekan in RILs was found to be 65.77% and 22.98%, respectively based on 14770 polymorphic markers. 1539 SNP marker loci followed expected Mendelian segregation (1:1) in the RIL mapping population at P<0.01. The linkage map was constructed with 1535 polymorphic markers. The composite interval mapping (CIM) analysis using QT IcMapping (v.4.0) software (www.isbreeding.net) identified two QTLs, *Qbs1* and *Qbs2* on chromosome 1 and 2, respectively. *Qbs1* with LOD score 2.62 explained phenotypic variance (PV) of 9.2%, while *Qbs2* with LOD score 2.88 explained 9.06%, respectively, towards the brown spot resistance. Similarly, one QTL, *Qpib6* with LOD score of 2.59 was identified on chromosome 6 which explained phenotypic variance (PV) of 5.91% towards the blast resistance.

Evaluation of rice germplasm for association analysis to identify QTLs/genes associated with drought tolerance

One hundred and eighteen (118) early duration rice genotypes were screened for drought tolerance under rain-out shelter facility during 2014 *kharif* season. Stress was imposed at vegetative stage for 20 days. Genotypes were scored for drought tolerance at the peak moisture stress following SES. Based on leaf rolling and drying score (SES), the genotypes were grouped for drought tolerance. Drought tolerance score among the genotypes ranged from 1 to 7. Only four genotypes found to have very good drought tolerance with a score of '1' (Fig. 1.32). Majority of the genotypes showed good (63 scored '3') to moderate (41 scored '5') tolerance for vegetative stage drought. Ten genotypes showed moderately susceptible (score '7') reaction, whereas none of the genotypes died completely as the soil

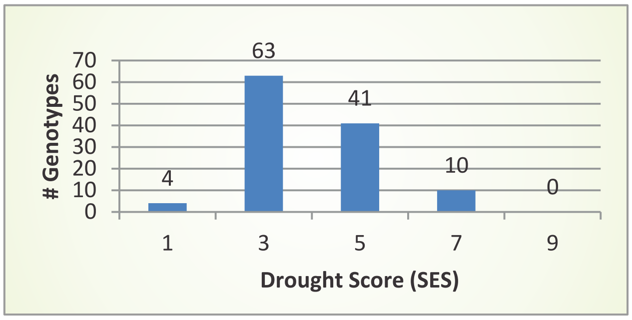
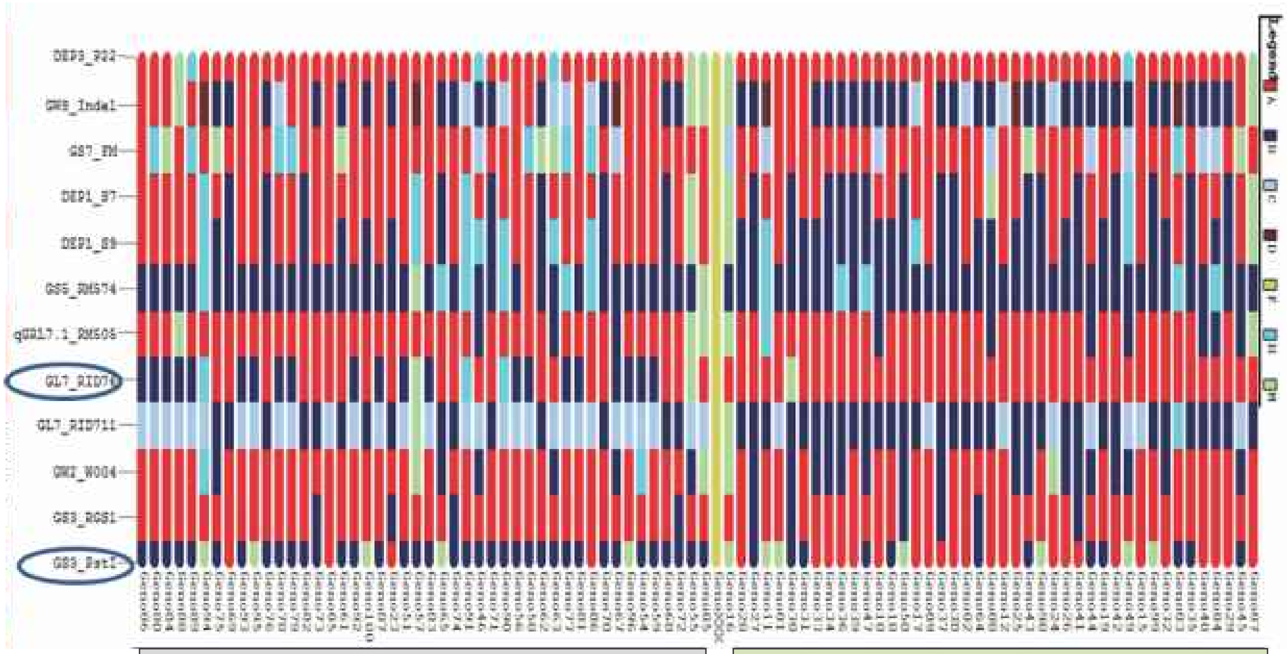


Fig. 1.32. Distribution of 118 genotypes for drought tolerance score based on SES

moisture tension was -23 to -30 kPa at 30 cm depth. These genotypes will be used for genotyping and association analysis for identification of QTLs/genes associated with drought tolerance.

Candidate gene based association analysis for grain size and identification of potential parental lines for mapping novel gene(s) related to grain size

Increasing rice yield is one of the important traits targeted by the rice breeders considering the future food demands. Rice yield is controlled directly by the quantitative traits such as grain number per panicle, number of panicles per plant and grain size/weight. Grain size/weight is a complex trait, which is further determined by grain length, breadth and thickness. Though, several genes/QTLs related to the grain size have been characterized, the complete molecular mechanism of grain size in rice is still unknown. In this study, 89 germplasm of extreme phenotype of grain length were selected, out of which 43 lines were short grain (range; 5.1 to 6.7mm) and 46 lines were long grain (range; 9.6 to 11.7mm). A total twelve markers for nine known genes (*GS3*; *GS3*-PstI, RGS1, *GS7*; GS7_FM, *GW8*; GW8-indel, *DEP3*; DEP3_P22, *DEP1*; S7, S9, *GS5*; RM574, *qGRL7.1*;RM505, *GL7*; RID76, RID711 & *GW2*; W004) related to grain size were included in the study of which four markers (GS3-PstI, RGS1, GW8-indel & GS7_FM) for three genes were functional markers and remaining eight markers for six genes were tightly linked markers. Association analysis using GGT 2.0 software revealed significant association of grain length with the *GS3* and *GL7* genes of 8.6 and 10.0 -10log (P) values, respectively (Fig. 1.33). Three long grain genotypes namely, DBT 2080, DBT 2495, and DBT 1495 were found to be carrying negative allele of *GS3* gene which can be used for identification of novel gene related to grain length. Some of the genotypes such as DBT 205, DBT 2650 etc. can be used as potential donors for positive alleles of *GS3, GW2, GL7,qGRL7, DEP1* and *GW8* for yield improvement of rice cultivars. The epistatic interaction of different genes can be studied by selecting different combinations of positive and negative alleles harboring genotypes from the present study.



Short grain (5.0-6.7 mm) | Long grain (9.6-11.7 mm)

Fig. 1.33. Graphical representation of genotyping with grain size related genes in selected germplasm using GGT 2.0 software

A, B & C: different alleles, D: BC heterozygote, H: AB heterozygote, M: null allele, F: demarking band to separate genotypes with extreme grain length

Development of resilient rice varieties for rainfed direct seeded upland ecosystem

Hybridization, generation and evaluation of breeding lines

Six new crosses were made for the development of resilient varieties for rainfed direct seeded uplands. The details of the parents utilized and the crosses made are given below (Table 1.29). Out of segregating progenies selected previous year, 401 advance generation lines (F_5 to F_7) from 62 crosses were evaluated during *kharif* 2014 and based on duration, plant type, panicle characters and reaction to abiotic and biotic stresses, 147 single plants and 14 bulk selections were made. Rest 662 segregating lines were grown at Cuttack during 2015 *rabi* season for generation advance. The F_2 population from the three crosses *viz*., Sahabhagidhan / CG323, Abhishek / MTU 1010 and CR Dhan 40 / CG 345 were grown during *kharif* 2014 and 150, 70 and 120 single plant selections were made from these crosses, respectively. These selected F_3 progenies were grown for generation advancement during *rabi* 2015.

Table 1.29: List of crosses made during *kharif* 2014

S. No.	Crosses
1	CRR 753-8-1/ IR 87707-118-B-B
2	CRR 752-9-1/ CRR750-6-B
3	IR84984-83-481-B-B/ CRR751-36-B-B
4	CRR 676-1/ IR 87707-118-B-B
5	CRR 747-16-3/ IR 87707-446-B-B
6	IR 87707-446-B-B/ CRR750-6-B

Preliminary yield trial

Eighteen genotypes including check were evaluated in an alpha-lattice design with three replications under direct seeded rainfed upland condition following recommended packages of practices. The trial was moderately affected by drought during post flowering and grain filling stage between last week of September and first fortnight of October. The promising entries significantly out yielded the check variety (Table 1.30). There were significant differences among genotypes for grain yield and other traits. Among the test entries CRR 716-4 (2153 kg/ha) produced the highest yield followed by CRR514-6-1-1-1 (1924 kg/ha) and CRR 687-B-10-B-B-B-37 (1590 kg/ha) as compared to the check Vandana (1562 kg/ha).

Entries promoted and new nominations in AICRIP trials

Three entries namely, IET 23339 (CRR 614-4-1), IET 24053 (CRR 647-56-1) and IET 24334 (CRR 484-2-1-1-1-1) showed yield advantage of more than 5% over best check in respective trials and promoted for advance testing under national coordinated trials. Eleven promising entries developed at this station were nominated for initial varietal testing under AICRIP trials.

Table 1.30: Performance of the selected entries under PYT, Hazaribag during *kharif* 2014

Designation	Days to 50% Flw.	Plant height (cm)	Panicle length (cm)	Sterility (%)	Grain yield (kg/ha)
CRR 716-4	68.7	102.4	21.7	17.61	2153
CRR514-6-1-1-1	65.7	90.3	16.9	20.86	1924
CRR 687-B-10-B-B-B-37	72.3	97.0	23.2	21.00	1590
CRR 483-24-1-1-1-1	72.7	100.1	28.7	37.43	1583
Vandana (check)	66.7	96.5	17.4	44.63	1563
Mean	72.8	93.5	22.1	46.62	1339.7
LSD 5%	2.3	11.4	2.6	10.6	205
CV (%)	1.9	7.4	7.1	13.7	9.3

Promising line identified

IET 23377 (CRR 523-2-2-1-1) derived from the cross Kalinga III/Bhupen has given a mean yield of 1680 and 3237 kg/ha under drought and normal locations, respectively, during *kharif* 2014. This entry flowers in 71 days with intermediate plant height (99 cm) and having very good grain quality with long slender grains. In region 3, it ranked 3rd with 11.25% higher yield than the best check. In the states of Jharkhand (1st), Maharashtra (2nd), Chhattisgarh (3rd) and Bihar (6th) it yielded 6.65, 31.86, 8.62 and 8.53% higher than the best check, respectively. This culture was tolerant to drought stress and moderately resistant to leaf blast and brown spot diseases. It had good cooking quality with 68.2% HRR, intermediate ASV (4), AC (25.55%) and low GC (42 mm). After three years of testing IET 23377 (CRR 523-2-2-1-1) showed promising in the state of Jharkhand (Fig. 1.34).

Fig. 1.34. Promising line CRR 523-2-2-1-1

IET 23345 (CRR 680-B-B-25-4) derived from the cross IR78875-176-B-2/IR 78875-207B-3 ranked 4th in the trials under drought affected locations during *kharif* 2014. Its mean yield was 1.99 t/ha with yield advantage of 10.12, 41.41 and 27.46% over national, regional and local checks, respectively. It showed yield superiority in the states of Jharkhand (1st) and West Bengal (2nd) by 20.89 and 12.91%, respectively. It had high HRR (69.1%), intermediate ASV (4.0), AC (20.86%), soft GC (70 mm) and high Zn (20.1 ppm) in milled rice. It showed moderately resistance to blast and RTD. IET 23345 showed yield advantage over best check under drought in the state of Jharkhand in 2014 and 2013, Maharashtra in 2013 and 2012, West Bengal in 2014 and under normal rainfall condition it was superior in Bihar during 2013 and 2012. Hence it was found to be promising for the states of Maharashtra and Jharkhand.

Identification of novel sources of resistance to drought and associated biotic stresses through MAB/MAS based introgression of known QTLs/genes

Phenotyping of QTL introgression lines

Vandana with blast R gene *Pi 2*

Vandana has been popular among farmers in several eastern Indian states as an upland rice cultivar because of its moderate tolerance to drought and adaptation to growing under direct seeded conditions. Since Vandana was susceptible to blast, especially at neck blast stage, an R gene *(Pi 2)* effective against majority of the eastern Indian populations of the blast fungus was introgressed from the monogenic line C101A51 through marker assisted backcrossing using the marker Ap5930. Agronomic evaluation of selected introgression lines in field plots and screening for blast in the UBN led to the identification of blast resistant near isogenic lines of the parent variety (Table 1.31).

Table 1.31: Agronomic performance & blast reaction of Vandana NILs *(Pi2)* at Hazaribag 2014 WS

Genotypes	Days to 50% Flw.	Plant height (cm)	Grain yield (kg/ha)	Leaf blast score (SES)
CRR747-102-5-B	68	117.4	2310	0
CRR746-76-2-B	67	119.6	2286	0
CRR746-44-7-B	71	98.8	2024	0
CRR747-102-10-B	67	108.4	2012	0
CRR746-76-24-B	72	104.2	2000	0
Vandana	65	100.9	2071	4
LSD 5%	2.5	4.9	570	

Fig. 1.35. Vandana & Vandana-IL under drought stress (A) and Vandana- ILs in the uniform blast nursery

Vandana with drought QTL & blast R gene (q*DTY12.1*+*Pi2*)

Introgression of *qDTY12.1* from Way Rarem into Vandana earlier led to marked improvement in its yield performance under stress. Further improvement of this popular cultivar was attempted by inter-mating the isogenic lines of Vandana carrying q*DTY12.1* and *Pi 2*. Ten introgression lines along with parent Vandana were evaluated in drought stress and non-stress conditions under direct seeding in uplands during *kharif* 2014. The same set was also screened for blast resistance in uniform blast nursery under artificial epiphytotics. The drought stress trial experienced 20 days of stress period corresponding to flowering to grain filling stage. Four ILs *viz.*, CRR 747-16-3-B, CRR 747-12-4-B, CRR7 47-12-3-B and CRR 747-16-5-B significantly outyielded the recurrent parent Vandana under stress condition and there was no significant difference under non-stress condition (Table 1.32). These ILs showed 33.4 to 60.6 % yield advantage over recurrent parent Vandana under stress condition. The introgression lines have same flowering duration as that of recurrent parent Vandana but were slightly taller in stature. In the uniform blast nursery the

Table 1.32: Performance of Vandana drought & blast QTLs (q*DTY12.1*+*Pi2*) introgression lines under stress & non-stress conditions during *kharif* 2014

ENTRY	Days to 50% Flw.		Plant height (cm)		Grain yield (kg/ha)		Leaf blast score (SES)
	Stress	NS	Stress	NS	Stress	NS	
CRR747-3-6-B	60	64	89.3	99.4	1219	2517	0
CRR747-3-7-B	63	64	84.7	110.9	388	2750	0
CRR747-3-8-B	63	66	88.5	110.4	938	2333	0
CRR747-16-1-B	63	65	93.0	107.4	1200	2750	0
CRR747-16-2-B	62	64	87.5	106.7	919	1750	0
CRR747-16-3-B	63	65	91.3	110.4	1656	2667	0
CRR747-12-1-B	64	66	87.3	102.8	938	1767	0
CRR747-12-3-B	61	65	95.9	108.9	1375	2417	0
CRR747-12-4-B	59	64	93.3	109.2	1469	2650	0
CRR747-16-5-B	63	66	89.8	108.3	1388	2350	0
Vandana	64	65	85.0	97.7	1031	2517	4
LSD5%	1.3	2.6	4.8	6.6	255	610	

NS= Non- stress

introgression lines did not take any infection and scored '0' for leaf blast disease (SES), whereas the parent Vandana scored '4'. The ILs developed will have an impact on the yield stability of Vandana in the drought and blast-prone areas of rainfed uplands and will serve as a breeding stock for further improvement of upland rice in breeding programs.

Samba Mahsuri with blast R gene *Pi 9* and *Pi b*

Agronomic evaluation of 23 introgressed lines of Samba Mahsuri with *Pi 9* and *Pi 2* was done under transplanted conditions in rainfed shallow lowlands. The lines fell into two duration groups, the first group was similar to the recurrent parent but the second group had maturity duration that is 15 days earlier to Samba Mahsuri. Lines introgressed with *Pi b* were not effective at Hazaribag, though the gene was known to contribute to resistance in other localities. Introgression lines carrying *Pi 9* were, however, highly resistant in the nursery and had no disease in the field plots. Two agronomically superior lines with *Pi 9* and having duration, phenotype and grain quality characteristics similar to Samba Mahsuri were selected for coordinated testing.

Evaluation of Anjali drought QTLs (q*DTY12.1*) introgression lines

Anjali is a moderately drought tolerant variety released for rainfed uplands in the states of Jharkhand, Bihar, Odisha, Assam and Tripura. This variety performed well under favourable upland conditions. Marker-assisted backcross breeding (MAB) approach was used to improve further drought tolerance of this popular upland variety in terms of grain yield under stress. Grain yield under stress QTLs *qDTY12.1* from Vandana X Way Rarem population was introgressed into Anjali using linked SSR markers and introgression lines developed. Ten (10) introgression lines along with recurrent parent Anjali were evaluated for grain yield under drought stress in direct seeded condition. The trial experienced 20 days dry spell during flowering to grain filling stage of the crop. The soil moisture tension at the peak stress period was (-)22 to (-)30 kPa at 30 cm depth. At this stress level five introgression lines significantly outyielded the recurrent parent Anjali by 66.5 to 109.3%. These NILs have lower sterility% and lower leaf rolling score based on SES scale as compared to

Table 1.33: Performance of Anjali introgression (q*DTY12.1*) lines under stress during *kharif* 2014

S No.	ENTRY	Days to 50% flw	Pl. ht (cm)	Grain yield (kg/ha)	Panicle length (cm)	Sterility (%)	Leaf rolling score (SES)
1	ANIL-3/225	62	64.4	1281	21.3	53.1	3.0
2	ANIL-1/39	58	64.2	1124	21.4	48.5	2.3
3	ANIL-7/342	66	63.7	1071	21.2	53.5	3.0
4	ANIL-5/325	64	70.6	1019	23.2	56.4	1.0
5	ANIL-10/460	65	59.9	1019	23.4	50.3	3.0
6	ANIL-2/63	61	72.3	929	21.1	61.2	4.3
7	ANIL-4/256	60	71.0	824	23.3	64.6	3.7
8	ANIL-8/359	68	52.4	319	21.7	74.1	5.0
9	ANIL-6/337	69	52.3	295	20.0	81.2	4.3
10	ANIL-9/365	67	57.9	252	20.9	85.3	7.0
11	ANJALI	65	59.7	612	20.6	67.6	5.7
	Mean	64	62.6	795	21.7	63.2	3.8
	LSD5%	2.1	9.9	379	2.5	13.4	2.1
	CV (%)	1.9	9.2	28.0	6.7	12.5	32.5

Fig. 1.36. Anjali NIL (qDTY12.1) and Anjali under drought stress, kharif 2014

Anjali (Table 1.33 & Fig. 1.36). The best NIL gave a yield of 1281 kg/ha as compared to Anjali (612 kg/ha). The NILs also differ from parent in duration and stature under stress condition. Few NILs were shorter in duration than Anjali. This was the first year of the study and would be validated over the years and locations.

Identification of genotypes with multiple stress tolerance and productivity

Evaluation of germplasm and elite lines (including coordinated trials) for abiotic stresses and yield under stress

AICRIP trials

IVT-VE-DS : The trial was conducted in rainfed upland under direct seeded condition. Thirteen entries including three checks were evaluated using randomized block design with three replications. The trial experienced one long dry spell of 20 days from 23 September to 12 October 2014 corresponding to grain filling stage of the crop. The best entry CRR 523-2-2-1-1, a cross between Kalinga III and Bhupen, out yielded the best check Vandana by 21.33%. This was also top ranking entry on overall mean yield basis across the locations during *kharif* 2013 under coordinated trial. Other promising entries, RP 5334-6-2-B and CRR-676-1 also yielded significantly better than the best check Vandana (2044 kg/ha) by 11.06% and 10.67%, respectively (Table 1.34).

AVT-1E-DS : The trial was conducted in rainfed bunded upland under direct seeded condition consisted 13 entries including three checks. The design followed was RBD with three replications. A long dry spell of 20 days affected the crop when most of the entries were at flowering stage. The top yielding entries in the trial were CRR 680-B-B-25-4 (2865

Table 1.34: Promising entries under very early and early (AICRIP) trials conducted at Hazaribag during *kharif* 2014

Trial	Grain yield (kg/ha)		Trial mean (kg/ha)	CD(0.05)	CV (%)
	Promising entry	Best check			
IVT VE - DS	CRR 523-2-2-1-1 (2480)	Vandana (2044)	1327	444	19.49
	RP 5334-6-2-B (2270)				
	CRR-676-1 (2262)				
AVT-1E-DS	CRR 680-B-B-25-4 (2865)	Sahabhagidhan (2370)	2079	389	11.05
	CR 3638-1-2 (2734)				
	CR 3617-1-1-2-1-1 (2729)				
IVT-E-DS	R-RF 105 (2951)	Sahabhagidhan (2410)	1996	473	14.43
	RCPR-16-IR-84894-143-CRA-17-1 (2833)				
	R-1672-126-1-24-1 (2806)				

kg/ha), CR 3638-1-2 (2734 kg/ha) and CR 3617-1-1-2-1-1 (2729 kg/ha) performing significantly better than the highest yielding check Sahabhagidhan (2370 kg/ha) (Table 1.34).

IVT-E-DS : Twenty four entries along with three checks of early duration were evaluated in RBD under rainfed bunded uplands.

AVT-2-IME : Altogether, seven entries including three checks were evaluated in RBD with three replications during *kharif* 2014.

AVT-1-IME : Twenty seven entries including four checks were tested in RBD with three replications (Table 1.35).

Table 1.35: Promising entries under irrigated mid-early (AICRIP) trials conducted at Hazaribag during *kharif* 2014

Trial	Grain yield (kg/ha)		Trial Mean	CD(0.05)	CV (%)
	Promising entry	Best check			
AVT2-IME	CN-1752-18-1-9-MLD-19 (5000)	Abhishek (4850)	4712	674	8.04
AVT1-IME	Indam-200-035 (5003)	Abhishek (3883)	4025	404	6.12
	CN 2015-5-4 (5000)				
	UPR-3737-1-1-1 (4913)				

INGER Nursery IURON: Forty three genetically diverse test entries along with seven checks were evaluated in unreplicated design under direct seeded rainfed uplands. Based on grain yield, spikelet fertility and phenotypic acceptability, the promising entries identified from the nursery were IR 12L361 (3000 kg/ha), IR 12L346 (2800 kg/ha), IR 12L339 (2530 t/ha), IR 08L150 (2130 kg/ha) and IR 12L342 (2000 kg/ha) (Table 1.36).

Evaluation of germplasm and elite lines (including coordinated trials) for blast

One thousand nine hundred and seventy three (1973) lines comprising of indigenous germplasm (659) and entries of the national screening nurseries (NSN 1{244} and 2{629}, National Hybrid Screening Nursery-130; Donor Screening Nursery- 222 and NSN-Hills - 89) were screened for their reaction to leaf blast in a Uniform Blast Nursery at Hazaribag. Distribution of reaction types was bimodal with about 22% of the lines exhibiting highly resistant reaction and the rest showing a range of disease intensities (Fig. 1.37). Breeding lines originating at blast endemic locations [NSN (H)] had the highest percentage of resistant entries, followed by hybrids. Landraces were highly susceptible with only 2.75% of them showing highly resistant reaction. Selection efficiency of the breeding programmes was reflected in the progressive reduction of susceptible entries (Fig. 1.38) in NSN 2 and NSN 1 compared to the landraces. Evaluation of a set of differentials at Hazaribag did not reveal changes in the virulence of known R genes but virulence on IR 64 appeared to have increased in frequency.

Table 1.36: Promising entries of IURON, Hazaribag during *kharif* 2014

Designation	Grain Yield (kg/ha)	Days to flw. (days)	Pl. height (cm)	PACP
IR 12L361	3000	75	93.2	1
IR 12L346	2800	73	95.1	1
IR 12L339	2530	73	90.8	1
IR 08L150	2130	81	86.7	3
IR 12L342	2000	75	99.4	1
Vandana	1670	66	77.7	1

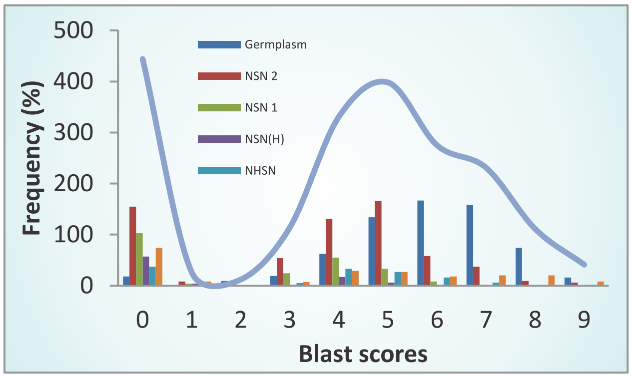


Fig. 1.37. Frequency distribution of blast scores in UBN, Hazaribag 2014

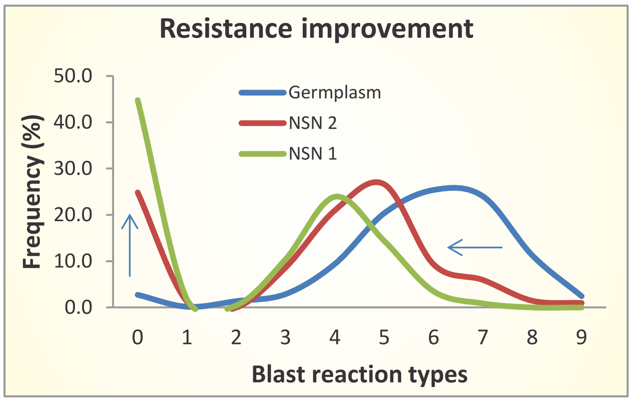


Fig. 1.38. Proportion of resistant and susceptible genotypes under different nurseries

Development of rice genotypes for rainfed flood-prone lowlands

Maintenance of rice germplasm

A total of 783 accessions of rice germplasm were rejuvenated for viability maintenance during *kharif* 2014. Observations on days to 50% flowering, plant height and grain yield were recorded.

Generation advancement of segregating materials

Pedigree nursery of 124 F_4 progenies of four crosses was raised for development of rainfed lowland (semi-glutinous and soft) rice and F_5 seeds were bulked for further selection and evaluation. BC_1F_3 of 36 crosses were raised and plants were bulked to BC_1F_4 for improvement of rainfed shallow lowland rice. For development of boro rice, 59 single plant progenies selected from 28 crosses were grown in F_5 nursery during *rabi* 2014 and F_6 seeds were bulked for further evaluation and selection. For the development of pre-flood *ahu* rice, F_4 nursery of 12 crosses were raised during *ahu* 2014 and F_5 seeds were bulked for selection in the next generation.

Promising rice cultures for boro season in AICRIP trial

Four promising genotypes including, CRL 2-12-7-2-3-2 under AVT1-Boro, three cultures *viz.*, CRL 192, CRL193, CRL194 under IVT-Boro were tested in AICRIP trial during *rabi* 2014.

Promising cultures for rainfed lowlands in AICRIP trial, *kharif* 2014

Altogether 20 entries from seven different categories, *viz.*, AVT1-L (1), IVT-RSL(1), NSDWSN(5), IVT-DW(9), AVT1-DW(2), IVT-ASG(1), and AVT2-ASG(1) were tested in AICRIP trials during *kharif* 2014.

Variety identified for release

One aromatic short grain entry, IET 23193 (CRL 74-89-2-4-1), a cross between Pankaj/Padumoni was identified by VIC for release in the states of Uttar Pradesh, Bihar, Assam and Maharashtra. It was a semi-dwarf culture with 110-115 days flowering duration, with medium slender grains. It had strong aroma with high HRR (70.0%) and good cooking quality.

PROGRAMME : 2

Enhancing Productivity, Sustainability and Resilience of Rice Based Production System

The productivity and sustainability of the rice production systems are dependent on combination of factors such as efficient use of resources, controlled by the farmers *viz.* nutrient, water and labour and managing the adverse effect of factors not within the reach of the farmer *viz.* climate/weather. This programme was formulated to develop and disseminate eco-friendly technologies to enhance productivity, profitability and sustainability of rice cultivation and provide food, nutritional and livelihood security of farming community.

Enhancing nutrient use efficiency and productivity in rice based system

Micronutrients (Fe, Mn, Zn and Cu) balance and nutrition under long term application of fertilizer and manure in a tropical rice-rice system

A study was conducted to analyze the balance of micronutrients and their interrelationship in the long term fertilizer experiment operational since 1969 at this Institute. The experiment is comprised of ten nutrient management treatments *viz.*, control, N, NP, NK, NPK, FYM, N+FYM, NP+FYM, NK+FYM, NPK+FYM with three replications. Micronutrients in soil (total and available), added fertilizers and organic manures and rice plants were measured. Besides, atmospheric deposition of the micronutrients to the experimental site was calculated using dust deposition and its micronutrient contents. A micronutrient balance sheet was prepared by the difference of total micronutrients output and input (Fig. 2.1). The results showed that application of FYM alone or in combination with chemical fertilizer increased the DTPA-Fe, Mn and Zn over the control treatment. The treatments with NPK+FYM had highest soil DTPA-extractable Fe, Mn, Zn and Cu after 41 years of cropping and fertilization. Application of chemical fertilizers without P reduced the DTPA-Zn over the control; however, inclusion of P in the fertilizer schedule maintained it, being on par with the control. Soil total Fe, Mn, Zn and Cu significantly increased with the application of P fertilizer and FYM either alone or in combination over control mainly due to their micronutrient content and atmospheric depositions. A negative balance for Zn was observed for the N, NP, NK and NPK treatments, while for remaining treatments positive balance was observed.

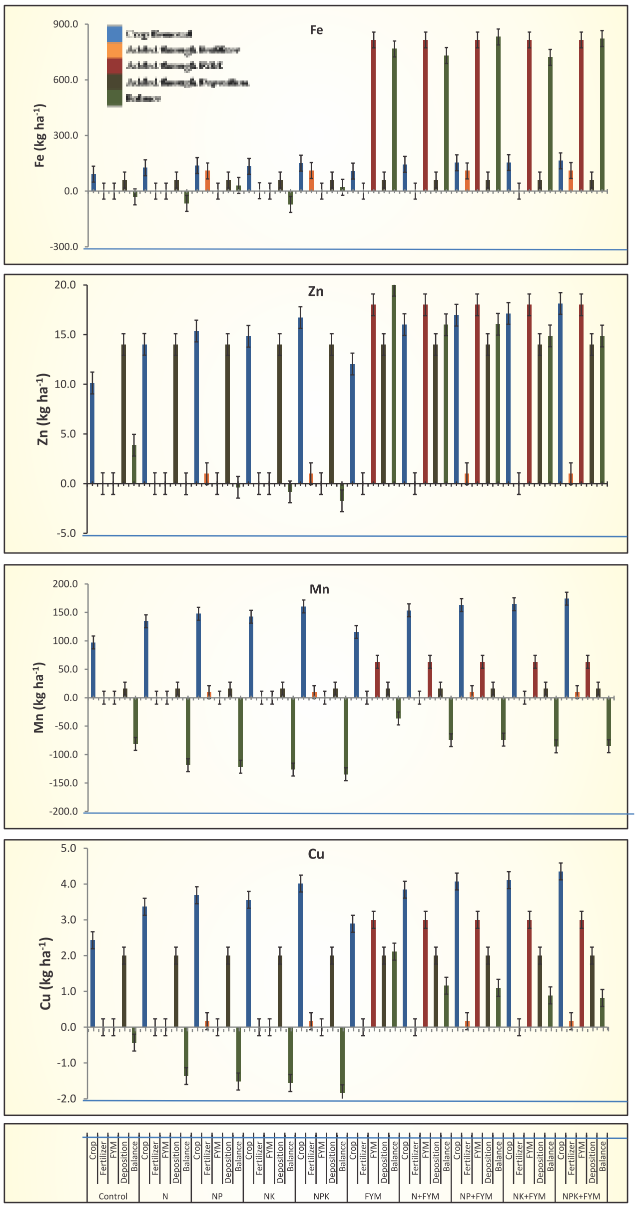


Fig. 2.1. Total inputs, outputs and balance of micronutrients in different treatments

A positive balance for Zn in control plots is due to the low uptake of Zn by the rice crop and addition through atmospheric deposition. The application of phosphatic fertilizer and organic manure contributed most towards the addition of micronutrients and a little addition was made through atmospheric deposition. The results showed that the balances of micronutrient were negative without fertilizer and manure applications. Phosphatic fertilizer contributed significantly towards compensating loss of Fe and to a lesser extent for Zn, whereas manure application increased the concentration of all the studied micronutrients in soil and hence maintained a positive balance for Fe, Zn and Cu. The balance of Mn was negative in all the treatments, because of less addition and higher uptake by the rice crop. Long-term fertilization affected Fe, Zn, Mn and Cu content in soil through the effects on soil physical and chemical properties and in turn regulated the micronutrients uptake by rice crop.

Effect of soil phosphorus and foliar spray of potassium in lowering the moisture stress in rice

A pot experiment was conducted with three levels of phosphorus i.e. 0, 20 and 40 mg/kg of soil, four cultivars *viz.*, IR-64 (Sensitive to moisture stress), Sahabhagidhan (polerant to moisture stress), Rajalaxmi (hybrid), Lalat (popular variety) and three level of spray treatment i.e. no spray, water spray and potassium spray (2% K solution). Spray treatments were imposed when soil moisture potential reached (-) 40 kPa. A moisture stress up to (-)60 kPa was imposed after 30 days of transplanting in all the varieties. Result revealed that the soil moisture potential reached to (-)60 kPa in 6 days in Rajalaxmi whereas in other varieties the same level of soil moisture stress was experienced on seventh day. Higher rate of transpiration due to higher vegetative growth of Rajalaxmi may have contributed to extract more water from the soil which resulted in higher soil moisture stress. Sahabhagidhan had significantly higher leaf water potential and relative leaf water content compared to other varieties during moisture stress, before imposition of moisture stress and also after moisture stress was revoked (Fig. 2.2). Water spray and 2% K spray during moisture stress was having significant positive effect over no spray. Catalase activity in the rice leaves of Sahabhagidhan was significantly higher compared to other cultivars during stress and also after moisture stress was revoked. Similarly, higher root length density (RLD) was recorded in Sahabhagidhan, whereas IR 64 had least RLD among four cultivars. Though the number of tillers after harvest was higher in Rajalaxmi, spikelet sterility was least in case of Sahbhagidhan which shows that Sahabhagidhan tolerated the vegetative stage moisture stress by maintaining higher leaf water potential, antioxidant enzymes and root length density.

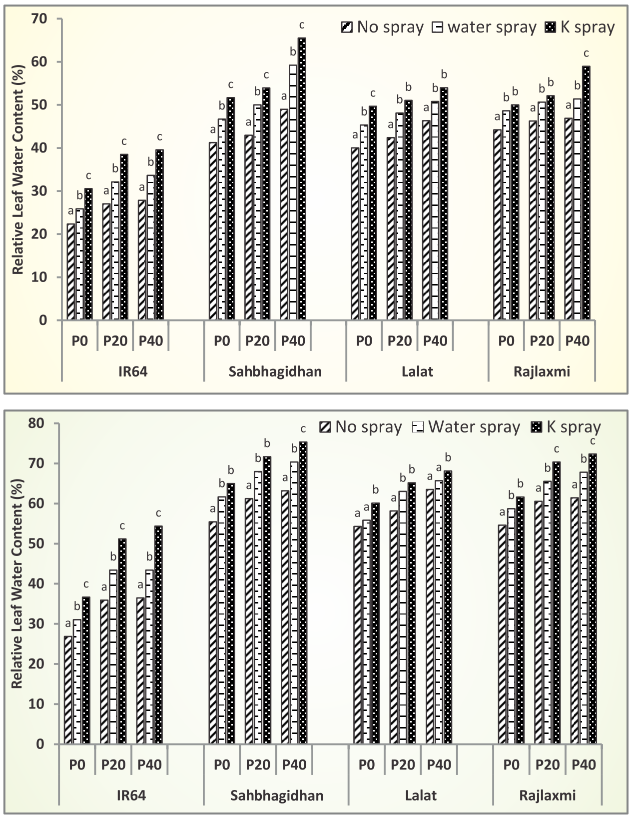
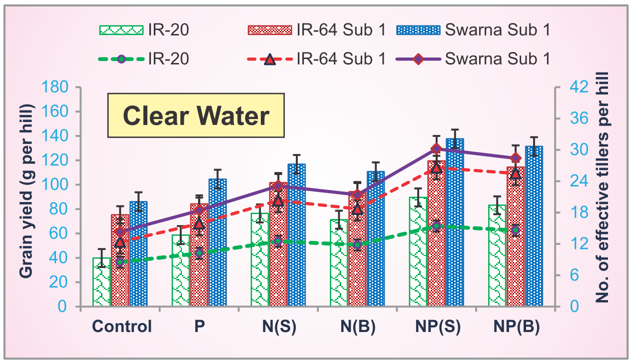


Fig. 2.2. Relative leaf water content of four cultivars under three phosphorus levels (a) during moisture stress and (b) after moisture stress was revoked. *(Column values represented by different letters for a cultivar within the same P treatment levels are significantly different at p ⩽ 0.05)*

Effect of flash flooding on rice and its recovery after flooding with nitrogen application

The experiment was carried out with three rice cultivars, IR 64 *Sub1* and Swarna *Sub1* (submergence tolerant) and IR 20 (susceptible to submergence); under clear and turbid water submergence with different schedules of N and P application including control. Fifteen day-old seedling of each cultivar was transplanted in the pots containing 10 kg of farm soil. For N, P and K supply, 80 mg urea, 114 mg SSP and 30 mg MoP was applied, respectively, to each pot as per the treatments. Nitrogen was applied in three equal splits at basal, maximum tillering (MT) and panicle initiation (PI) stage, second split of N at MT was applied after 48 hrs of de-submergence as urea foliar spray and broadcasting as per the treatments. Leaves of rice were sprayed on their adaxial surface with 2.0% (w/v) urea solution through a back-pack sprayer in a water carrier until they were completely wetted. The effect of basal P and post-flood N (six different nutrient schedules) on the performance of *Sub1* (IR 64 *Sub1* and Swarna *Sub1*) and non-*Sub1* (IR 20) cultivars of rice was tested under clear and turbid water submergence for their tolerance to submergence.



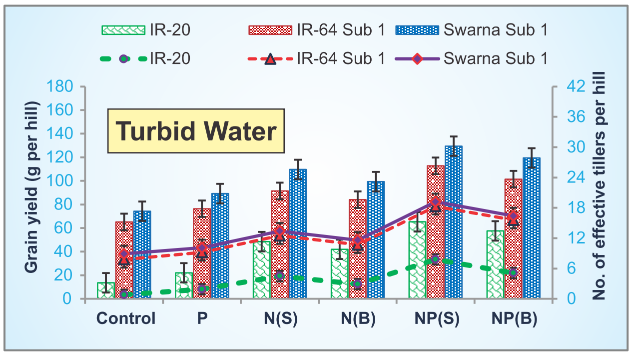


Fig. 2.3. Grain yield (bars, on primary axis) and number of effective tillers (lines, on secondary axis) of IR 20, IR 64 Sub1 and Swarna Sub1 at harvest under clear and turbid water submergence (vertical bars in each column and line represents standard error). P-phosphorus, N-nitrogen, B-broadcasting, S-spray

Leaf N concentration decreased significantly (*P=0.05*) after submergence irrespective of the cultivars; on the progression of survival, N content of leaves gradually increased. Nitrogen content before submergence was recorded significantly *(P=0.05)* higher in the treatments receiving nitrogen over control and basal P alone. On progression of submergence, N content decreased in all the treatments, but post-flood N application resulted in increased N content of leaves in all the cultivars. However, foliar spray of urea with basal P recorded significantly *(P=0.05)* highest leaf N content during all the sampling days. Photosynthesis, yield and N concentration of rice subjected to complete submergence for 15 days was decreased significantly over non-submerged rice plants. Turbid water submergence was fatal in terms of photosynthesis, stomatal conductance, effective tillers and yield because of low light and dissolved oxygen in under-water. Rice plants fertilized with P tolerated flooding better and produced significantly higher grain yields than no P application. The crop fertilized with N produced more number of effective tillers and grain yield than the unfertilized crop under complete submergence at MT stage. When post-flood N was applied alone, grain yield was 25.8, 17.8 and 17.1% lower in IR 20, IR 64 *Sub1* and Swarna *Sub1*, respectively, as compared to N and basal P application (Fig. 2.3). Urea foliar spray after de-submergence significantly enhanced the photosynthesis and narrowed down the flowering time which led to higher grain yield and productivity. The results open up new opportunity for enhancing the productivity of rice cultivars by manipulating the N application time and method in flood-prone areas.

Effect of combined application of silica, nitrogen and phosphorus in submerged rice

The experiment was carried out under natural conditions with four rice cultivars, IR 64 *Sub1*, Swarna *Sub1*, Savitri *Sub1* (having *Sub1* gene for submergence tolerance) and IR 20 (susceptible to submergence) under clear and turbid water submergence. Best treatments of our earlier study i.e. post-submergence urea foliar spray and basal phosphorus were combined with basal silica (Si) application. Approximately 100 pre-soaked seeds of each cultivar were directly sown in plastic tray (37 x 35 x 25 cm) containing 10 kg of farm soil (Sandy clay loam, pH: 6.5, EC: 0.078 dS/m, available N, P and K: 55.8, 4.7 and 62.1 mg/kg of soil, respectively), and later on plants were thinned up to 70 per tray. Each tray was applied with 0.49 g urea, 1.14 g SSP, 0.31 g MoP and 3.35 g Calcium silicate as per the treatments as N, P, K and Si source, respectively. Submergence tolerance on allometry, metabolic changes, photosynthetic (Pn) rate and ethylene accumulation was evaluated. Basal application of Si and P resulted in suppressed (*P=0.05*) under-water shoot elongation, either in combination or individually in all the cultivars. Combined application of basal Si and P reduced the shoot elongation to the extent of 104.5, 209.3, 166.2 and 241.1% in IR 20, IR 64 *Sub1*, Swarna *Sub1*, and Savitri *Sub1*, respectively, compared to control in both clear and turbid water. Application of Si reduced lodging and leaf senescence, with more prominent effects when applied with basal P. Basal Si and P application in combination with post-flood N contributed to highest plant survival followed by basal Si and N application. Though the effect of Si application alone was not visible in survival but when combined with N and P, it resulted in significant higher survival and better recovery. IR 20, IR 64 *Sub1*, Swarna *Sub1* and Savitri *Sub1* recorded 124.1, 77.6, 66.8 and 60.7% greater survival on application of Si with N and P, respectively, over control (Table 2.1). Combined effect of Si, N and P significantly improved after flood recovery of rice, growth, Pn rate, concentrations of chlorophyll and soluble sugars, which led to higher plant survival. The findings suggest that combined application of Si, N and P can significantly contribute to higher survival of rice seedlings and establishment thereafter in flash-flood prone areas.

Table 2.1: Plant survival (%) of IR 20, IR 64 *Sub1*, Swarna *Sub1* and Savitri *Sub1* after 7 and 15 days of de-submergence influenced due to basal phosphorus (P), silica (Si) and post-flood nitrogen (N) application under clear and turbid water submergence.

Treatments	IR 20		IR 64 *Sub1*		Swarna *Sub1*		Savitri *Sub1*	
	Clear	Turbid	Clear	Turbid	Clear	Turbid	Clear	Turbid
Plant survival (%) after 7 days of desubmergence								
Control	14.7^{e}	4.1^{e}	31.1^{f}	17.9^{f}	38.7^{f}	27.1^{f}	41.2^{f}	29.8^{f}
N	20.1^{cd}	7.3^{cd}	42.6^{d}	33.5^{d}	52.4^{d}	47.1^{d}	55.6^{d}	47.9^{d}
P	16.5^{e}	6.4^{d}	36.9^{e}	28.8^{e}	48.7^{e}	39.8^{e}	50.8^{e}	43.5^{e}
Si	17.4^{de}	6.6^{d}	37.4^{e}	29.5^{e}	49.3^{e}	41.3^{e}	51.1^{e}	44.2^{e}
N x Si	27.8^{b}	11.9^{b}	53.4^{b}	44.1^{b}	61.2^{b}	54.1^{b}	63.1^{b}	57.4^{b}
P x Si	22.3^{c}	9.8b^{c}	49.1^{c}	41.2^{c}	55.4^{c}	50.2^{c}	58.4^{c}	52.8^{c}
NP x Si	31.4^{a}	17.5^{a}	58.7^{a}	52.3^{a}	65.1^{a}	58.7^{a}	68.5^{a}	61.1^{a}
Plant survival (%) after 15 days of desubmergence								
Control	17.5^{e}	5.7^{e}	35.2^{f}	21.4^{f}	41.3^{f}	30.4^{f}	44.1^{e}	32.5^{f}
N	28.6^{c}	8.5^{cd}	46.9^{d}	37.3^{d}	56.2^{d}	49.1^{d}	58.7^{c}	51.4^{d}
P	22.1^{d}	7.2^{d}	40.5^{e}	32.8^{e}	51.9^{e}	43.2^{e}	53.2^{d}	45.6^{e}
Si	23.3^{d}	7.6^{d}	41.1^{e}	33.5^{e}	53.2^{e}	44.8^{e}	53.9^{d}	47.1^{e}
N x Si	35.6^{b}	13.7^{b}	57.8^{b}	48.7^{b}	64.5^{b}	59.8^{b}	66.3^{b}	59.9^{b}
P x Si	29.1^{c}	11.2^{c}	52.7^{c}	44.6^{c}	59.7^{c}	53.7^{c}	61.6^{c}	56.3^{c}
NP x Si	39.2^{a}	19.5^{a}	62.5^{a}	55.1^{a}	68.9^{a}	61.5^{a}	70.9^{a}	64.2^{a}

Plant survival was determined by counting the number of plants that were able to produce at least one new leaf after 7 and 15 days of de-submergence and was expressed as percentage of the initial number before submergence.

Application of rice husk biochar improves grain yield of rice

Effect of application of 0, 0.5, 1, 2, 4, 8 and 10 t/ha of rice husk biochar to a sandy clay loam soil in addition to recommended dose of fertilizer (RDF): 100:50:50 kg/ha (NPK) on rice grain yield was studied. Biochar used in the study had pH 8.7 and EC 0.72 dS/m. The scanning election microscopy (SEM) images of rice husk biochar showed highly porous structure indicating higher surface area (Fig. 2.4 and 2.5).The energy dispersive X–ray spectroscopy (EDX) revealed that biochar used in the miniplot experiment had about 45-50, 30 and 15-20% of C, O and Si, respectively on weight basis. Though significant difference was not observed in number of panicles/m^2, grain and straw yields in the first crop (*rabi* 2013-14), all biochar applied treatments recorded significantly higher number of panicles/m^2, grain and straw yields over control (RDF) in the second crop during *kharif* 2014 (Fig. 2.6). Application of RDF+10 t/ha of rice husk biochar recorded 29.6% increased grain yield (682 g/m^2) *vis-a-vis* 526 g/m^2 in control plot ($p \leqslant 0.05$). As biochar application improves the physical and biochemical properties of soil, the increased yield could be attributed primarily to higher nutrient uptake due to increased soil CEC (32 cmol (p+) kg^{-1}) and microbial activity (430 mg C/kg microbial biomass carbon) in soils where biochar was applied.

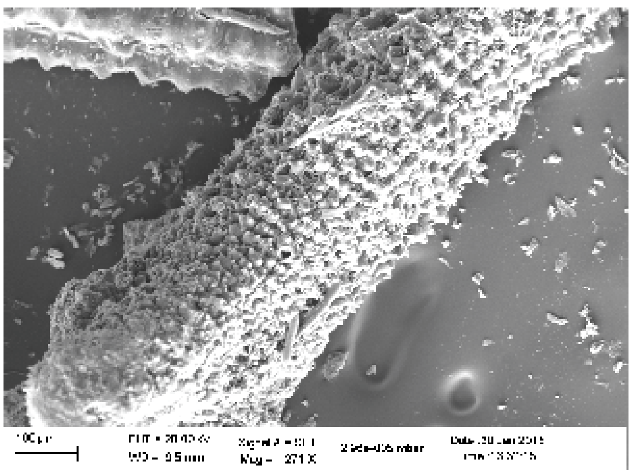


Fig. 2.4. Scanning electron microscope images of rice husk biochar (outer surface)

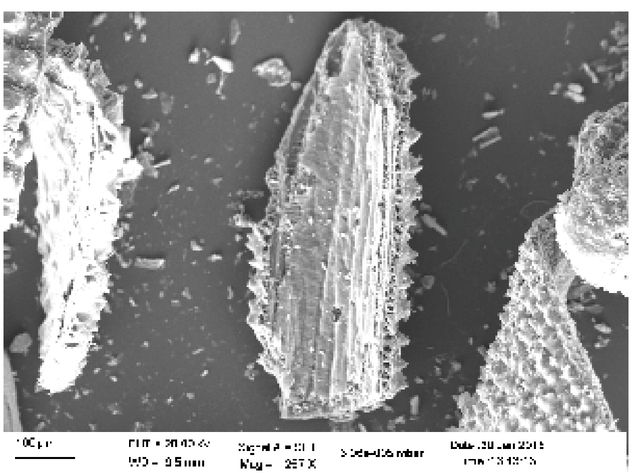


Fig. 2.5. Scanning electron microscope image of rice husk biochar (inner surface)

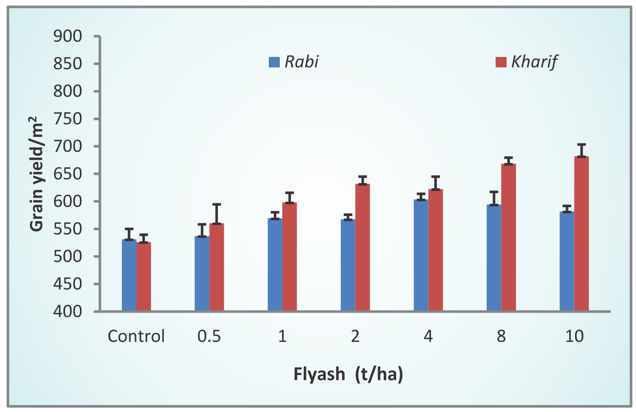


Fig. 2.6. Grain yield as influenced by different doses of biochar

Agro-management for enhancing water productivity and rice productivity under water shortage condition

Field experiment was conducted during 2014-15 with the objectives to identify promising rice genotypes on aerobic adaptation with higher water use efficiency, to improve irrigation management reducing water requirement balancing a trade-off between crop and water productivity and to develop suitable crop and nutrient management improving grain yield at water deficit regions.

Initial soil status of the experimental sites revealed 38.5% sand, 29.1% silt and 32.4% clay content with bulk density of 1.46 mg/m^3. The field capacity and standard hydraulic conductivity were 0.29 cm^3 water/cm^3 soil and 0.14 cm/hour, respectively. Two rice varieties namely CR Dhan 200 and Sahabhagidhan were treated with five levels of irrigation *viz.*, irrigations at aerobic condition (S_1);

irrigations at all three critical growth stages (CGS) - tiller, panicle and grain development stage (S_2); irrigations at tiller and panicle development stage (S_3); irrigations at tiller and grain development stage (S_4) and irrigations at panicle and grain development stage (S_5) of the crop with measured quantity of irrigation water.

Results showed higher grain yield (4.24 t/ha) in CR Dhan 200 than Sahabhagidhan (3.88 t/ha) and 15-20% more grain yield with additional irrigation at all three CGS or each at tiller and grain development stage than aerobic condition. Grain yield (4.15 t/ha) was significantly higher with additional irrigation at all three CGS closely followed by that (4.02 t/ha) at tiller and grain development stage. However, it was at the cost of maximum irrigation requirement (IR) of 1425 mm. Instead, lowest IR (1000 mm) accounting for higher water productivity (0.35 g grain/litre of water applied) was recorded at aerobic condition. No significant difference on IR was recorded between the varieties in the study.

Crop weather relationship studies in rice for development of adaptation strategies under changing climatic scenario

Rice canopy level radiation interception studies under different date of sowing

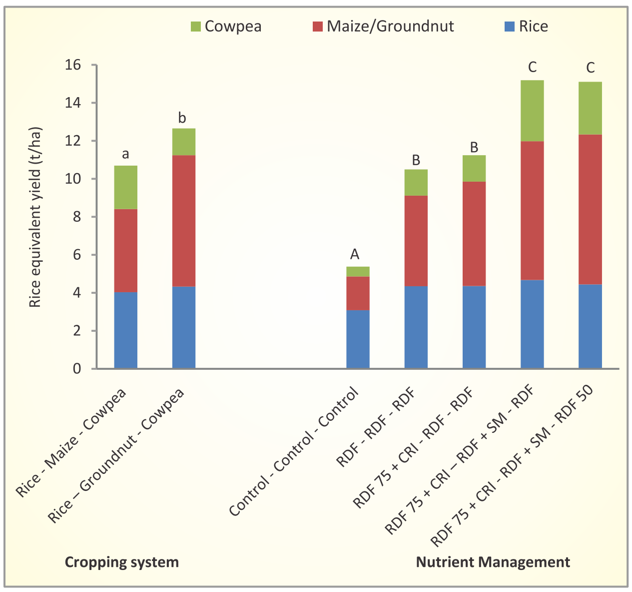
Field experiment was conducted during *kharif* 2014 with three methods of establishment (wet direct seeding, transplanting and modified SRI) in the main plot and four dates of main field sowing/ nursery sowing (1st week of June, 3rd week of June, 1st week of July and 3rd week of July) in sub plot and varieties (Pooja and Naveen) in sub sub plot in order to study the canopy level radiation interception. The results revealed that method of establishment, dates of sowing and variety had a significant effect on rice grain yield. Highest grain yield of 6.23 t/ha was recorded with modified SRI which was significantly higher than wet direct seeded rice. Rice sown after first week of July produced significantly lower grain yield. Among the two verities Pooja recorded higher grain yield compared to Naveen. However, Naveen intercepted more photosynthicaly active rediation (PAR) compared to Pooja at early stage of crop growth. There was no significant interaction among methods of establishment, date of sowing and variety.

Development of sustainable production technology 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 different nutrient management options on the rice-maize-cowpea and rice-groundnut-cowpea cropping system. The experiment was laid out in a split plot design with two cropping system i.e. rice-maize-cowpea and rice-groundnut-cowpea in main plots and five system based nutrient management option i.e. control-control-control, RDF - RDF - RDF, RDF_{75} + Crop residue incorporation of previous crop (CRI) – RDF - RDF, RDF_{75}+CRI - RDF + Straw mulching (SM) - RDF and RDF_{75}+CRI-RDF+SM-RDF_{50} in subplots replicated thrice. The variety Naveen (Rice), Super 36 (Maize) and Banamali (Cowpea) was used in the experiment.

Rice yield did not differ significantly with respect to different systems in *kharif* in second year of the system. However, significantly higher grain yield and yield attributes were recorded with all the fertilized treatments over control and highest grain yield of 4.67 t/ha was observed with RDF_{75}+CRI - RDF + SM - RDF. In second crop of the sequence, significantly higher grain yield was recorded with RDF+SM plots compared to RDF applied plots in maize. The rice equivalent yield (REY) of groundnut was significantly higher (58.0%) compared to maize in *rabi*. In groundnut, straw mulched plots also recorded higher pod yield compared to RDF applied plots. In summer season, significantly higher yield of cowpea was recorded in rice - maize -cowpea system compared to rice - groundnut - cowpea system. The REY of cowpea in rice - maize - cowpea system was 61.3% higher over the yield obtained in rice - groundnut - cowpea system. The total productivity of the rice - groundnut - cowpea system was significantly higher compared to that of rice - maize - cowpea system (Fig. 2.7). Among the nutrient management options, the highest REY of 15.19 t/ha was achieved with RDF_{75}+CRI- RDF+SM - RDF treatment, which was at par with that of RDF_{75}+CRI- RDF+SM - RDF_{50} treatments but significantly higher than all other nutrient management treatments. After a cycle of the system the organic carbon, available N and P content of the soil did not change with the cropping systems but



RDF: Recommended dose of fertilizers, CRI: Crop residue incorporation, SM: Straw mulching

Fig. 2.7. Productivity of component crops and the system (on rice equivalent yield basis) of rice based cropping system under nutrient management options.

Crop/varietal diversification in rice based cropping system for climate change adaptation

A field experiment was conducted on crop/varietal diversification in rice based cropping system for climate change adaptation involving seven different cropping systems i.e., rice-rice, rice-green gram, rice-horse gram, rice-coriander, rice-toria, rice-lathyrus and rice-black gram on rainfed rice based system during 2013-14. The experiment was laid out in Randomized Complete Block design and replicated thrice. In *kharif* season, three varieties of rice (Naveen

Table 2.2: Economic yield and rice equivalent yield of individual crops and system productivity of different cropping systems

Rice (*kharif*)	Dry season crops	Grain yield (kg/ha)		REY (kg/ha)	System Productivity (kg/ha)
		Rice	Dry season crops		
Naveen-1^{st} July	GG	4387	286.5	948.0	5335
	HG		214.4	551.8	4939
	T		209.2	461.5	4848
	Co		62.2	434.5	4821
Swarna-1^{st} July	GG	4713	381.4	1262.0	5975
	HG		251.2	646.5	5359
	T		442.3	975.7	5689
	Co		89.4	624.5	5337
Gayatri-1^{st} July	GG	4102	249.5	825.6	4928
	HG		229.7	591.1	4693
	T		322.8	712.1	4814
	Co		75.4	526.7	4629
Naveen-1^{st} Aug	BG	3741	457.8	1615.8	5357
	GG		392.3	1298.1	5039
	T		451.7	996.4	4737
	HG		268.1	690.0	4431
Swarna-1^{st} Aug	BG	2818	264.5	933.5	3752
	GG		193.4	639.9	3458
	T		273.7	603.8	3422
	HG		201.1	517.5	3336
Swarna-1^{st} July*	BG	-	127.8	451.1	451
	GG		124.1	410.6	411
	T		112.4	247.9	248
	Rice		1145.4	1145.4	1145

GG-Green gram; HG-Horse gram; T-Toria; Co-Coriander; BG-Black gram

(N), Swarna (S) and Gayatri (G) with different durations i.e., 120, 145 and 160 days, respectively were transplanted during 1^{st} week of July and 1^{st} week of August. In the rice-rice system, first crop of rice cv.

Swarna sown on 1st week of July was damaged artificially assuming drought/flood occurred due to weather aberrations, after that a short duration (95 days) rice variety Annada (A) was sown in October. After harvesting the rice, dry season crops were directly sown on residual moisture of preceding crop. The weather condition in October 2013 was aberrant due to cyclone (*Phailin*) and a rainfall of 700 mm was received during this month alone, out of 1587 mm rainfall received during the whole year. These aberrant weather conditions coincided with the reproductive stage of rice cv. Gayatri and late sown Naveen and Swarna led to significant reduction in yield (Table 2.2). In terms of system productivity, Swarna (July) resulted in 17.3 and 12.2% higher productivity than Gayatri and Naveen, respectively. Naveen and Swarna transplanted in July resulted in 17.3 and 67.2% higher yield as compared to transplanting in August, respectively. Dry season crops sown after harvesting of Swarna (1st July) performed better in terms of rice equivalent yield and system productivity. The non-rice crops sown after Naveen and Swarna (1st July) were performed better in terms of equivalent yield compared to crops sown after Gayatri. Among seven cropping systems, rice-black gram, rice-toria, rice-green gram and rice-horse gram require fewer inputs and are also less risky, which probably makes them more suitable for resource poor small farmers.

Development of aerobic rice based cropping system for arresting yield decline

A field experiment was conducted to arrest the yield decline in aerobic rice through rotation of aerobic rice with non rice crops in *rabi*. The experiment was laid out in a factorial randomised design with two rotation ratios i.e., Non rice crops in alternate year (1:1) and every two years (2:1) and four non rice crops i.e. maize, groundnut, green gram and cowpea and an absolute control of aerobic rice in every year in *rabi*. During the *kharif* aerobic rice was grown in every year. Results indicated that after 10 seasons of aerobic rice, the grain yield has been reduced by 18.3%. However, growing non rice crops i.e. maize, groundnut, green gram and cowpea lowered the yield reduction occurred due to continuous cultivation of aerobic rice. The differential rotations of non rice crops i.e., when grown every alternate year or every two years did not differ in arresting the yield decline level in aerobic rice system. Stand ratio did not show any differences in nematode population over the season. Yield improvement (5-15%) was pronounced with non rice crops; more in rice- green gram rotation followed by rice - groundnut rotation. Root knot nematode population was more in continuously grown aerobic rice but rice root nematode was more in rice-maize cropping system.

Farm implements and post harvest technology for rice

Design and development of single row and two row power weeder for dry and wet land condition

Modification and field performance evaluation of single row dry land power weeder

Single row power weeder, developed earlier, was having the problem of throwing soil causing risk to the operator. To overcome this problem, rear rubber flap of weeder was replaced with metallic sheet and curvature of front G.I. sheet cover over rotary blades

Fig. 2.8. Single row dry land weeder

was modified. Wheel spacing was made adjustable to work in different row spacing of crops. After this modification, the machine was tested in line sown rice crop (cv. Naveen) during *rabi* 2014-15 with the field condition where weed biomass was 2.86 t/ha. Soil moisture content and height of the crop were 11% and 19 cm, respectively.

The field capacity of machine was observed to be 0.031 ha/hr with blade width of 12 cm, 0.042 ha/hr with blade width of 16 cm and 0.052 ha/hr with blade width of 18 cm in 20, 25 and 30 cm row spacing, respectively at forward speed of 2.1 km/hr. There was no plant damage due to rotating blade and wheels. With one pass, 60 - 64 % of weed destruction was observed. Modified rear flap performance was found satisfactory. It did not allow soil throwing. Front cover threw the soil up to the distance of three meter in front direction of which 75% soil fall within one meter distance. After these modifications, there still remains the problem of maintaining constant depth of penetration of blades in to the soil.

Development of wet land single row power weeder

A single row power weeder for wet land is in the process of development with a 1.3 KW petrol start kerosene run engine as the source of power. Fabrication of clutch, gear box, bevel gear unit and main frame has been completed. Power from engine is taken to the rotor unit through clutch, bevel gear unit, gear box and chain assembly. Speed reduction of 7.3 times from engine was obtained through gearbox assembly.

Modification of two row self propelled dry land weeder to work under wetland condition

Two row self propelled dry land weeder developed at NRRI, Cuttack was modified to work as wet land weeder by incorporating cage wheels in place of rubber wheels. Two different sizes cage wheels were fabricated, suitable for 20 cm and 25 to 30 cm row spacing, respectively. Cage wheels were designed and fabricated in such a way that they move in the inter row space without damaging /pressing the plants. Width of each pad strip of cage wheel for 20 and 25-30 cm row spacing was kept at 11 cm and 14 cm, respectively. Diameter of cage wheel was kept at 72 cm and wheel base (centre to centre distance) for 20 cm row spacing was kept at 61 cm, whereas for 25 and 30 cm row spacing, it was kept at 76 cm. The two row self propelled wet land weeder (Fig. 2.9) was tested in Naveen variety of paddy, sown with row spacing of 20, 25 and 30 cm during *rabi* 2014-15 (Table 2.3).

Results revealed that for 20 and 25 cm row spaced rice crop, blade width of 9 cm worked very well. The weed destruction was in the order of 51% and 49% without damaging crop plants. In 30 cm row spaced crop, blade of width 12 cm recorded maximum destruction of weed (50%) without damaging the plants. Some modification is further needed in the machine. Due to narrow width of rear control of wheels, the wheels go deeper than the requirement, necessitating its widening. Also back side cover of rotary unit needs modification. It presses the paddy plant down.

Table 2.3: Field performance of two row self propelled wet land weeder under different blade widths and row spacing in rice crop

Width of blades (cm)	20 cm row spacing			25 cm row spacing			30 cm row spacing		
	Field capacity (ha/hr)	Rice plant damage (%)	Weed destruction (%)	Field capacity (ha/hr)	Rice plant damage (%)	Weed destruction (%)	Field capacity (ha/hr)	Rice plant damage (%)	Weed destruction (%)
6	0.051	Nil	38	0.079	Nil	30	0.095	Nil	25
9		Nil	51		Nil	49		Nil	35
12		36.8	66		2.2	57		Nil	50

Fig. 2.9. Two row self propelled wet land weeder

Design and development of a power operated seeder and a four row transplanter using mat type seedling for planting of rice

Modification and performance evaluation of the 8 row self propelled paddy seeder with cup feed type seed metering mechanism

The self propelled paddy drum seeder comprising of 2.97 KW diesel engine was modified to overcome the problem of missing hills and in-appropriate seed falling. The cup size was increased to 10 mm from 9 mm, the total number of cups in one wheel was reduced to 8 from 9 and the seed guide was modified. The changes required reassembling of metering unit. The modified machine (Fig. 2.10) was tested with sowing of pre-germinated seed of Naveen variety of paddy during *rabi* 2014-15. After the modifications, seed placement was proper without missing hills. Seed fall of 1 to 3 seed per hill was observed. The field capacity of machine was 0.2 ha/hr at the forward speed of 1.6 km/hr and the seed rate was 25 kg/ha. However, the machine needs further modification in float arrangement to avoid the problem of seed scattering.

Fig. 2.10. Eight row self propelled paddy seeder with cup type seed metering mechanism

Fabrication of oscillating mechanism of self propelled four- row rice transplanter

Cam shaft mechanism for power operated four-row rice transplanter using mat type seedlings was developed and fitted with the transplanter, developed earlier. During field testing, oscillating mechanism worked well at the designed distance of 240 mm but at turnings and forward movement was not found to be satisfactory. Hence, modifications in transmission, front wheel and turning systems are required for proper working of the transplanter.

Resource conservation technologies for sustainable rice production

Field experiment was conducted with the rice cultivar Naveen, in the *kharif* season of 2014. Six resource conservation technologies (RCTs) were implemented with three replications in randomized block design. The treatments briefly included, T1: conventional practice as control; T2: minimum tillage + brown manuring (*Sesbania aculeata*); T3: minimum tillage + green manuring (*Sesbania aculeata*); T4: wet direct seeding of rice by drum seeder; T5: Zero tilled dry direct seeded rice; T6: Paired row dry direct seeded rice. The grain yield varied in the range of 4.08 to 4.98 t/ha and the highest yield was obtained in the paired row dry direct seeded rice (Table 2.4). The input and output energy was in the range of 17.9-31.1 and 147.1-190 GJ/ha, respectively (Table 2.4). The energy ratio was found highest (9.3) in the paired row rice with *dhaincha* treatment. The net carbon gain was also found highest in the T6 treatment. The input and output energy was calculated as per different

Table 2.4: Grain yield, energy input, output and energy ratio and carbon gain under different RCT treatments

Treatments	Grain yield (t/ha)	Input energy (GJ/ha)	Output energy (GJ/ha)	Energy ratio	Carbon gain (Mg C/ha)
T_1	4.83	31.1	182.3	5.9	3.0
T_2	4.32	20.7	158.7	7.7	2.8
T_3	4.38	19.4	150.3	7.7	2.6
T_4	4.86	28.2	190.0	6.7	3.3
T_5	4.23	17.9	147.1	8.2	2.6
T_6	4.98	20.9	194.3	9.3	3.5

Table 2.5: Input and output energy parameters in different RCT treatments in *kharif* season 2014

	T_1	T_2	T_3	T_4	T_5	T_6
Inputs						
Plot size (m^2)	90	90	90	90	90	90
Plot size (ha)	0.009	0.009	0.009	0.009	0.009	0.009
Power tiller (MJ) land preparation	14.98284	14.98284	14.98284	14.98284	0	14.98284
No. of manual labors for puddling	0	0	0	0	0	0
Man hours for puddling	0	0	0	0	0	0
Energy for puddling by Powertiller (MJ)	12.77181	0	0	12.77181	0	0
Rice Seed (kg/ha)	40	40	40	35	40	40
Rice seed energy (MJ)	6.12	6.12	6.12	5.355	6.12	6.12
Dhaincha seed (kg/ha)	0	5	5	0	0	5
Dhaincha seed energy (MJ)	0	0.9	0.9	0	0	0.9
Energy for sowing (MJ)	1.5876	0.43668	0.43668	0.57429	1.5876	0.43668
No. of weeding	3	3	3	3	1	3
Energy for weeding (MJ)	19.0512	14.8176	6.33852	6.33852	4.9392	6.33852
No. of irrigation	11	6	6	11	6	6
Energy for irrigation (MJ)	121.0008	66.00042	66.00042	121.0008	66.00042	66.00042
No. of split fertilizer application	3	3	3	3	3	3
Energy for Fertilizer application (MJ)	0.84672	0.84672	0.84672	0.84672	0.84672	0.84672
N dose(kg/ha)	80	46	46	69	46	69
Energy for N	43.632	25.0884	25.0884	37.6326	25.0884	37.6326
P_2O_5 dose (kg/ha)	40	40	40	40	40	40
energy for P_2O_5	3.996	3.996	3.996	3.996	3.996	3.996
K_2O dose	40	40	40	40	40	40
Energy for K_2O(kg/ha)	2.412	2.412	2.412	2.412	2.412	2.412
Energy for Chemical fertilizer (MJ)	50.04	31.4964	31.4964	44.0406	31.4964	44.0406
No. of application of herbicide	0	1	0	0	4	1
Energy for Herbicide (MJ)	0	0.5355	0	0	2.142	0.5355
No. of application pesticides	2	2	2	2	2	2
Energy for Pesticides (MJ)	47.90808	47.90808	47.90808	47.90808	47.90808	47.90808
Harvesting (manual: 432.30; reaper(117.91)+thresher(38.80)+ bunding (115.0)(MJ)	5.2749	2.44539	0.34398	0.34398	0.34398	0.34398

	T_1	T_2	T_3	T_4	T_5	T_6
Output						
Grain yield(t/ha)	4.8	4.47	3.96	4.93	5	5.06
Energy for grain yield	635.04	591.381	523.908	652.239	661.5	669.438
Etraw yield (t/ha)	7.71	7.3	6.18	8.93	5.95	9.71
Energy for straw yield	867.375	821.25	695.25	1004.625	669.375	1092.375
Husk yield (t/ha)	0.5	0.5	0.5	0.5	0.5	0.5
Energy for husk	62.1	62.1	62.1	62.1	62.1	62.1

agricultural operations in the respective treatments (Table 2.5). The input energy included in different agricultural activities *i.e.* land preparation, puddling, sowing by manually, seed drill or by drum seeder, energy in rice seed and *dhaincha* seed, irrigation, fertilizer application, energy in herbicides and pesticides, manual or mechanical harvesting. The output energy included energy in grain, straw and husk.

There was significant amount of energy savings and net C gain in paired row dry direct seeded rice with green manuring treatment compared to the rest of the treatments in this study. The treatment consist the package of practices like power tiller puddling, dry direct seeded with seed drill, 75% N with CLCC application (customized leaf color chart) and 100% RDF for P and K, mechanical weeding and harvesting. In this technology considerable amount of energy was saved during land preparation like, 15% of energy was saved here as compared to power tiller operated puddling. Further, energy was saved during the operation of dry direct sowing with seed drill over control (72%) and wet direct seeding by drum seeder (24%). Apart from this, significant energy was saved (32%) during N management as 25% N was supplemented by *dhaincha*. Moreover, practicing of mechanical weeding saved 67% of energy as compared to manual weeding. Although, in zero and minimum tillage the energy savings was more than this technology but the yield and C gain were significantly higher in this treatment as compared to minimum and or zero tillage. The organic carbon varied in different RCTs was in the range of 14.1-15.1 Mg C/ha (Fig. 2.11) and was found highest in the T_6 treatment. The dehydrogenase (Fig. 2.12) and fluorescein hydrolytic activity (Fig. 2.13) was also found highest in T_6 treatment.

In our study, a significant increase in dehydrogenase activity in paired row dhaincha treatment was due to increased microbial activity. Green manuring affect

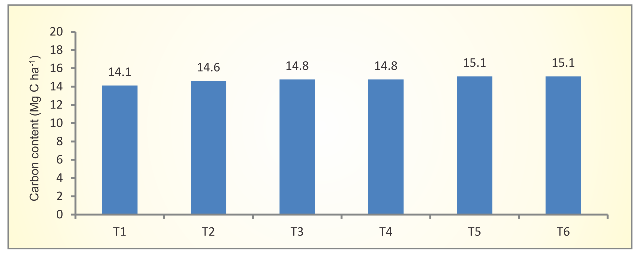


Fig. 2.11. Organic carbon under different RCT treatments

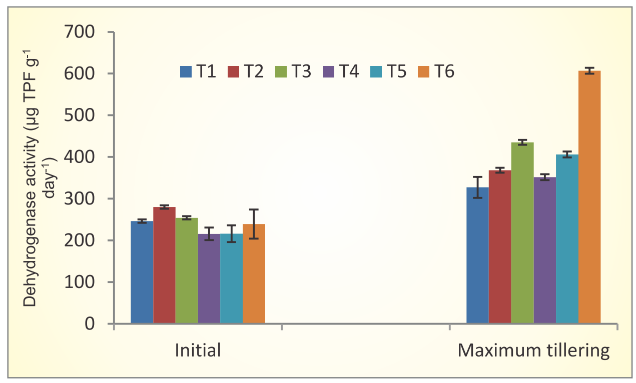


Fig. 2.12. Dehydrogenase activity under different RCT treatments

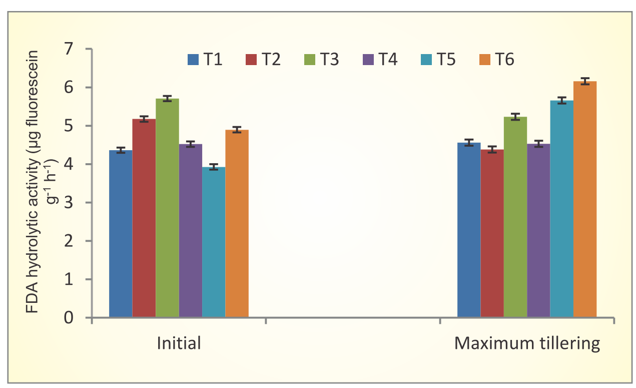


Fig. 2.13. Fluorescein hydrolytic activity under different RCT treatments

the dynamics of the soil microbial biomass in the flooded soil. With the primary effect of green manuring being in the enhancement of C-assimilation, the microbial biomass may benefit the most from the increased C availability through higher labile C content in soil. Higher dehydrogenase activity under green manuring was due to higher organic matter; labile C contents lead to higher microbial activities in soil. The Fluorescein diacetate (3, 6-diacetyl fluorescein) hydrolysis assay evaluates the potential activity of ester-cleaving enzymes and can be used to measure microbial activity in soils. The activities of this enzyme depend on the taxonomic structure of the microbial community and the interference of other physicochemical processes. FDA hydrolysis activity was increased significantly under green manure treatment owing to the abundance of increased soil labile C content.

The paired row dry direct seeded rice with green manuring showed a trend to build up organic C in soil. Energy output was significantly higher in this treatment and it also saved energy. So, from environmental sustainability point of view this technology offers a potential option to increase in net C gain, and output energy. Therefore, this technological package of practice including mechanization offered energy savings as well as sustainable yield in tropical lowland flooded rice ecology.

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 was initiated for the rainfed upland at KVK, Santhapur where experiment was executed during the *kharif* season of 2014 with five treatments replicated five times i.e., two varieties of upland rice (Sahabhagidhan and Anjali) as sole crop and with short duration cassava cv. Sree Jaya (160 days) as intercrop and sole crop under rainfed upland condition. Results revealed that plant height of rice was significantly affected by cropping system. Maximum grain yield of 2.9 t/ha of rice was recorded with sole rice cv. Sahabhagidhan but was comparable with cassava intercropping and sole Anjali (2.7 t/ha). Maximum system yield of 2.8 t/ha was recorded with sole Anjali and was at par with all the treatments except sole cassava. Highest gross return Rs. 31,280/ha was achieved with sole cropping of rice cv. Anjali which was comparable with cassava intercropping and sole cropping of rice cv. Sahabhagidhan. Cassava + Anjali intercropping system recorded more land equivalent ratio than cassava intercropped with Sahabhagidhan.

Maintenance/ refinement of multitier rice-fish-horticulture based farming system for deepwater areas

Rice-fish-horticulture based integrated farming system with components of various crops and livestock was taken up in deepwater ecology. The grain yield of wet season rice Gayatri , Pooja and CR 1014 were sown in Tier III during the first week of June in rainfed medium-deep water (up to 50 cm water depth) in the upper part of the field yielded 5.8 t, 4.1 t and 4.6 t/ha, respectively. In the Tier IV under deepwater situation with more than 50 cm water depth at lower end of the field, the grain yield of Sarala, Durga and Varshadhan were 5.2, 4.8 and 4.6 t/ha, respectively. The fish yield was 0.68 t/ha with an average weight of 2.5 – 3.6 kg, whereas the yield was 0.36 t/ha with an average weight less than a kilogram. After the *kharif* rice various dry season crops were grown in sequence (water melon, cucumber, owith harvested rainwater. Watermelon was the highest yielder 12.8 t/ha followed by cucumber (10.0 t/ha). The productivity of vegetable crops in raised land (Tier II) was in the range of 11.3-38.6 t/ha during *rabi* and 5.3-8.0 t/ha during *kharif* seasons. During *kharif* cowpea (Arka Garima (7.2 t/ha), okra Arka Anamika (7.2 t/ha) and ridge gourd Arka Sujata (8.7 t/ha) were the highest yielder. During the *rabi* season bottle gourd on platform yielded 42.2 t/ha, tomato (18.9 t/ha), french bean (8.7 t/ha), radish (9.8 t/ha) and leafy vegetables yielded 12.2 – 24.6 t/ha. Elephant foot yam (Gajendra) grown as intercrop with guava yielded 6.7 t/ha, whereas guava yield was 11.6-14.7 kg fruits/plant. Among the bird components, poultry birds (breed, Vanaraja) attained average weight of 1.9 kg/90 days, while ducks (breed, Khaki Campbell) recorded an average weight of 1.5-2.0 kg/180 days.

Maintenance and improvement of integrated farming system model for small and marginal farmers under irrigated condition

The objective to improve the productivity per unit of land per unit of time for judicious utilization of available resources, components rice, fish, poultry fruit trees and round the year vegetables grown on the bund helped in stabilizing the system productivity by providing stable income and employment opportunities. During the *kharif*, rice *cv.* Durga and newly released variety CR Dhan 407 and during the *rabi* season Naveen were planted along with the fish rohu, catla and mrigal. Three rice crops together (CR Dhan 407, Durga and Naveen) produced a total grain yield of 11.8 t/ha. Around 0.6 q of fish were harvested with an average size of 1.2 kg in a year and 0.5 q were harvested with an average size below 1 kg. On the bunds winter leafy vegetables (*Amaranthus*, spinach, fenugreek), coriander, french bean, tomato and radish performed better with an average productivity of 9.2 – 24.6 t/ha. As a whole, the system could produce about 11 q of food crops, 1.2 q of fish, 0.5 q of meat, 24 q of vegetables and 0.9 q of fruits besides 15 to 20 q of rice straw annually to ensure food and nutritional security, stable income on short and long term basis and year round employment of farm family.

Crop - livestock - agro forestry based integrated farming system

Successfully developed the highly remunerative rice-fish-horticultural and livestock based integrated farming system model which provide sustainability in production and economic, employment and nutritional security to the farmer. The system successfully integrates the crop, livestocks, agro-forestry and other components which promote ecological balance and ecological recycling of waste products to improve the livelihood of the farmers in one hectare area. Integrated farming was undertaken with design of water refuge area (15%), rice cultivation (65% area) and complete bunding on four side of the plot (20% area). The bund area used for horticultural crops cultivation (mango, guava, coconuts, arecanuts, banana, pineapple, papaya etc.), agro forestry plantation and different types of vegetables depending upon the season. Also animals were reared by making suitable shed provisions for different animals (goat, duck and poultry etc.).

During *rabi* 2014, Naveen was undertaken having production of 4.75 t/ha. In the bund area radish (Chetaki, 55 t/ha) and tomato (47 t/ha.) was undertaken. During *kharif* season rice varieties Varshadhan and Durga were planted and the yielded was 4.8 t/ha, 3.7 t/ha, respectively. Fish, ducks, poultry birds and goat were reared in the system. Ducks (Khaki Campbell) provided average 110-130 no. of eggs/birds. Poultry bird (Vanaraj and Black rock) attained 2.0-2.5 kg in three months of rearing. Among the fishes the maximum growth was observed in catla (900 g), followed by rohu (560 g) and mrigal (450 g). Among horticultural crops guava (9 kg/plant), Mango (4 kg/plant), papaya (8 kg/plant), coconut (30 nos. /plant), Banana (2100 nos.) and arecanuts (1000 nos.) were produced. In the bund area Napier grass was grown yielding 10-12 kg fodder/bunch/6 months. The system produced about 18.0 – 19.0 t of food and fodder crops (bio-mass), 0.6 - 0.9 t of fish and prawn, 0.9 t of meat in addition to fuel wood and other crop residues. In addition to this crop residues added to the system through composting, which substantially helps in nutrient recycling of the system. The recycling of various farm wastes in the crop-livestock based integrated farming systems enhanced the various production systems including rice and can reduced the fertilizer application in comparison to standard rate of fertilizer application in rice cultivation.

The integrated farming system is well adoptable and provides returns of around Rs. 80,000/- to 150,000/- for the farmers depending upon nature and extent of integration of the components. In addition to this, from the animal components goat, duck, poultry bird etc. generate 2.0-3.0 t of excreta materials, which were used as organic fertilizers and maintained the sustainability of production. The developed model rice–fish–horticulture and livestock and agro-forestry based integrated farming system has a great potential for enhancing the livelihood and economic condition of the farmer.

Management of rice weeds by integrated approach

Population dynamics of major rice weeds under different rice crop establishment

The population dynamics of major rice weeds was studied under different stand establishment methods of rice during *kharif*, 2014. Results showed that *Echinochloa colona* was the most predominant weed species in weedy plots at vegetative stage followed by *Cyperus difformis*, *Sphenoclea zeylanica* and *Leptochloa chinensis* in dry direct-sown rice field. The grassy weeds constituted 67% of the total weed population in weedy plots followed by sedges (20%) and broad leaf weeds (13%). In wet direct-sown rice field, *Echinochloa* *colona* and *Cyperus difformis* were most prevalent occupying 71% of total weed population at early vegetative stage i.e., at 30 days after sowing (DAS). However, *Leptochloa chinensis, Sphenochlea zeylanica, Fimbristylis mileacea* and *Marsilea quadrifolia* were predominant (90% of total weed population) at 60 DAS. In transplanted rice, the dominance of a mixed population of weeds *viz., Echinochloa colona, Echinochloa crus-galli, Cyperus difformis, Cyperus iria, Ludwigia octovalvis, Sphenoclea zeylanica* and *Marsilea quadrifolia* were recorded at 30 days after transplanting (DAT) in weedy plots. At late vegetative stage (60 DAT), *Leptochloa chinensis, Sphenoclea zeylanica, Ludwigia adscendens, Cleome viscosa* and *Fimbristylis mileacea* were prevalent. The grassy weeds constituted 41% of the total weed population followed by sedges (31%) and broadleaf weeds (28%).

Screening of early maturing germplasms for their weed competitiveness

One hundred and twelve early maturing rice germplasms (95-115 days duration) with five checks *viz*., Vandana, Anjali, Heera, Annada and Kalinga III were screened in augmented design with four blocks for weed competitiveness during *kharif* 2014. The germplasms *viz*., IC 426096, RH 145-55, Jhum Fulbadam, Deng-deng, IC 337590, IC 298485, IC 447256, CR 453 and DBT 2722 were found to be weed competitive with average plant height ranged from 107-127, weed canopy coverage ranged from 78-100 cm, total weed biomass (dry weight basis) at 45 days after sowing varied from 10.5- 19.8 g/m^2 and grain yield in the range of 670-880 g/m^2.

Study on effect of burial depth and application of pre and post-emergence herbicides on seedling emergence of *Echinochloa colona*

A pot study was conducted to investigate the effect of burial depth and application of pre and post-emergence herbicides on seedling emergence of *Echinochloa colona*. Seedling emergence was found to decrease as the seed burial depth increased from 1 to 8 cm. About 23% of the seeds that were buried at 1 and 2 cm emerged in one week of sowing and only 13% seeds emerged from 4 cm depth after one week. No emergence was observed at 8 cm depth. Application of pretilachlor at half of the recommended dose (1/2 RD) registered maximum seedling emergence of 20%, 12.5% and 8.3% at 1, 2 and 4 cm depth, respectively. With application of full recommended dose (RD) of petilachlor, 16.7, 8.3 and 4.2 % seedling emergence was recorded at 1, 2 and 4 cm depth, respectively. At double the recommended dose (2RD), only 12.5% seedlings emerged from 1 cm burial depth with complete inhibition of seedling emergence from 2 and 4 cm burial depth. One week after application of post-emergence herbicide, azimsulfuron at 15 days after sowing, survival % of emerged seedlings was reduced drastically At RD, 18%, 13% and 11% seedlings survived at 1, 2 and 4 cm burial depths, respectively and at 2RD, no seedling was survived beyond 21 days.

Study on weed spectrum and the efficacy of low dose post-emergent herbicides under varying establishment methods in dry direct-sown rice

A field experiment was carried out during the *kharif* 2014 to study the weed spectrum and the efficacy of low dose post-emergent herbicides under varying establishment methods in dry direct-sown rice (D-DSR). Three crop establishment methods *viz*., broadcast seeding, continuous seeding at 15 cm apart rows, and sowing by seed drill in main plots and five weed control treatments *viz*., bispyribac-sodium (30 g/ha), azimsulfuron (35 g/ha) and bensulfuron methyl + pretilachlor (70+700 g/ha) along with hand weeding (twice) and weedy check, in subplots were evaluated in split plot design with three replications. Grassy weeds *viz*., *Echinochloa colona* and *Leptochloa chinensis* were the most predominant weed species in weedy plots. Application of azimsulfuron (35 g/ha) controlled the weeds effectively with weed control efficiency 91% and produced comparable yield (5.42 t/ha) with hand weeding twice (5.61 t/ha). Weed infestation was comparatively less in plots where crop was established by seed drill that resulted in better crop growth and significantly higher grain yield (5.18 t/ha). The yield reduction in weedy plot was 51%.

Study on weed spectrum and efficacy of low-dose herbicide/ herbicide mixtures under varying seed rate in dry-direct sown rice

A field experiment was conducted during *kharif* 2014 to study the weed spectrum and efficacy of low-dose herbicide/ herbicide mixtures under varying seed rate in dry-direct sown rice (cv Naveen and CR Dhan 304). The experiment was laid out in a split-split plot design with two rice varieties *viz.*, Naveen and CR Dhan 304 in main plots, four seed rates *viz.*, 20, 30, 40 and 50 kg/ha in subplots and three weed control treatments *viz.*, azimsulfuron (35 g/ha), azimsulfuron + bispyribac sodium (22+25 g/ha) and weedy check in sub-sub plots. The major weed species in weedy plots were *Echinochloa colona, Cyperus difformis, Cyperus iria, Fimbristylis miliacea, Sphenoclea zeylanica, Leptochloa chinensis* and *Cleome viscosa*. Among herbicide treatments, the lowest weed biomass (9.0 g/m^2) was recorded in the azimsulfuron + bispyribac sodium treated plots with the WCE of 89%. The weed population and biomass were significantly reduced with increasing seed rates from 20 to 50 kg/ha. The yield (5.6 t/ha) with application of azimsulfuron + bispyribac sodium was statistically at par with the yield of azimsulfuron treated plots (5.2 t/ha) and higher over the other treatments. There was 34% reduction in grain yield due to weed completion in weedy check plots over azimsulfuron + bispyribac sodium treated plots.

Management of problem soils for enhancing the productivity of rice

Delineation of site specific nutrient management zones for paddy cultivated area around the Bhitarkanika mangrove ecosystem of India

The present study aims at dividing the study area spreading around the Bhitarkanika sanctuary and includes nearly two hundred fifty five inhabited villages under the administrative jurisdiction of Rajnagar block in Kendrapada district of Odisha, into homogenous management zones based on soil fertility and other physicochemical properties. A grid soil sampling pattern was adapted and soil samples were collected. Soil pH, EC, available K (AK), available P (AP), available N (AN), soil organic carbon, DTPA extractable Fe, Zn, Cu and Mn were analyzed. First step in delineating MZs was to analyze the descriptive statistics of the above soil variables and distribution of these properties was tested for normality using the skewness and kurtosis significance test. Subsequently correlation analysis was performed between all the soil properties. Then, semi-variance calculations and semi-variogram model fitting were performed using the Arc GIS 10. The fitted models were then used in an ordinary kriging procedure to estimate different properties at non-measured points as interpolated values for mapping. The cross-validation analysis was conducted for evaluating kriging interpolation bias and accuracy.

Principal component analysis (PCA) was performed with assumption that principal components (PCs) receiving high eigen values best represented the soil properties. In the present study, PCs with eigen values $\geqslant$ 1.0 were selected to develop the management zone classes. Finally AN, AP, AK, Mn, Zn, Fe and Cu were selected and the fuzzy k-mean was used to divide the field into different unique management zones. The objective of fuzzy cluster analysis is to statistically minimize the within-group variability while maximizing the among-group variability based on two cluster validity functions; including fuzzy performance index (FPI) and normalized classification entropy (NCE) (Fig. 2.14) were used as indicators of optimum cluster number as follows and three homogeneous MZs were produced finally (Fig. 2.15).

$$FPI = 1 - \frac{c}{c-1}\left[1 - \frac{\sum_{i=1}^{c}\sum_{k=1}^{n}(\mu_{ik})^2}{n}\right]$$

$$NCE = \frac{n}{n-c}\left[-\frac{\sum_{k=1}^{n}\sum_{i=1}^{c}\mu_{ik}\log_a(\mu_{ik})}{n}\right]$$

Where, c is the number of cluster and n is the number of observations.

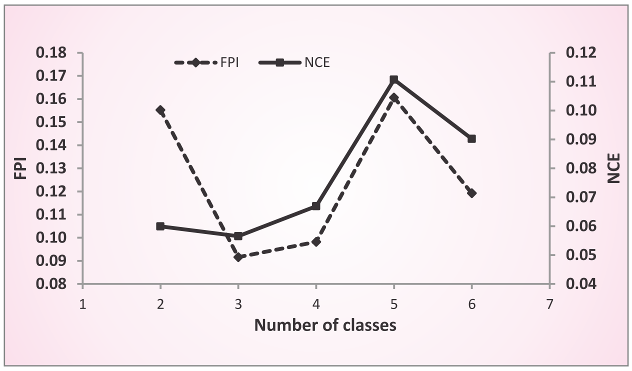


Fig. 2.14. Fuzzy performance index (FPI) and normalized classification entropy (NCE) for different number of cluster classes.

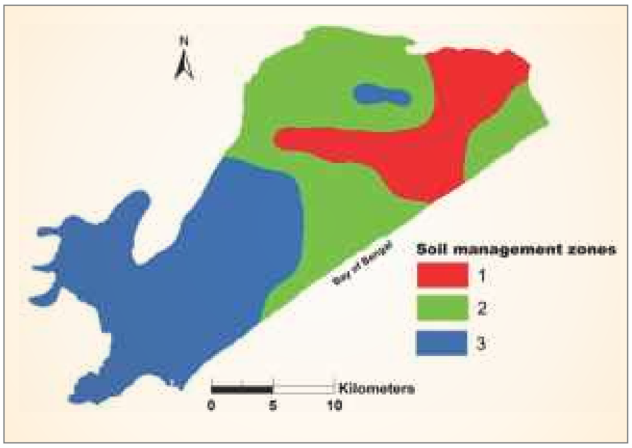


Fig. 2.15. Soil management zones developed on the basis of fuzzy cluster algorithm

Uptake and accumulation of Arsenic and its amelioration in rice

A pot experiment was conducted with rice variety Naveen to investigate the effect of elevated level of arsenic in irrigation water on uptake of arsenic by rice and effect on yield. Irrigation was provided by synthetic solution containing 1 ppm, 2 ppm and 4 ppm arsenic under two moisture conditions (flooded and alternate wetting and dry (AWD)). Agronomic parameters like plant height, tiller number, ear bearing tillers and straw biomass decreased significantly with increasing arsenate concentration in irrigation water. Rice grain yield was found to be strongly affected by the concentration of arsenate in irrigation water which decreased significantly with increasing arsenate concentration of irrigation water. Highest grain yield was obtained with 1 ppm arsenate contaminated water, while lowest yield was obtained with 4 ppm arsenate contaminated irrigation water. Arsenic concentrations in rice roots, straw, husk and grain increased significantly with increasing arsenate concentration in irrigation water. Regardless of arsenate concentration in irrigation water, concentration of arsenic in rice tissue followed the trend: root > straw > husk > grain (Fig. 2.16). Husk arsenic concentration, though much lower compared to rice straw, followed a similar increasing trend, increasing with increasing arsenate concentrations. The highest accumulation of arsenic was recorded in roots compared to straw and grains (root > straw > husk > grain) (Fig. 2.16); which might be due to differential As mobility within the plant. Among two water regimes, accumulation of arsenic under AWD was lower compared to the flooded water regime.

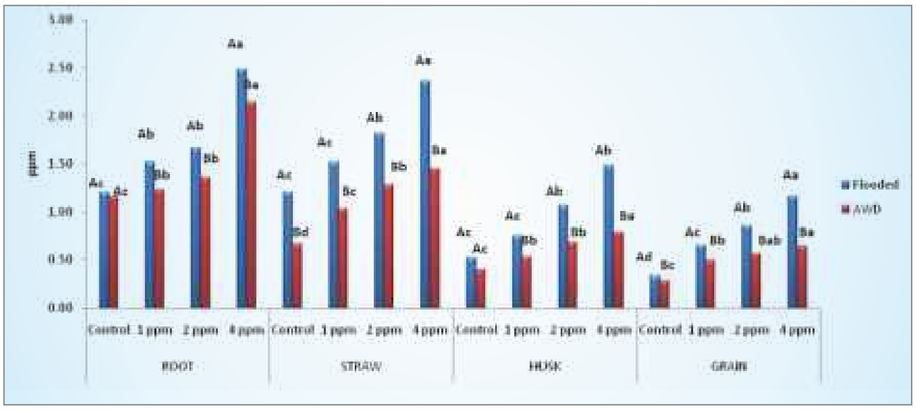


Fig. 2.16. Accumulation of arsenic under different arsenic levels in irrigation water under flooded and AWD condition. (Means with the same upper case letter are not significantly different under different water regime; means with the same lower case letter are not significantly different in different treatments of the same plant part)

Developing management options for boron deficiency in rice

A pot culture experiment during *rabi* 2014 was conducted to develop the management strategies for boron deficiency in rice and to study the effect of B on high temperature tolerance of rice genotypes. The treatments comprised of two temperature regimes (T) *viz.*, ambient and high temperature (2-4 °C); four boron application treatments (B) *viz.*, control, soil application of 1 kg B/ha, soil application of 2 kg B/ha and foliar spray of 0.2% B and three rice cultivars (V) *viz.*, Annapurna, Naveen and Shatabdi. The results revealed that under high temperature, % filled grain decreased significantly (Table 2.6). With the B application a significant increase was recorded as compared to control, however, it remained at par with respect to the method of B application. Annapurna variety recorded maximum filled grain percentage (79%) which was at par with Naveen (77%) and significantly higher than Shatabdi (72%). At ambient temperature no significant difference was observed between Annapurna and Naveen, however, at higher temperature, % filled grain in Annapurna (71%) was significantly higher than Naveen (66%), which indicated a lesser impact of high temperature on Annapurna as compared to Naveen. With the application of B, a significant increase in % filled grain was recorded; higher increase was recorded under high temperature as compared to ambient temperature. Boron application reduced the negative effect of high temperature on the filled grains percentage. Application of B results into higher grain yield under both ambient and high temperature condition over control. Higher yields were observed with soil application of B as compared to foliar spray. Soil application of 2 kg B/ha recorded highest increase in grain yield both under ambient (23.4%) and high temperature (52.8%) conditions.

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

Thermo-tolerant plant-growth promoting fungi (PGPF) from hot springs of Odisha

Taxonomically and genetically (18S-rRNA) identified six thermo-tolerant plant growth-promoting fungi were characterized for PGP traits and submitted to NCBI and NFCCI and received the accession numbers (Table 2.7). All six isolates showed the ability of phosphate solubilization (83.63–423.67 µg/ml) and ammonia production (11mM-23mM) in both ambient (30^0C) and elevated temperature (55^0C). However, IAA (43.28-55.23 µg/ml) was produced by only two isolate (DEF2 and DEF4) and none of isolates showed other PGP traits like siderophore, HCN and ACC deaminase.

Rhizoctonia solani strain KM1: a novel virulent strain responsible for sheath blight in rice

A novel virulent strain KM1 of *Rhizoctonia solani* responsible for sheath blight disease in rice was isolated from naturally infected rice from NRRI farm, Cuttack. The concerned strain was tested by artificial inoculation in rice genotype Naveen and found to be infecting 18% of sheath after 7 days of inoculation and the infection progressed gradually to 28.24% after 28 days of inoculation. Further, Basic Local Alignment of Search Tool (BLAST) homology of 18S-rDNA

Table 2.6: Effect of temperature conditions and B application on % filled grain and grain yield (g/pot) of rice cultivars

Treatments	% filled grain				Grain yield (g/pot)			
Temperature	A*	N	S	Mean	A	N	S	Mean
Ambient temperature	86	88	79	85	23.6	27.1	24.3	25.0
High temperature (2-4 °C)	71	66	64	67	19.4	18.3	13.8	17.2
Boron application								
Control (No Boron)	74	72	65	70	17.8	19.0	15.7	17.5
Soil application of B @ 1 kg ha^{-1}	81	80	75	78	23.7	23.9	20.4	22.7
Soil application of B @ 2 kg ha^{-1}	81	80	72	78	24.1	25.3	21.2	23.5
Boron Foliar Spray (0.2%)	79	78	76	77	20.3	22.7	18.9	20.6
Mean	79	77	72		21.5	22.7	19.1	
CD ($p \leq 0.05$)								
T				2.5				1.3
B				3.6				1.9
V				3.1				NS
TxB				5.1				2.6
TxV				4.4				2.3
BxV				NS				NS
TxBxV				NS				NS
*A=Annapurna; N=Naveen; S=Shatabdi								

Table 2.7: Registration of six thermo-tolerant plant-growth promoting fungi

Isolate no.	Source (Hot spring of Odisha)	NFCCI* (Culture Accession no.)	NCBI^ (Gene accession no.)	Organism
ATF1	Atri	NFCCI-3438	KJ652020	*Aspergillus fumigatus* Fresen.
DEF1	Deulajhari	NFCCI-3439	KJ652021	*Aspergillus fumigatus* Fresen.
DEF2	Deulajhari	NFCCI-3440	KJ652023	*Aspergillus oryzae* (Ahlb.) Cohn
DEF4	Deulajhari	NFCCI-3441	KJ652024	*Aspergillus oryzae* (Ahlb.) Cohn
DEF7	Deulajhari	NFCCI-3442	KJ652025	*Aspergillus niger* Link
DFR1	Deulajhari	NFCCI-3443	KJ652022	*Cunninghamella echinulata* Kuhn

*NFCCI: National Fungal Culture Collection of India, Pune, India
^NCBI: National Center for Biotechnology Information, New York, USA

sequence of strain KM1 confirmed the identity as *Rhizoctonia solani* and also showed distinct strain from

NaCl) diazotrophic rhizobacteria were screened and tested for other PGP traits. Out of them, three isolates (CA54, GH47 and HR12) showed wide range of functional diversity (carbon-source utilization) and PGP traits. Finally, eleven salt-tolerant polyvalent PGPR were identified though 16S-rDNA sequencing. Out of eleven, two isolates (RM19 and HR 62)

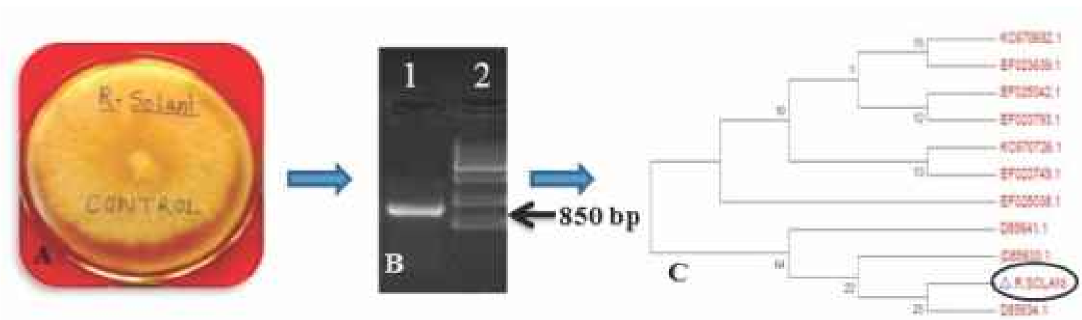


Fig. 2.17. (A). Virulent strain KM1of Rhizoctonia solani; (B). 18S-rDNA amplicon of R. solani, lane 1: R. solani KM1 (850 bp), lane 2: 1kb ladder; (C). Dendrogram represents distinct strain of R. solani from other strains.

the insecticides, except for the chlorpyriphos and quinalphos. The results suggested that combinations of the pathogens and recommended field (FR) doses i.e. 0.0075-0.06% a.i. depending on the insecticides can be used to control LF in the field.

Characterization of salt-tolerant diazotrophs from rhizosphere of diverse rice ecology

Soil samples were collected from three diverse rice ecologies i.e. upland (BAU, Ranchi & CRURRS, Hazaribag), lowland (NRRI, Cuttack) and shallow lowland (RRLRRS, Gerua). All together, 78 distinct rhizobacteria were isolated from rhizospheric soils of above regions. Among them, 38 salt-tolerant (15%

identified as *Brevibacterium halotolerans*; eight isolates (CA54, GH47, CA66, CA68, GH21, HR40, HR58 and HR61) belonged to different species of genus *Bacillus* and one isolate (RM77) identified as *Pantoea agglomerans*. In *silico* restriction with *HaeIII* showed different cutting frequency within the 16S sequences of all identified isolates showed the diversity among selected strains. Two isolates (CA54, GH47) were identified as nitrogen fixers after confirmation of *nif*H-PCR and in *silico* detection of gene in nitrogenase component. The PGP-efficacy of salt-tolerant isolates (CA54, GH47, HR12) was tested in salt-sensitive rice variety (Naveen) for growth promotion at both AS (0 dS/m) and ES (2 dS/m) conditions. All strains significantly increased the shoot length, root length, fresh and dry weight compared to control.

Comparative analysis of endophytic and epiphytic microbial community in phytonic parts of three cultivated (*Oryza* spp.) and one wild rice (*Oryza eichengeri*)

Comparative analysis of community level physiological profiling (Biolog ecoplates), culture dependent (cfu/g phytonic part) and independent (DGGE) approaches based on nitrogen response of three predominant Indian cultivars (*Oryza sativa* var Sabita, Swarna and Swarna-*Sub 1*) and one wild rice (*Oryza eichengeri*) was performed in terms of microbial community as epiphytes and endophytes in phytonic parts (leaves, phylosphere, stem, root and rhizoplane). Analysis of the population dynamics exposed that microbial load was the highest in the wild rice followed by respective cultivated ones (Sabita > Swarna > Swarna *Sub 1*). It also discloses that the overall microbial activity was superior in rhizoplane followed by root, leaf, phyllosphere and stem among experimental rice varieties. As compared to other phytonic parts the microbial community in terms of community level physiological profiling (CLPP) was significantly ($p<0.01$) observed more in roots (Wild > Sabita > Swarna > Swarna *Sub 1*) of all rice varieties. The principal component analysis pattern showed the wild and Swarna *Sub 1* had a close proximity to each other among all studied parts. Shannon–Weaver and Simpson's index in different phytonic parts of the cultivated varieties were considerably higher than the wild one, while McIntosh index was lower in different part of four varieties. The similar trend of carbohydrate and phenolic compounds with a higher utilization ratio in rhizoplanes was observed by phytonic microbes. The uncultured endophytic community based on DGGE pattern showed the Swarna root was distinct from others part of different rice varieties (Fig. 2.18). Furthermore, Shannon–Weaver (H) of CPPL and DGGE were found much higher in root (3.44; 2.32), stem (3.42; 2.04) and leaves (3.36; 1.59) of Swarna than others.

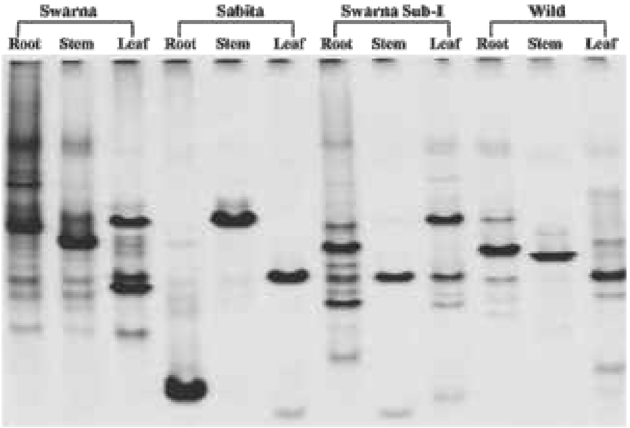


Fig. 2.18. DGGE profiles of V3 region-16S rRNA genes amplified from twelve phytonic samples displays diversity of endophytic bacteria in four rice varieties

Survival of the biocides under desiccated condition

Four Bt (TB 160, 161, 261 and 263), *B. bassiana* and *M. anisopliae* lime stone based formulations with 20% moisture content were preserved up to 6 months in desiccators with fused calcium chloride, anhydrous sodium sulfate and silica gel. Survival of the pathogens and moisture content assessment of the formulations at bimonthly intervals showed that viability of the pathogens declined to about 85.23-91.99% in 6 months with concomitant loss of moisture continent to about 8.76-14.11% of the formulations compared to about 99% viability and about 19.8% moisture content of different formulations preserved in air tight containers without desiccation (control). The pathogens survived better in presence of silica gel.

Identification of cry genes of rhizoplanic *B. thuringiensis* by PCR amplification

Lepidoptera specific *cry* toxin gene amplification of 40 rhizoplanic and rhizospheric Bt detected *cry1, 2, 3, 4* and *11* genes from 10, 10, 6, 4 and 1 Bt, respectively (Table 2.8). Nevertheless, the *cry 3* and *cry 4* amplicons were smaller than conventional ones in some Bt strains and were not identical among different bacteria which suggested that the concerned genes would be different alleles. Presence of more than one *cry* gene *viz., cry1, 2* in TB 113, 114, 118 and 155, *cry1, 3* in TB 116, 118 and 121 and *cry 2, 4* in TB 117 implied that the concerned Bt might be virulent against wide hosts.

Table 2.8: The cry diversity of rhizoplanic and rhizospheric Bt

Cry gene (bp)	Positive Bt (TB)
cry1 (272-290)	113, 114, 116, 118, 121, 142, 155, 210, 223, 226
cry 2 (689-701)	111, 113, 114, 117, 118, 155, 164, 190, 209, 279
cry 3 (858)	97, 116*, 118*, 121, 127*, 209*
cry 4 (797)	97#, 115, 117$, 164
cry 11 (305)	210

Non-conventional amplicons: *290 bp, # 375, $495

Identification of new Arbuscular Mycorrhiza (AM)-supportive crop management components

AM-supportive agro-management (off-season tillage method)

Two off season tillage methods *viz.*, conventional tillage (CT; using tractor drawn cultivator) and deep tillage (DT; using tractor drawn MB plough) were compared following the AM-supportive OST schedule of spacing two OST operations by minimum 13 weeks. CT supported higher initial (June) native AM-fungal population leading to higher root colonization and grain yield (Fig. 2.19) in rice variety CR Dhan 40 grown as DSR using seed drill. The results followed the similar trend as observed in 2013.

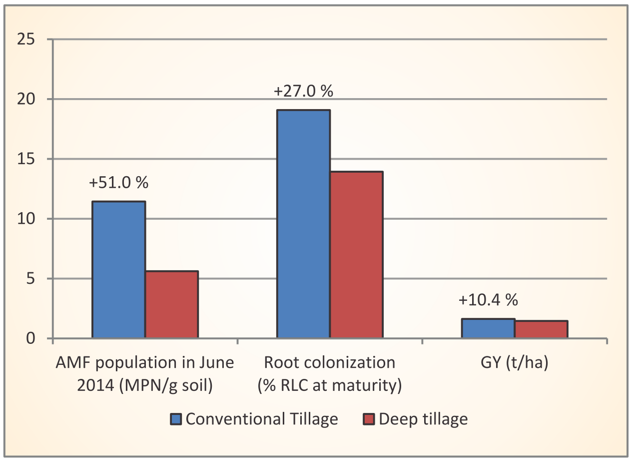


Fig. 2.19. Effects of off-season tillage methods on native AMF population dynamics in DSR (CR Dhan 40)

Integration of compatible arbuscular mycorrhiza (AM)-supportive crop management components

The fixed plot experiment on integration of AM-supportive crop management component options with two years crop rotation was conducted during the *kharif* 2011 (first rotation), 2012 (second rotation) and further repeated during 2014 to be completed in *kharif* 2015 (third rotation) to ascertain possible stability of added AMF inoculums in soil over years. The AM-supportive component options were: (i) two rice based crop rotations (two year) *viz.*, (a) pigeon pea –rice (PP/R) in alternate year, (b) maize relay cropped by horse gram in first year and rice in 2nd year (M-HG/R); (ii) Dual inoculum application of on-farm produced soil-root based AMF+P-solubilizer (*Bacillus licheniformis*) inoculum applied @1.25 t/ha; (iii) three P source combinations: *viz.*, (a) 100% P as DAP, (ii) 100% P as Purulia Rock Phosphate (PRP) containing 18-20% P_2O_5, (iii) 50% P as DAP and 50% as PRP. A progressive AMF population buildup with additive effects was confirmed in M-HG/R rotation applied with dual inoculum under P source of 50% P as DAP and 50% as PRP (Fig. 2.20). MI inculcation was done continuously for five years (in each year during 2010 to 2014). Post application higher initial (pre-monsoon) population (AMF) stability started attaining from second year (June 2011) and showed to reach a plateau during third year which continued until 5th year (June 2014). The results, however, indicated that application of AMF inoculum for two consecutive years would lead to attain a maximum population hike in soil. AMF application will be withdrawn during *kharif* 2015 to ascertain extent of sustainability of the increased AMF population.

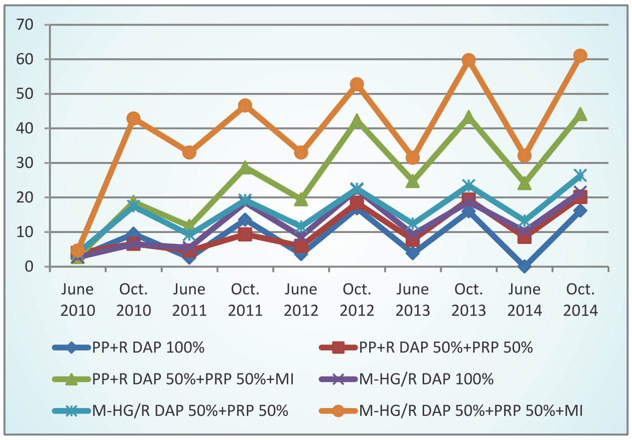


Fig. 2.20. AMF population dynamics under AM-supportive crop culture components

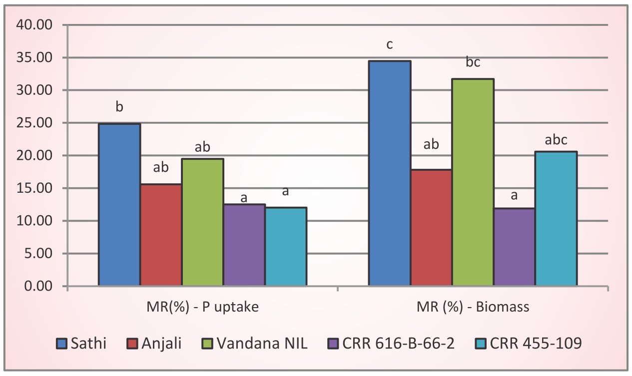


Fig. 2.21. Mycorrhiza response (% MR) of selected advance breeding lines (upland) at early stage (30 DAE)

Varietal response to AMF

Mycorrhiza response (MR) to inoculation (AM) at early growth stage (30 DAE) of one upland variety (Anjali) and four advanced breeding lines were evaluated (under glass house condition) during 2013 as compared to Sathi 34-36, the established highly responsive variety. The same set of breeding lines and varieties were further evaluated for their response at maturity under field condition during wet season of 2014 to compare trends of responses between early and matured stages. The MR in terms of total dry matter production and P uptake were calculated using the following formula.

$$\%MR = \frac{(AM+) - (AM-)}{AM+} \text{ x } 100$$

Up to 30 DAE, Anjali showed negative response (% MR) and CRR 676-1 (Vandana NIL) showed highest % MR among the tested four breeding lines which tended to be at par with Sathi 34-36 both in terms of biomass production and P uptake. At maturity, the trends remained similar (Fig. 2.21) with Anjali responded positively but significantly lower than Sathi. Vandana NIL remained highest responsive among breeding lines tested and statistically *at par* with Sathi following the same trend. This indicated that, rice varieties respond positively but differentially to AM inoculation. Varieties with initial poor or negative response also respond positively by maturity but with lower magnitude as compared to those showing higher initial response.

Soil and crop management for productivity enhancement in rainfed flood prone lowland ecosystem

Nutrient management in late-planted sali rice under post-flood situation in rainfed lowland ecosystem

A field experiment was conducted during *kharif* 2014 to standardize nutrient management in late planted *sali* rice under post-flood situation. The experiment was laid out in randomized block design with seven treatments comprised of (i) absolute control, (ii) NPK @ 40:20:20 kg/ha, (iii) NPK @ 50:25:25 kg/ha, (iv) NPK @ 60:30:30 kg/ha, (v) 40 kg N based on LCC along with PK @ 20:20 kg/ha, (vi) 50 kg N based on LCC along with PK @ 25:25 kg/ha, (vii) 60 kg N based on LCC along with PK @ 30:30 kg/ha. The crop was planted on the 10 September and harvested on first week of December. Results indicated that N application based on LCC registered higher rice grain yield than conventional method. The plots applied with 60 kg N/ha based on LCC along with PK @ 30:30 kg/ha recorded highest grain yield of 4.59 t/ha which was at *par* with the plots applied with 50 kg N based on LCC along with PK @ 25:25 kg/ha (4.36 kg/ha).

Standardization of integrated nutrient management practices under rainfed flood-prone lowland ecosystem

Profitability of rice-based cropping system under green manuring, rice residue incorporation and fertility level in rainfed lowlands was evaluated during the *sali/kharif* and *rabi* seasons of 2013 -14 at research farm of RRLRRS, Gerua. The treatment combinations were namely, green manuring and rice residue incorporation in main plots and four fertilizers inputs (control, 50, 75 & 100% recommended doses of fertilizers (RDF) in sub-plots) for rice and two succeeding crops (lentil and linseed) in sub-sub-plots. Green manuring significantly increased the rice grain and straw yield by 9.5 and 8.9%, respectively over rice residue incorporation. Increment in fertility level up to 100 % RDF increased grain yield by 26.6 and 16% and straw yield by 24.7 and 13.7% of rice over control and 50% RDF, respectively. Seed yield of succeeding *rabi* crops increased significantly in response to residual doses of fertilizers up to 100% fertility level and the increase was to the tune of 25 and 12.9% over control and 50% RDF, respectively. The system productivity in terms of rice equivalent yield (REY) and B:C ratios were significantly higher with green manuring. Rice equivalent yield, production efficiency, net return and B:C ratio of rice-based cropping system was favourably and significantly influenced by fertility levels applied to rice. The REY was the maximum at 100% RDF and was 26.7, 15.9 and 6.4% higher over the control, 50 and 75% RDF, respectively. Linseed provided more economic return per rupee invested as compared to lentil due to its higher price.

Standardization of integrated weed management practices in *boro* rice

Performance of transplanted rice under different weed management techniques was evaluated during *boro* season of 2013-14 at the research farm of RRLRRS, Gerua. The treatments consisted of seven weed management practices *viz.*, weedy check, two hand weeding at 25 and 50 days after transplanting (DAT), weeding with cono-weeder at 25 and 50 DAT, Butachlor @ 1.5 kg ai/ha, Bensulfuron methyl 0.6% + Pretilachlor 6% G @ 10.0 kg/ha, Pyrazosulfuron ethyl @ 30 g ai/ha and Chlorimuron ethyl + Metsulfuron methyl 20 WP @ 4 g ai/ha. The maximum weed density was recorded in weedy check followed by cono-weeder treatment which was also significantly higher over herbicide treatments. Weed control efficiency was higher with herbicide treatments as compared to weedy check, cono-weeder and hand weeding while the weed index values were lower with herbicide treatments. Higher number of tillers per hill, panicle length and filled grains per panicle were registered in hand weeded plots resulting into the highest grain yield (4.77 t/ha) but remained statistically at *par* with the low volume pre-emergence herbicides. Among the pre-emergence herbicides, Pyrazosulfuron ethyl recorded higher grain yield (4.58 t/ha) followed by ready mix Chlorimuron+Metsulfuron methyl (4.54 t/ha).

Influence of different dates of planting on the performance of rice varieties in *boro* season

Field experiments were conducted at the research farm of RRLRRS, Gerua during *boro* season of 2013-14 to find out the optimum time of planting of *boro* rice in the north eastern region. Performance of two rice varieties, *viz.*, Chandrama and Naveen were tested under five different dates of transplanting (5th, 15th and 25th January, 5th and 15th February). Age of seedlings at the time of transplanting was 45 days. The crop transplanted on the 5th January yielded the lowest (4.53 t/ha) which might be due to low temperature during early vegetative stage. Grain yield was the highest (6.26 t/ha) in the crop transplanted on the 25 January. Thereafter, the varieties had non-significant yield differences up to 15 February. Chandrama recorded significantly higher grain yield (5.60 t/ha) over Naveen (5.10 t/ha) but Chandrama took 20 to 25 days more than Naveen to mature. Thus, the optimum time for transplanting of rice was found to be the 25th January or the second fortnight of January.

Influence of age of seedling on the performance of rice varieties in *boro* season

An experiment was conducted during the *boro/rabi* season of 2013-14 at research farm of RRLRRS, Gerua in split-plot design with two rice varieties *viz.*, Chandrama and Naveen in main plots and five different ages of seeding *viz.*, 50, 60, 70, 80 and 90 days in the sub plots. Chandrama recorded significantly higher grain (6.37 t/ha) and straw (7.1 t/ha) yield over Naveen (4.9 t/ha and 5.87 t/ha). Chandrama had more number of filled grains (131.6) as compared to Naveen (127.9). Among the age of seedlings, younger seedling recorded maximum grain yield (6.18 t/ha). There was gradual yield penalty for increment in the age of seedling up to 70 days due to reduced values for tillers per hill and filled grains per panicle. The grain yield gap (1.17 t/ha) was significantly higher between youngest (50 days) and oldest (90 days) seedlings. The yield penalty was non-significant in long duration rice variety Chandrama but in case of Naveen, there was significant reduction in grain yield when seedling age exceeded 60 days.

PROGRAMME : 3

Rice Pests and Diseases-Emerging Problems and Their Management

Pests and diseases play a major role in decreasing yield of rice crop. Their statuses are to be monitored with the changing climatic scenario and cultivation method. There is a need to generate basic and strategic information on present important pests and diseases so that effective management strategies can be developed for the benefit of rice farmers of the country. So, the present programme has been framed keeping in view of an holistic approach of increasing crop yield through proper crop protection with resistant cultivars, management of diseases and insect pests using eco-friendly chemicals, botanicals and biotic agents. There is also a need to study the population structure of pathogens and pests in present climatic scenario. During the reported period, the scientists of crop protection have developed thorough knowledge on various aspects of crop protection like prevalent pests and pathogens, identification of resistant genotypes, identification of new biocontrol agents against rice diseases, proper application method of chemicals and botanicals. Different integrated pest management (IPM) packages are developed/validated in farmers' field for yield enhancement in rice.

Management of rice diseases in different ecologies

Identification of donors for resistance to different diseases

A total of 1109 varieties/genotypes comprising of 604 farmers’ varieties from different parts of Odisha and 288 genotypes from National Hybridization Nursery provided by Crop Improvement Division, NRRI were screened for resistance/tolerance against sheath blight pathogen, *Rhizoctonia solani* Kuhn under field condition during *kharif* 2014. Variety Tapaswini was raised after each 10 entries as susceptible check. In the maximum tillering stage, plants of each genotype were artificially inoculated with the sheath blight pathogen, *R.solani* by inserting five sclerotial bodies alongwith bits of mycelia inside the leaf sheaths and sprayed with clean water regularly for creating proper environment for the inoculums. The sheath blight disease incidences were recorded for each entry by adopting 0-9 SES scale. The experimental findings showed that out of 604 farmer's varieties, 47 varieties were moderately resistant (at disease scale 1.1-3), 91 varieties tolerant (at disease scale 3.1-5), 164 varieties susceptible(at disease scale 5.1-7) and 302 varieties highly susceptible (7.1-9). Whereas, in the case of 505 genotypes from National Hybridization Nursery, 35 were moderately resistant, 39 tolerant, 104 moderately susceptible and rest were highly susceptible. The check Tapaswini showed highly susceptible reaction at a disease scale of 7.8. The genotypes/farmer's varieties found to be moderately resistant/tolerant will be revalidated again to confirm their reaction.

Similarly, out of 199 entries tested against brown spot, only 4 showed resistant reaction. Two hundred and twenty seven lines were screened against bacterial blight disease in rice out of which four lines showed highly resistant reaction, 14 lines showed moderately resistant reaction and rest showed moderate to high susceptibility.

Identification and genetic variability of major and emerging diseases of rice

Mating types analysis of *Magnaporthe oryzae* populations by molecular markers

Forty six isolates of *M. oryzae* were collected from leaf blast lesions of rice from various ecosystems of coastal Odisha, India and mating type analysis using molecular markers was carried out. *MAT1-1* type was dominating in all the ecosystems and *MAT1-2* was found to be present in uplands as well as in irrigated fields. Both mating types were present in the same field in irrigated ecosystem where the disease spread was very fast vertically as well as horizontally resulting in blast lesions looking as 'green islands' (gi) produced in senescence leaves and management of blast in those plots was very difficult. The ability and superiority of *IGS* regions as a highly variable marker for detecting compatible mating spores was reported for some fungi hence *IGS* region was amplified for

Table 3.1: Details of 13 RAPD primers, their amplified products and polymorphism

Primers	Primer sequence (5′ to 3′)	GC %	Annealing temp. (°C)	Range of amplicons (bp)	No. of bands	No. of polymorphic bands	% Poly-morphism	PIC
R3	ACGATCGCGG	70	36	300-1600	11	6	54.5	0.492
R-1	CGGCCACCCT	80	38	165-2570	21	16	76.2	0.588
R-2	CGCGTGCCAG	80	38	300-2570	14	12	85.7	0.752
P-160	CATGGCCAGC	70	36	330-2750	15	13	86.7	0.639
PU-1	AGATGCAGCC	60	36	400-2860	16	14	87.5	0.599
ap12h	CGGCCCCTGT	80	36	350-2500	18	16	88.9	0.615
R-108	GTATTGCCCT	50	27	260-2875	18	16	88.9	0.653
P-117	TGGCGTCTCCA	63	40	585-2710	10	9	90	0.714
PU-2	ACGGATCCTG	60	36	355-3000	12	11	91.7	0.750
OPB-10	CTGCTGGGAC	70	36	465-3000	14	13	92.9	0.662
3B	GAGCGCCTTG	70	36	330-3800	26	25	96.1	0.66
P-54	GGCGATTTTTGCCG	57	50	820-1600	7	7	100	0.70
PU-3	ACTGGGACTC	60	35	465-4000	11	11	100	0.827

detecting compatible mating types. The *IGS* region wasn't amplified in *MAT1-2* isolates but consistent amplification was obtained from isolates possessing *MAT1-1*.

Genetic variability of *Fusarium* isolates

Genomic DNA of 28 *Fusarium* isolates was amplified by thirteen RAPD primers. The GC content of primers was 50% (R-108) to 80% (R-1, R-2 and ap12h). Differences in banding patterns between isolates were assessed visually by observing amplified bands on agarose gel. All the thirteen primers were found to be polymorphic, amplified a total of 193 bands (averaging 14.84 bands per primer) of which 169 were polymorphic indicating a polymorphism of about 88% among 28 *Fusarium* isolates. Polymorphism by individual primers was shown in Table 3.1. This showed a high genetic variation among isolates. Primer wise maximum number of fragments (26 numbers) were obtained by primer 3B and lowest number by primer P-54 (7 fragments). The size of amplified bands ranged from 165 bp (by primer R-1) to 4000 bp by primer PU-3 (Table 3.1). Isolate wise from the combination of 13 primers, highest number of fragments was amplified in F115 (107) followed by F40 with 106 bands. All other isolates were having fragments ranging from 81 to 98 numbers except that of F47 which had a total of 74 fragments.

The similarity index depicted a minimum of 36% to maximum 98% similarity between 28 *Fusarium* isolates. The dendrogram constructed from cluster analysis separated 28 *Fusarium* isolates in to two major groups 'A' and 'B' (Fig. 3.1) at a similarity co-efficient of 0.52. One branch in group 'A' included F47, F90, F92 and F96 at a similarity level more than 87%. These four isolates weren't amplified by *Fum*5F and *Fum*6R, indicating non producers of fumonisin and have been consistently placed in one separate group by RAPD primers ap12h, R-1, R-2, PU-1, PU- 3, OPB-10 and 3B. These four isolates were grouped together more by the absence of bands at a particular position as depicted in case of primer ap12h where absence of unique bands was marked at 600 bp and 480 bp.

Precise disease severity assessment for false smut disease of rice

Rice false smut has increasingly become a major grain disease in rice production worldwide. However, severity assessment of this disease is continually debated. The precise assessment method to evaluate

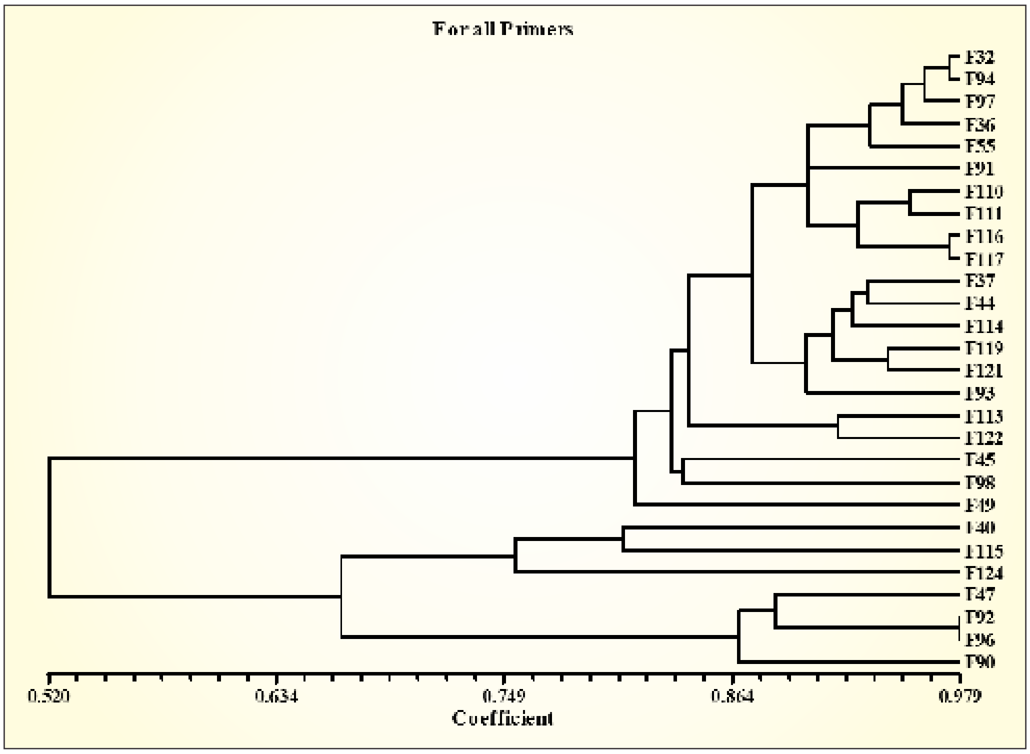


Fig. 3.1. UPGMA cluster analysis based dendrogram depicting genetic variability among 28 Fusarium spp. calculated from 193 bands generated by 13 RAPD primers

Table 3.2. Comparative grading of cultivars by SES system of IRRI and by proposed YR based system

Rice variety	Av. no. of diseased florets / panicle	% diseased florets /panicle	Grading by IRRI- SES system	Grading by YR based method		
				YR diseased / YR healthy	ball type	scale
Savitri	3	1.2	Scale 3	1.05	Small balls	1
Sarala	3	1.3	Scale 3	0.93	Big balls	2
Padmini	4	2.00	Scale 3	1.13	Big balls	2
Pooja	9	4.5	Scale 3	0.82	Big balls	3
Gayatri	2	1.25	Scale 3	0.98	Small balls	1
Mayurkantha	1.5	1.0	Scale 3	0.71	Small balls	4
Dharitri	8	6.2	Scale 5	0.78	Small balls	4
Lunishree	8	8.0	Scale 5	0.3	Big balls	5
CR 1030	9	4.6	Scale 3	0.65	Big balls	5

the severity of the disease was developed. By using the ratio of yield representative of diseased samples / yield representative of healthy samples the disease severity among nine cultivars was compared. The topic and the major results have potential impacts in field application. Seven rice cultivars *viz.* Savitri, Sarala, Padmini, Pooja, Gayatri, Mayurkantha and CR 1030 (Utkalprabha) were in scale 3 and Dharitri & Lunishree were graded as susceptible according to IRRI- SES system of disease severity assessment.

Whereas by YR based method the rice cultivars Gayatri & Savitri were highly tolerant. Rice varieties Sarala & Padmini with score 2 though tolerant but degraded the produce. Rice genotype Pooja with score 3 was moderately susceptible to false smut. Rice varieties Lunisree and CR 1030 (Utkalprabha) were highly susceptible to false smut. Rice cultivar Mayurkantha was scored 3 in SES system, whereas it was moderately susceptible as per YR based scoring (Table 3.2).

Seedling blight

Heavy incidence of seedling blight of rice (c.o. *Sclerotium* sp.) was reported during 2009-10 in seed beds of rice var. Sarala and since then it was observed on various rice cultivars The isolates collected during 2013 (NCBI GenBank accession number KC832506) was compared with the pathogen isolated during 2010 (NCBI GenBank accession number HM572290) and variability in their nucleotide sequences was evident.

Biocontrol of rice diseases

Effect of bio-control agents on rice var. Ketekijoha

Two strains of *Bacillus spp.* (BC-1 & BC-2) isolated from cowshed were applied in nursery beds infected with seedling blight of rice (c.o. *Sclerotium* sp.). It restricted the damage of seedlings without further spread of the disease. Seedling root dip in solution containing the bio-control agents prior to transplanting, could significantly enhance the growth of rice seedlings (Fig. 3.2)

Fig. 3.2. Effect of biocontrol agents on growth of rice seedlings

Effect of *Trichoderma* on growth of rice

A total of four different *Trichoderma* isolates were selected on the basis of their performance in pot experiment and used for the field trial of 1m x 1m plot. The seeds were treated with *Trichoderma* conidia @10 gm/kg of seeds. Each gm contained 10^7 spores. Observations were recorded for root, shoot and leaf length and fresh and dry weight of root and shoot. It was observed that plants which were treated with different *Trichoderma* isolates showed better performance in comparison to that of control (Fig. 3.3). The NPK content of plants treated with different species of *Trichoderma* showed that the nitrogen content is mostly higher in the treated plant than the untreated one but interestingly the %K is always higher in the treated plants in comparison to the untreated one (Fig. 3.4). The higher nitrogen content in the treated plant was reflected in the greener appearance of the treated plant than the untreated one (Fig. 3.5).

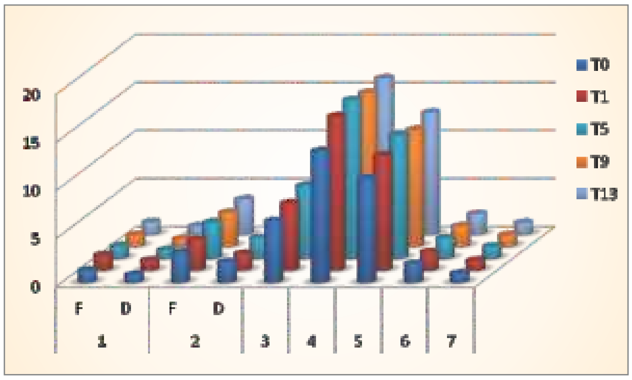


Fig. 3.3. Effect of Trichoderma spp. on growth of rice variety Karuna (1=root weight/ 5 plant in gm, 2= shoot weight/ 5 plant in gm, 3=root length in cm, 4= shoot length in cm, 5= leaf length in cm, 6= leaf width in cm, 7= leaf weight/5 leaves in gm, D=dry & F=fresh)

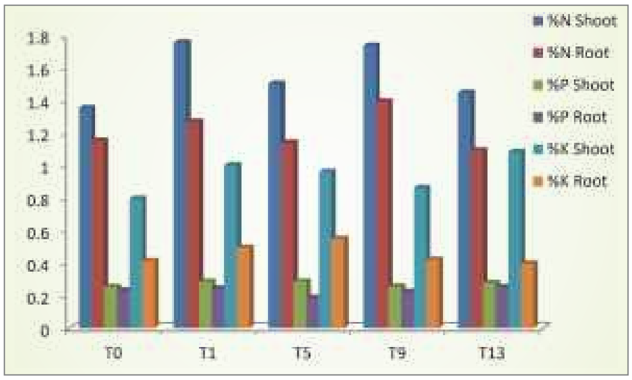


Fig. 3.4. The NPK content of rice plant treated with different isolates of Trichoderma spp.

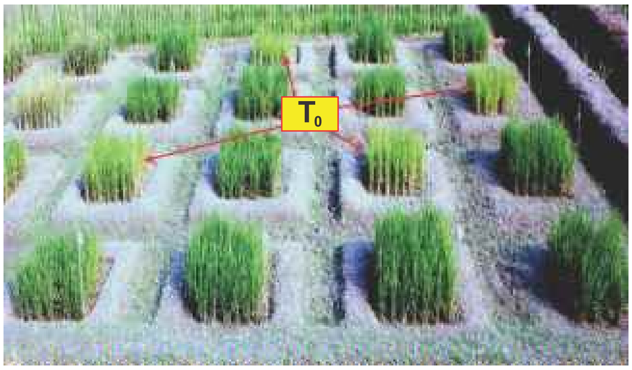


Fig. 3.5. Effect of Trichoderma seed treatment on rice plant under field condition (T_0=control)

Evaluation of fungicides against sheath blight disease in rice caused by *Rhizoctonia solani* Kuhn

The effect of seven fungicides namely tricyclazole 45% + hexaconazole 10% WG (ICF-110) @ 1g/litre, tricyclazole 18%+ mancozeb 62% WP (MERGER) @2.5g/litre, tricyclazole 75%WP @0.6g/litre, hexaconazole 5%EC@2ml/litre, mancozeb 75%WP@2g/litre, mancozeb 63%WP+carbendazim 12%WP (Companion) @1.5g/litre, and carbendazim 50% WP 1g/litre were evaluated for the management of sheath blight disease in susceptible variety Tapaswini in a field trial during *kharif* 2014 (artificially inoculated with sheath blight pathogen) in R.B.D. Out of eight treatments including untreated check, the fungicide tricyclazole 45% + hexaconazole 10% WG, @1g/l caused 73.9% reduction in sheath blight severity and 64.4% reduction in sheath blight disease incidence. It was followed by tricyclazole 18%+mancozeb 62% WP@2.5g/l and mancozeb 63%WP+carbendazim 12% WP@1.5g/l the former reducing the disease severity by 71.3%, sheath blight disease incidence by 51.7% and the latter causing reduction in disease severity by 67.9% and sheath blight incidence by 47.6%. Grain yield was the highest (5.83 t/ha) due to treatment with tricyclazole 45% + hexaconazole 10% WG followed by 5.58 t/ha due to tricyclazole 18%+ mancozeb 62% WP and by 4.9 t/ha due to mancozeb 63% WP+carbendazim 12% WP, while it was 3.67 t/ha in untreated control.

Preventive and curative actions of new fungicides against sheath blight

Preventive and curative actions of four fungicides, namely, Trifloxystrobin 25%+Tebuconazole 50% (Nativo 75WG@0.4g/L), Kresoxim methyl (Ergon 44.3SC@1ml/L), Azoxystrobin (Amistar 25SC @1ml/L), Carbendazim (Bavistin 50WP @1g/L) along with control were tested against artificially inoculated sheath blight disease in susceptible variety Annapurna. Fungicides were sprayed four days before the artificial inoculation and fungicides were sprayed after seven days of inoculation. Over the period of experimentation, no significant difference was observed between preventive and curative action of the fungicides. After 21 days of curative spray, curative application performed better comparatively. All the fungicides could control *Rhizoctonia solani* effectively compared to control.

Rice-endophyte interaction with pathogens in response to environment

Isolation, identification, of endophytes associated with rice cultivars

Twenty two endophyte cultures associated with farmer's rice varieties were isolated out of which fourteen isolates were of *Dendryphiella* sp. Endophyte *Myceliophthora verrucosa* was isolated from rice variety Dubraj Bhog, the cultivar collected from Sundargarh district of Odisha. *M. verrucosa* was reported to be thermo tolerant. Endophyte *Dendryphiella* was isolated from rice variety Gahamphul. This farmer's variety was collected from Sundargarh district of Odisha .

Effect of *Penicillium* sp. (NCBI Gene Bank accession no. KC 690014), an endophyte isolated from rice cultivar Lunishree on rice var. Swarna *Sub1* was studied.The CCF of this endophyte had significantly enhanced root and shoot length and also the weight of rice var. Swarna *Sub1* (Fig. 3.6).

Interaction of effective endophytes with rice pathogens

Cell free cultural filtrates(CCF) of three endophytes were tested against three soil borne rice pathogens *viz. Rhizoctonia solani* (c.o. sheath blight), *R. oryzae* sativae (c.o. aggregate sheath spot) and *Sclerotium* spp. (seedling blight) *in vitro*. Out of three endophytes studied, two were from farmer's var. Malbati & Champa. Third endophyte was *Penicillium* sp. (NCBI Gene Bank accession no. KC690014) from rice var. Lunishree. The CCF of all the endophytes checked the germination of sclerotia of *Sclerotium* spp. and reduced the sclerotia production by about 80-90% in *R. solani* (Fig. 3.7) and *R. oryzae sativae*. The *Penicillium*

Fig. 3.6. One month old seedlings of rice variety Swarana sub1: Effect of CCF of Penicillium endophyte

Fig. 3.7. Effect of CCF of Penicillium endophyte on R. solani in vitro: 10 days old culture

sp. (NCBI Gene Bank accession no. KC690014) was effective against pathogenic *Fusarium in vitro*. This endophyte was tested against *Magnaporthe oryzae* (c.o. rice blast disease) in dual culture and was found effective.

A method was developed to grow endophytes in soil. The growth of *Rhizoctonia* spp. (c.o. aggregate sheath spot and sheath blight) in 'untreated soil' and in soil treated with CCF of endophte isolate FV 16-II (*Dendryphiella* sp.) was studied. The growth and number of sclerotia produced in soil was significantly reduced in enophyte treatments. The unit weight of sclerotia of CCF treated test organism was considerably lesser than the sclerotia of untreated cultures.

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

Host plant resistance provides an effective, economical and ecofriendly method of pest management in rice against different rice pests. The method includes identification of resistant rice genotypes through screening of genetic resources and studying the mechanism of resistance of donors. These donors can be utilized successfully in resistant breeding programme for the development of high yielding rice varieties with resistance to different pests.

Brown planthopper resistance was again confirmed in NRRI developed breeding line CR 3006-8-2(Pusa 44 x Salkathi) through AICRIP trial.

Resistance to BPH was also confirmed in nine earlier identified farmers' varieties though antibiosis study. Seven more varieties were identified as highly resistant through replicated screening.

The accession IR 65482-7-216-1-2-B with *Bph 18* gene showed susceptibility to BPH population of NRRI .

Preliminary net house screening of two entries *viz.*, B2 11 (4.8%) and DS-04 (6.1%) showed damage score of 1 and tropical *japonica* lines WC 35 and WC 297 didn't show any white ear head (WEH) formation.

Brown plant hopper (BPH): reaction to known gene differentials

The reaction of 12 known gene differentials (Source: IIRR, Hyderabad) were validated against NRRI

Table 3.3: Reaction of known gene differentials against BPH population of NRRI, Cuttack.

Sl.No.	R gene	List of entries		Damage score			
		Designation	Genotype/Cross	R-1	R-2	R-3	Mean
1	*bph2*	ASD 7 (ACC 6303)	Karsamba Red	9	9	9	9
2	*Bph3+Bph17*	Rathu Heenati (ACC 11730)	Rathu Heenati	9	9	9	9
3	*bph4*	Babawee (ACC 8978)	-	9	9	9	9
4	*Bph6*	Swarnalatha (ACC 33964)	-	9	9	9	9
5	*bph7*	T 12 (ACC 56989)	-	9	7	7	7.7
6	*bph8*	Chinsaba (ACC 33016)	-	9	9	9	9
7	*bph9*	Pokkali	-	9	9	9	9
8	*Bph1+*	IR 64	IR 5657-33-2-1/IR 2061-465-1-5-5	9	9	7	8.3
9	*Bph18*	IR 65482-7-216-1-2-B	IR 31917-45-3-2-2*3/*O.australiensis*	9	9	9	9
10	*bph2*	IR 36	IR 1561-228//4*IR661-1-140-3-117/O.nivara///CR 94-13	9	9	9	9
11	*bph2+Bph3+*	Ptb33		1	1	0	0.7
12	*BPH20/21*	IR71033-121-15		9	9	9	9
13	None	TN1	S.Check	9	9	9	9

population under nethouse condition. Each genotype was sown in three replications along with suceptible check TN1 in CRD design and standard modified seedbox method was followed for insect release and scoring (IRRI, 2002). All the genotypes except Ptb 33 were susceptible or highly susceptible as was observed for last two years revealing the constant reaction of the population without any variation. The genotype Ptb 33 with both *bph2* and *Bph3* gene, was continuously exhibiting highly resistant reaction against BPH (Table 3.3).

The lines IR 65482-7-216-1-2-B (EC 796738) and IR 71033-121-15B (EC 796734) received from IRRI during the year 2014 were again screened against BPH . All of them were found susceptible indicating that these lines having genes *Bph 18* and *Bph 20/21* respectively will not be able to provide resistance to the insect population of NRRI.

Fig. 3.8 Resistant entries in greenhouse screening

Table 3.4. Rate of egglaying, nymphal survival and feeding of BPH on resistant varieties.

Sl. No.	FV No.	Designation	% Plant death*	%Eggs laid over TN1*	% Nymphal survival*	Area fed (cm²)*	Source
1	9	Akula (Reg-11/619)	2.7	12.35	12.77	0.37	Sonepur (Odisha)
2	14	Asanchudi (Reg-11/1185)	8.7	24.88	18.77	0.87	Bolangir (Odisha)
3	16	Asanchudi (Reg-11/740)	3.0	34.12	12.60	0.33	Kalahandi (Odisha)
4	23	Baigan Manji (Reg-11/1106)	2.7	11.0	10.83	0.27	Nayagarh (Odisha)
5	30	Balibhanjan-T (Reg-11/860)	5.8	31.18	22.93	0.77	Mayurbhanj (Odisha)
6	95	Champa (Reg. 11/883)	3.8	23.53	14.03	0.43	Puri (Odisha)
7	102	Champeisiali (Reg-11/1109)	7.6	31.35	22.83	0.73	Nayagarh (Odisha)
8	157	Ganjei jata-P (Reg-11/1249)	7.6	34.71	22.0	0.70	Angul (Odisha)
9	192	Harishankar (Reg-11/952)	10	39.59	29.17	0.87	Dhenkanal (Odisha)
10	R. check	Ptb 33 (*bph2+Bph 3*)	4	13.12	8.33	0.33	NRRI
11	R. check	Salkathi	4	12.53	11.67	0.33	NRRI
12	S. check	TN1	100	100	100.00	5.63	NRRI

FV: Farmer's variety, * Average of three replications.

Identification of new resistant donors through antibiosis

The nine farmers' varieties found highly resistant earlier were evaluated for oviposition rate of gravid females, feeding rate and survival of nymphal instars. The oviposition rate ranged within 11 – 40 numbers in resistant varieties against 100% (170 numbers of eggs) in susceptible check TN1. Nymphal survival was studied by releasing fifty numbers of 1st instar nymphs to each replication of varieties and rate of feeding was worked out by conducting nynhydrin test as per the method followed by Sogawa and Pathak (1976). The data showed drastic reduction of eggs laid and also the feeding of the insect on these varieties (Table 3.4).

Validation of resistance

Validation of resistance in genotypes from earlier mass- screening of 300 farmers' varieties confirmed Jalgudi (Reg.2011/551), Kakudimanji (Reg.2011/885), Kalakrushna (Reg.2011/1183), Kalajeera (Reg.2011/1170), Katkala(Reg.2011/648), Kuja(Reg.2011/995), Laxmi vikash(Reg.2011/1006) as highly resistant (Fig. 3.8 on page 107).

Mass Screening

One hundred and thirty entries of plant hopper screening trial (PHS) and multiple resistance screening trial (MRST) under All India Coordinated Rice Improvement Project (AICRIP) were evaluated against BPH in net house condition of NRRI, Cuttack. The entries CR 3006-8-2, RP 2068-18-3-5, MTU 1160, KAUM 179-1, KAUM 179-2, KAUM 182-1, CB 11 161, CB 11 609, CB 12 532, CB 12 546 and CB 12 584 were found highly resistant to BPH with score 1.

Evaluation of known gene differentials against gall midge population of NRRI

Eleven known gene differentials were evaluated against gallmidge as per the standard evaluation system of IRRI (SES, 2002) under net house condition. ARC 5984 with Gm5 showed resistant reaction of score 3, whereas W1263 (Gm1) was moderately resistant with score 5. All the other gene differentials registered susceptible to highly susceptible reaction of score 7 and 9. However, two genotypes Aganni and INRC 3021 with unknown genes, were highly resistant with score 0 (Table 3.5).

The screening data of previous years were looked into and found out that no infestation was incurred in genotypes W1263, ARC 5984, RP 23335-156-8, BG 380-2, MR 1523 and INRC 3021 and Aganni during the year 2012. But during 2013, only W1263, BG 380-2, MR 1523 and INRC 3021 could retain their resistant status whereas during 2014 only MR 1523 and INRC 3021 with unknown gene(s) were resistant with '0' score. This result indicates towards close monitoring of the NRRI population (biotype) as well as confirmation of

Fig. 3.9. Silver shoot formation in screening tray

Table 3.5. Reaction of gall midge to known gene differentials

Entry No.	Designation	Gene	TT	SS	% SS	Score
1	Kavya	*Gm1*	25	22	88	9
2	W 1263	*Gm1*	25	5	20	5
3	ARC 6605	*Unknown*	25	8	32	7
4	Phalguna	*Gm2*	25	24	96	9
5	ARC 5984	*Gm5*	25	2	8	3
6	Dukong 1	*Gm6*	25	20	80	9
7	RP 2333-156-8	*Gm7*	25	10	40	7
8	Madhuri L 9	*Gm9*	25	21	84	9
9	BG 380-2	*Gm10*	25	23	92	9
10	MR 1523	*Gm11*	25	20	80	9
11	RP 2068-18-3-5	*gm3*	25	6	24	7
12	Abhay	*Gm4*	25	23	96	9
13	INRC 3021`	*Unknown*	25	0	0	0
14	Aganni	*Unknown*	25	0	0	0
15	INRC 15888	*Unknown*	25	21	84	9
16	B 95-1	None	25	19	76	9
17	TN1	None	25	22	88	9

moderately susceptible (Score-7) and rest thirty were highly susceptible (Score 9).

Yellow stem borer, *Scirpophaga incertulas* Walk

Preliminary net house screening at vegetative stage of 27 breeding lines from the crosses of CR 1009 x *Oryza brachyantha* along with one susceptible check TN 1 were undertaken during *kharif* 2014. The results revealed that two entries viz., B2 11 (4.8%) and DS-04 (6.1%) showed damage score of 1 as against the susceptible check TN1 (43.3%) recorded damage score of 7.

Preliminary field screening of sixty tropical *japonica* lines including susceptible check TN1 were conducted against yellow stem borer (YSB) in field under natural condition during *kharif* 2014. In vegetative stage, the dead heart formation was significantly low both in test entries as well as standard susceptible check. In reproductive stage, the entries like, WC 35 and WC 297 didn't show any white ear head (WEH) formation while TN 1 registered highest WEH (8.3%).

Rice root knot nematode, *Meloidogyne graminicola*

Sixty-four NRRI released varieties and 84 landraces (farmers' varieties) were screened against rice root knot nematode under artificial infestation. All varieties showed susceptible to highly susceptible reaction.

Screening of previously reported resistant / tolerant varieties

Out of eleven varieties previously reported as resistant or tolerant varieties screened against rice root knot nematode for consecutive five times during 2013-2014, none of them showed the resistance reaction. The TKM 1 and MDU 2 showed tolerance reaction thrice followed by Ratna and Ramakrishna for single time (Table 3.6).

Bio-ecology and management of pests under changing climatic scenario

Species-wise occurrence of stem borer in *kharif* rice at NRRI

In the year 2014, dissection of infested tillers during

Table 3.6: Reaction of previously reported resistant / tolerant varieties

Varieties	Previous report	Gall Index (Dec 2012-Jan 2013)	Gall Index (Jul -Aug 2013)	Gall Index (Dec 2013-Jan 2014)	Gall Index (Jun -Jul 2014)	Gall Index (Dec 2014-Jan 2015)
Tadukan	T	HS	HS	HS	HS	HS
Zenith	T	HS	HS	HS	HS	HS
Ramakrishna	R	HS	HS	T	HS	HS
TKM-6	T	HS	HS	HS	HS	HS
MDU-2	T	T	S	T	S	T
TKM-1	T	T	S	T	S	T
Abhisek	T	HS	HS	HS	HS	HS
Hamsa	R	HS	HS	HS	HS	HS
Tetep		HS	HS	HS	HS	HS
Ratna	HS	T	HS	HS	HS	HS
Peta		HS	HS	HS	HS	HS
IR 64 (Check)	HS	HS	HS	HS	HS	HS

R : Resistant , T: Tolerant , S : Susceptible , HS : Highly susceptible.

November/December showed increased population of pink stem borer and striped stem borers in low land variety Varshadhan. Larvae of yellow stem borer (YSB), *Scirpophaga incertulus* were prominent in the population(60.9%) followed by pink stem borer or PSB *(Sesamia inferens)* and striped stem borer or SSB *(Chilo supressalis)*. However, PSB population was increased to about 22.2% of the total population as cmpared to about 3.5% in the previous year.

Monitoring YSB population through pheromone trap

In *rabi* crop, prolonged emergence of YSB moths was observed from 3rd week of January to last week of March (3–23 SMW) which was similar to the previous year. Continuous populations caused heavy damage to *rabi* crop of Naveen through dead heart (DH) formation upto about 40% and white earhead (WEH) formation upto 12% in untreated control.

During *kharif* season, though YSB moths were observed visually from 2nd week of September @ 2-3 moths /20 m^2 area, it appeared in pheromone trap towards last week of September(38 SMW). But the population was as low as 14 moths/SMW. High brood emergence was experienced towards 1st week of October which affected the medium duration crops like Pooja. Rain (Hudhud) during 2nd week of October decreased the rate of brood emergence to some extent but the emergence continued upto 2nd week of December (48 SMW) and mostly affected the long duration varieties like Varshadhan which were at the panicle initiation stage (Fig. 3.10).

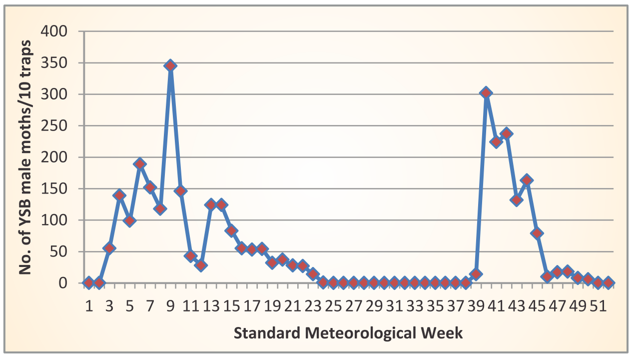


Fig. 3.10. YSB incidence during 2014 as per pheromone trap catch of male moths

The light trap data also revealed the occurrence of YSB moths from 3rd week of September (37 SMW) and the emergence continued upto last week of December (52 SMW). The trend of insect emergence was more or less similar with the trend of pheromone trapping though population size was big in light trap as it trapped both male and female moths (Fig. 3.11). But pheromone trap data showed high brood emergence covering 40–45 SMW, whereas it was towards 43-45 SMW during 2013. The total population size was also high (1310/10 traps) within its total emergence period as compared to 512 numbers of moths during 2013 (3.12). The low incidence during 2013 was due to cyclone and heavy rain during 2nd and 3rd week of October (*Phailin*). Though another cyclone *'Hudhud'* affected Odisha during 2nd week of October 2014, no wind speed or heavy rain was experienced in NRRI which perhaps favoured more YSB emergence.

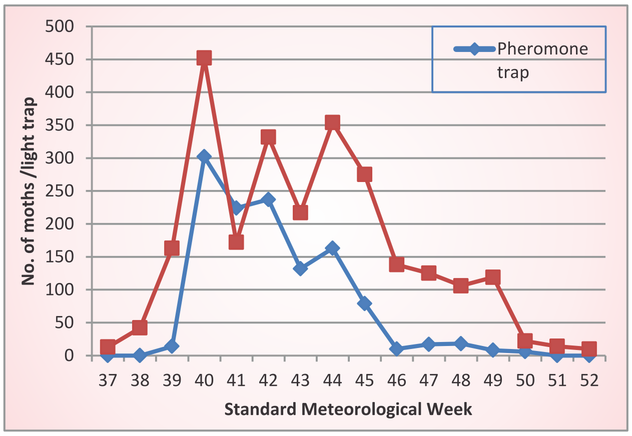


Fig. 3.11. Light trap and pheromone trap catch of YSB during kharif, 2014.

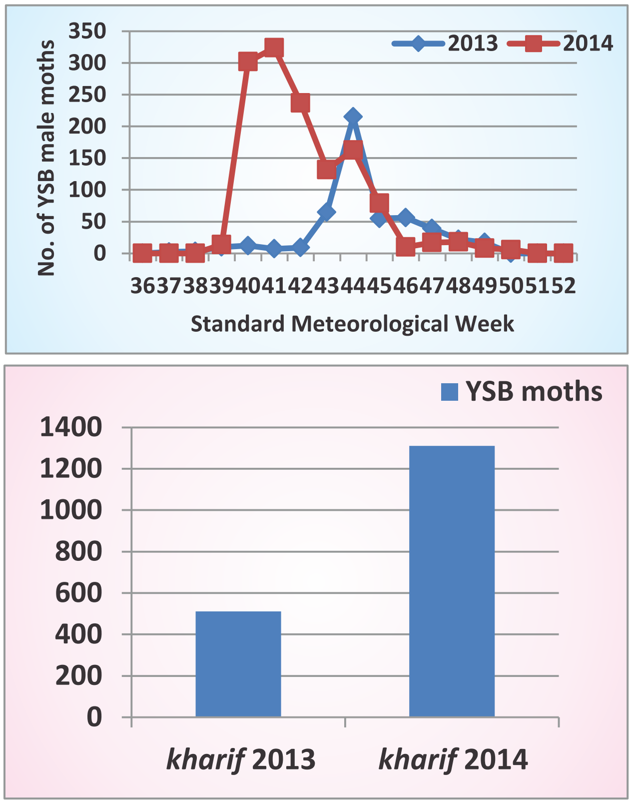


Fig. 3.12. Duration and Population size of YSB moths in pheromone trapping during 2014 and 2013.

Brown plant hopper (BPH) population was observed towards 3rd week of October. Though it did not cause damage to rice crop at NRRI, but extensive BPH infestation was observed in farmers' field during third to last week of October. Lack of proper monitoring resulted in hopper burn in many areas of Odisha, perticularly in Balasore, Bhadrak, Jagatsinghpur, Cuttack, Puri, Ganjam and Kendrapada districts towards last week of November and 1st week of December, 2014.

Effects of insecticides on insect-pest natural enemies in lowland rice ecosystem

The effect of nine insecticides *viz*., flubendiamide, fipronil, chlorantiniriprole, azadirachtin, *Bacillus thuringiensis* (Bt), spinosad, chlorpyriphos, imidacloprid, thiamethoxam were assessed against the insect pests-natural enemies occurring in lowland rice (cv. Lalat) ecosystem in the NRRI farm of Cuttack district, Odisha during *kharif* 2014. Among the insecticides, the highest per cent dead heart (5.0) and white ear head (4.8) incidence due to yellow stem borer was observed in Bt treated plot, whereas chlorantiniriprole and flubendiamide recorded 1.6 and 1.7% DH and 1.0, 1.3% WEH respectively compared to 7.8% DH and 6.7% WEH in the water sprayed plots.

Observations on spider population indicated that among the chemical treatments chlorpyriphos recorded lowest spider population (2.5/sweep) followed by imidacloprid (2.6/ sweep) and thiamethoxam (2.7/ sweep) which are significantly lower than water spray (4.6/sweep). Chlorantiniriprole and flubendiamide which are effective in lowering the stem borer damage recorded spider population of 3.8 and 3.4/ sweep (Fig. 3.13). Among the biorational insecticide treatments, azadirachtin registered spider population of 4.2/sweep followed by Bt (3.9/ sweep) as against water spray. Similar trend was observed in the parasitoid population. Among the parasitoids, *Xanthopimpla* sp., *Apanteles flavipes, Brachymeria* sp. were predominantly occurring in lowland rice ecosystem during the cropping season.

Diversity of insect pests and natural enemies in lowland rice ecosystems

The collection of insect pests and their natural enemies was mainly done through sweep net in the rice (cv. Varshadhan, a semi-deep water rice variety) during *kharif* 2014. Among the predatory arthropods, spiders (3.35/sweep) outnumbered the other predatory groups and were widely distributed throughout the study area. The other major predatory arthropods include *Coccinella* sp. (2.07/sweep), *Ophionea* sp. (1.78/ sweep), damsel fly (1.78/sweep) and dragon fly (1.35/sweep) (Fig. 3.13). Among the *parasitoids*, *Xanthopimpla* sp., *Apanteles flavipes*, *Brachymeria* sp., *Cardiochiles* sp. were the predominant ones occuring

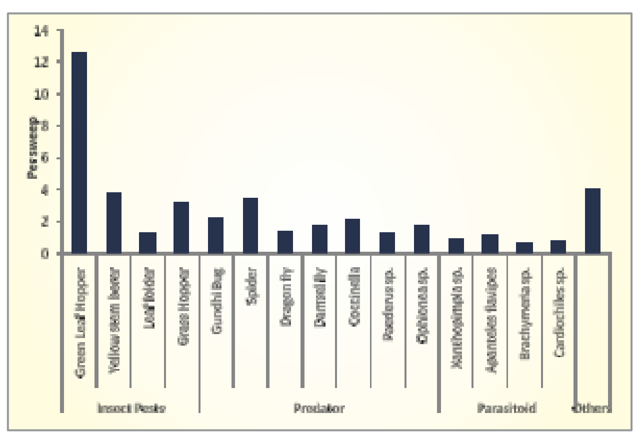


Fig. 3.13. Diversity of insect pests and natural enemies in lowland rice ecosystem

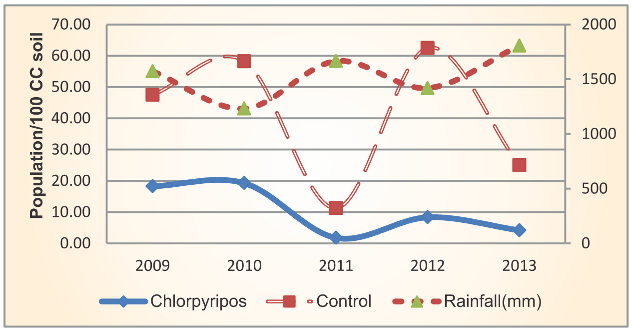


Fig. 3.14. Effect of long term use of pesticides on Meloidogyne graminicola population in soil

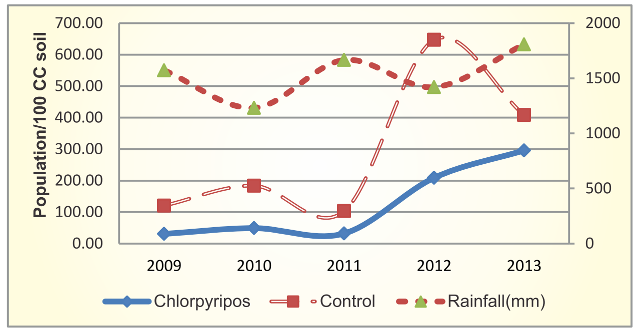


Fig. 3.15. Effect of long term use of pesticides on Hirschmanniella spp. population in soil

in the study area. Based on the sweep net catches of rice insect pests and their natural enemies in rice ecosystem, the diversity indices were computed to provide important information about rarity and commonness of insect pests and natural enemies. Various diversity indices *viz*., Simpson's index [1/D] (7.577), Shannon-Wiener index [H'] (2.407), Margalef's index [M] (2.352) were computed to quantify diversity and understand community structure.

Long term effect of pesticide on flora and fauna in rice ecology

Insect pests and diseases

In long term pesticide trial during *rabi* 2014, lowest dead heart (2.45%),white ear head (3.0%), gundhi bug damage (6.13%)and leaf folder (2.42%) were observed in cartap 4G @1kg a.i./ha followed by chlorpyriphos 1.5% dust @ 0.5kg a.i./ha. (2.65, 3.2, 6.0 and 2.87%), respectively. The highest grain yield in variety Naveen was 4.84 t/ha in Cartap followed by 4.82 t/ha in chlorpyriphos. Similar observation was also observed in *kharif* where the treatment cartap 4G @1 kg a.i./ha recorded lowest pest damage DH (2.45%) WEH (3.15%), leaf folder (2.05%) and gundhi bug (6.15%) followed by chlorpyriphos 1.5% dust @ 0.5 kg a.i./ha. (3.15%), (3.25%), (2.35%), (6.35%).The highest grain yield was 5.20 t/ha in cartap, followed by 4.70 t/ha in chlorpyriphos, 4.25 t/ha in carbendazim, 3.867 t/ha in pritilachlor and 3.55 t/ha in control (Table 3.7)

Nematodes

Study was conducted to understand the long term effect of pesticide application on non target organisms in rice fields from 2009-13. The population of root knot nematode (RRKN), *Meloidogyne graminicola* fluctuated between 2-19 and 10-54 nematodes/100 CC soil in pesticide treated and control fields, respectively, over

Table 3.7: Long term effect of pesticides against insect pests and diseases of rice during *rabi* & *kharif*, 2014

Treatment with dose	% DH		% WEH		% LF		% G.bug damage		% Blast		Yield (t/ha)	
	Rabi	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*
Cartap@1kg a.i./ha	2.45 (9.0)d	2.45d (9.0)	3.0c (9.96)	3.15b (10.22)	2.42c (8.9)	2.05d (8.22)	6.13b (14.32)	6.15d (14.35)	2.65b (9.36)	2.45e ((8.81)	4.835a	5.2a
Chlorpyriphos @0.5kg a.i./ha	2.65c (9.36)	3.15c (10.22)	3.2c (10.28)	3.25b (10.38)	2.87c (9.75)	2.35c (8.81)	6.0b (14.15)	6.35c (14.59)	2.75b (9.54)	2.15d (8.42)	4.815a	4.7ab
Carbendazim @0.1%	4.05b (11.6)	4.65b (12.45)	4.37b (12.07)	4.65a (12.45)	4.02b (11.56)	3.5b (10.77)	7.73a (16.14)	8.45b (16.89)	1.35c (6.66)	1.25c (6.41)	3.735b	4.25bc
Pritilachlor @0.75kg a.i./ha	4.25b (11.89)	4.75b (12.58)	4.55ab (12.31)	4.75a (12.58)	4.35ab (12.03)	3.55b (10.85)	7.75a (16.16)	8.55ab (17.0)	3.15a (10.22)	3.25ab (10.38)	3.715b	3.875bc
Control	4.65a (12.45)	5.15a (13.11)	4.9a (12.78)	4.87a (12.75)	4.72a (12.55)	4.17a (11.78)	7.84a (16.25)	8.75a (17.20)	3.25a (10.38)	3.65a (11.03)	3.605b	3.55c
CD at 5%	**0.30**	**0.30**	**0.68**	**0.35**	**0.88**	**0.40**	**0.96**	**0.22**	**0.40**	**0.34**	**0.21**	**1.1**

Data in parenthesis are angular transformed values DH = Dead Heart, WEH = White Ear head, G.bug = Gundhi bug

Table 3.8: Effect of pesticides on soil microbial biomass and activities

Treatment Name	MBC (µg MBC g $^{-1}$ h $^{-1}$)	DHA (µg TPF g $^{-1}$ h $^{-1}$)	FDA (µg fluorescin g $^{-1}$ h $^{-1}$)
Cartap@1kg a.i./ha	2020.19^{a}	46.42^{b}	11.70^{c}
Chlorpyriphos @ 0.5kg a.i./ha	308.71^{bc}	35.76^{b}	18.96^{ab}
Carbendazim @ 0.1%	76.75^{c}	81.42^{a}	21.95^{a}
Pretilachlor @ 0.75kg a.i./ha	206.32^{c}	51.42^{b}	21.12^{a}
Control	798.96^{b}	47.93^{b}	15.01^{bc}
SE(d)	246.421	3.670	1.021
LSD at 5%	549.06	8.1766	2.2758

MBC: microbial biomass carbon; DHA: dehydrogenase activity; FDA: fluorecein diacetate activity.
Values in each column followed by a different letter are significantly different LSD at 5%.

the period of five years. In rice root nematode (RRN), *Hirschmanniella* spp. very high population fluctuation was observed, which ranged from 31-296 and 103-647 nematodes/100 CC soil. In both the species, the fluctuation showed inverse relationship to total rainfall of the particular year. The population of RRKN and RRN were found to be significantly less in pesticide (chlorpyripos) treated fields compared to pesticide free fields in all the five years of observation.

Soil microbes

In long term trail during *kharif* 2014, the 2.5 times more soil microbial biomass carbon (MBC) was recorded in cartap treated plot, whereas 35.5 %, 9.6% and 25.7% lesser MBC were obtained in plots treated with chlorpyriphos, carbendazim and pretilachlor, respectively with respect to control at 3rd day after application of pesticides. The trend of reducing dehydrogenase activity of soil (DHA) was obtained in the following order of carbendazim > chlorpyriphos > cartap > control > pretilachlor. On the other hand, fluorecein diacetate activity of soil (FDA) was significantly reduced in cartap treated plot than other pesticides treated plot (Table 3.8).

Studies on pesticide residues in soil and plant in rice environment

Persistence of fipronil in soil under rice ecosystem

Fipronil (5-amino-3-cyano-1-(2, 6-dichloro-4-trifluoromethylphenyl)-4-trifluoromethyl sulfinyl pyrazole) is a broad spectrum insecticide for the management of the yellow stem borer and leaf folder in rice. Persistence of fipronil (Regent 0.3G) at recommended dose (RD) @ 75g a.i./ha and at double the recommended dose (DRD) @ 150 g a.i./ha was studied. For residue analysis, soil samples were collected at 0, 1, 3, 5, 7, 10, 15 and 30 days after application of the insecticide. Initial residue recovered was 0.065 µg/g for the recommended dose and was 0.136 µg/g for double the recommended dose. After 30 days of study, total fipronil residue recorded less than 0.005 µg/g for recommended dose. Overall, fipronil persisted in rice cultivated soil with 23 days half life for the recommended dose @ 75g a.i./ha. Whereas, half life of fipronil was 19 days at double the recommended dose @ 150 g a.i./ha (Fig. 3.16).

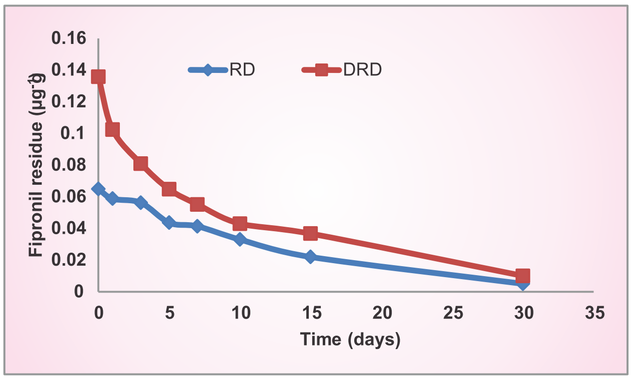


Fig. 3.16. Persistence of fipronil in rice soil

Sorption kinetics of fipronil in rice soil with or without amendment

Fipronil can be applied as granule to control yellow rice stem borer and leaf folder. Bioavailability of

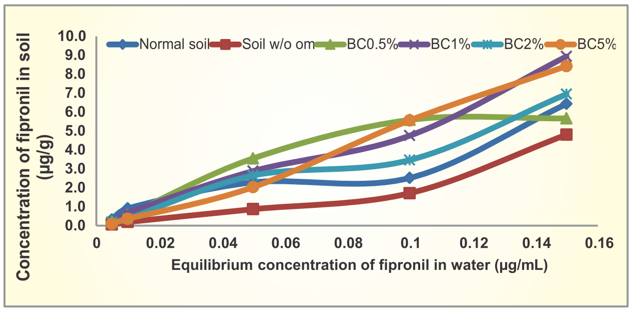


Fig. 3.17. Sorption kinetics of fipronil in rice soil with different concentration of biochar as amendments

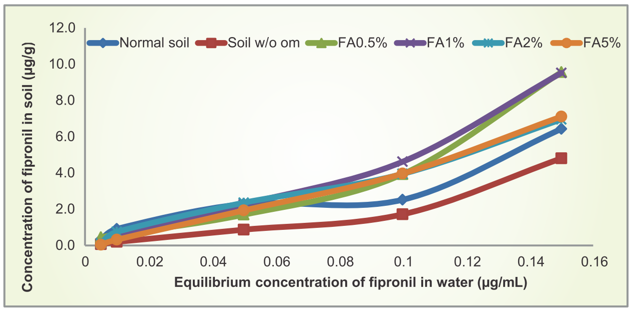


Fig. 3.18. Sorption kinetics of fipronil in rice soil with different concentration of fly ash as amendments

fipronil depends on sorption kinetics which will differ from soil to soil. In our study, we tried to establish the role of different concentration (0.5 to 5%) of two different types of amendment (fly ash- an aluminosilictae mineral and rice husk biochar-a charred but condensed organic carbon material) on firpronil sorption. Diverse properties of these materials may help to retain the pesticides on the soil surface and prevent it from leaching and run-off losses. We found the S-type isotherms when we plotted quantity of fipronil adsorbed in soil versus equilibrium concentration of fipronil present in water in both fly ash and biochar amended soils. Soil treated with hydrogen peroxide for partial removal the organic material, had the least capacity to adsorb fipronil. The isotherms obtained fitted well with the Freundlich adsorption equation (coefficient of determination > 0.94). The slope (1/n) values of fipronil adsorption isotherms in amended soil were more than 1 except in natural soil and soil amended with 0.5% fly ash. This also proves that isotherms are S-type. It means fipronil adsorption at low concentrations got disturbed due to strong competition between the water molecule and the pesticide for the adsorption sites. The sorption increases at higher concentrations of fipronil. Freundlich adsorption isotherm coefficient was 28 for natural soil, whereas it was 21 for hydrogen peroxide treated soil. In case of fly ash treated soil, the Kf values ranged from 31-59 and for biochar treated soil it was 38-66. Increased sorption in fly ash and biochar amended soils may be attributed to the increased organic carbon content and more active sites for adsorption i.e. alumina and silica edges. We found desorption was higher in normal and oxidized soil compared to amended soil. The study concludes that loss of fipronil can be prevented using biochar and fly ash amendment (Fig. 3.17 & 3.18).

Formulation, validation and refinement of IPM modules in rice

On-farm validation of IPM modules

Rainfed shallow land

An area of 25 acres in a compact block was selected involving 24 farmers for validation of IPM modules in rainfed shallow land situation in Jhadeswar pur village of Mahanga block in Cuttack district during *kharif*, 2014 with varities Swarna and Pooja under IPM and non-IPM condition.

In IPM practice farmers had followed seed treatment with carbendazim @ 2 gm/kg seed before sowing along with clean cultivation and line transplanting. They followed need based applications of pesticides in the affected areas only in following ways:

- Carbendazim @ 2 gm/lit water against sheath blight, sheath rot and brown spot.
- Cartap @ 1 kg a.i./ha against YSB,LF and BPH, Chlorpyriphos @ 0.5 kg a.i./ha against gundhibug.
- For monitoring purpose pheromone traps were installed and trichocards were used in the field for biocontrol of YSB. Farmers were trained to identify the harmful and beneficial insect pest in farmer's field.
- Regular field visit were followed to access the insect pest infestation.

In farmers' practice they use pesticide in whole plot and in schedule based manner, irrespective of pest incidence, at least 4-5 times in a season. In this way the cost of plant protection was increased as compared to IPM practice and natural enemies were destroyed and environmental pollution was made without much increase in grain yield.

Variety Swarna with IPM practice has significantly higher yield (5.014 t/ha) as compared to farmers' practice (4.436 t/ha). in case of Swarna IPM 3.12% brown spot, 5.42% sheath blight, 3.88% sheath rot, 3.6% false smut incidence were recorded, whereas in case of Swarna non-IPM 9.46% brown spot, 10.6% sheath blight, 7.34% sheath rot, 5.86% false smut incidence were found. Significantly, higher straw yield of 5.17 t/ha were obtained from the variety Swarna with IPM practice, whereas in case of Swarna non-IPM, straw yield of 4.41 t/ha were obtained. In case of Pooja IPM, 2.8% brown spot, 4.84% sheath blight, 4.26% sheath rot, 5.33% false smut infections were recorded, while, the variety Pooja under non-IPM practice showed 7.72% brown spot, 8.54% sheath blight,7.42% sheath rot, 8.82% false smut incidence. Significantly, higher grain yield of 4.446 t/ha and straw yield of 5.7 t/ha were obtained from the variety Pooja under IPM practice compare to grain yield of 3.918 t/hand straw yield of 4.91 t/ha in case of Pooja non-IPM. The dead heart, white ear head, leaf folder damage and gundhibug damage were significantly less and natural enemies population was significantly more in IPM practice in both the tested varieties.

Favourable lowland ecology

IPM practice

The trial was conducted at Mahanga block, Cuttack district with Pooja variety in about 80 acres (Seed production plots). The IPM practice consisted of (1) seed treatment with carbendazim @ 2 gm/Kg of seed before sowing. (2) Monitoring for thrips, case worm and hispa during August-September and application of imidacloprid (3) monitoring for YSB, BPH , WBPH and leaf folder during mid September-October and for gundhi bug at milk stage of the panicle (3) Fixing pheromone traps @ 2 traps /acre from 1st week of September for monitoring YSB (4) Need-based application of neem oil/ imidacloprid/ thiamethoxam/ acephate/ chlorpyrifos/ propiconazol/ streptomycin for insect pests and diseases. The multiple insect resistant breeding line CR 2711-76 developed at NRRI, was also grown in two hactares, one hactere with seed treatment and another without seed treatment to assess the insect and disease intensity.

Pest monitoring could enable the farmers to detect initiation of leaf folder incidence (5- 6.5 % infested leafs with less than one-third portion of a leaf) during 1st week of September in about 6 acres, case worm infestation (leaf damage on 2-5 % hills / 3 plots) towards 3rd week of September in about 7 acres, yellow stem borer (YSB) incidence crossing ETL as per pheromone trap catch (30 moths/week) towards 3rd week of october in about 2 acres, and BPH (3-5 insects/hill) towards 3rd week of october in about 5 acres. Application of 0.5 % neem oil with 0.2 % teepol for leaf folder, thiamethoxam @ 125 g/ha for case worm, acephate 75 sp @ 667 g/ha for YSB and imidacloprid 17.8% SL @ 125 ml/ha for BPH as folior spray at the initial stage of pest infestation with power sprayer could manage the pests effectively without further development. The grain yield ranged within 4.54 – 5.50 t/ha with an average yield of 5.06 t/ha.

Farmers' practice (non-IPM)

Under farmers' practice of 30 acres, no seed treatment was followed by the farmers. Monitoring for pest occurrence was the major drawback. Detection of pests was always delayed. Cholopyrifos/ Ghatak/

Hopper burn in Farmers' field

Interaction with farmers about BPH damage synthetic pyrethroid based pesticides (Triazophos + Deltamethrin) was applied for leaffolder control at 20-25 % leaf damage, for case worm at 82 % hill damage, phorate granule was applied for YSB towards last week of september when the insect was below the ETL level but sheath blight infection was @ 2.8 hills/sq mt. No fungicide was applied. Cholopyrifos and synthetic pyrethroid based pesticides were applied 2-3 times for BPH infestation when 'hopper burn' symptom was visible in some patches. So, inspite of repeated insecticide application, crop damage was severe. Farmers suffered 60-100 % crop loss, the yield ranging within 0.0-3.25 t/ha with an average yield of 1.39 t/ha.

IPM with BPH-resistant genotype CR 2711-76

The breeding line CR 2711-76, with or without seed treatment did not suffer any insect damage with or without seed treatment. Hills where seed treatment was not made showed sheath blight infection no pesticide had been applied to the crop. The average gram yield was about 1.3 % hills showed sheath blight infection in crop with seed treatment, whereas it was increased to 8.7 % in crop without seed treatment. The grain yield was 5.13 t/ha in treated one compared to 4.93 on untreated crop.

Rainfed lowland rice ecosystem

On-farm IPM trial on rice (cv. Pooja) was conducted in rainfed low land ecosystem of Pipili block of Puri District in Odisha during *kharif* 2014. The pest scenario and management strategies were evaluated under Farmers' practice (FP) and IPM Practice. The farmers' practice consisted of (a) direct seeding (b) non-specific pest monitoring both in the nursery and main fields (c) Application of carbofuran in the nursery/ main field after seeing the damage, whereas IPM treatments constituted (a) seed treatment with carbendazim @ 2g/kg seed (b) row planting (20 x 15 cm^2) (c) fixing of pheromone traps @ 8 traps /ha for monitoring yellow stem borer and routine field survey and (d) rynaxypyr 0.4G @ 10 kg/ha applied at 25 DAT (c) need based application of foliar spray of flubendiamide 480SC @ 30g a.i./ha and thiomethoxam (d) need based application of fungicide.

In case of IPM, 4.5% dead heart (DH), 2.5% white ear head (WEH) due to stem borer, 3.2% leaf folder damaged leaf, 6.8% sheath blight infections, 1.8% balls due to false smut were recorded, whereas in case of Farmers Practice, 10.2% DH, 6.5% WEH, 8.4 BPH/ hill, 2.2 gundhi bug/ hill, 10.6 % sheath blight, 3.5% smut balls were found. In IPM plots, natural enemies population was more (5.2/sweep) compared to FP plots (3.8/sweep) which includes spider, damselfly, dragon fly, mirid bugs, whereas parasitoid population was 4.2/sweep in IPM and 3.7 $sweep^{-1}$ in FP plots. The grain and straw yields in IPM treatments were 5.6, 10.2 t/ha, respectively compared to 4.2 and 9.8 t/ha in FP treatment. BC ratio in IPM was 2.34 whereas in FP it was 1.74. Farmers were trained for the identification of insect pests and their natural enemies to decide the timing of pest management practices.

Chemical control of insect pests of rice

Evaluation of insecticides against YSB in controlled condition

Experiment conducted under net house condition revealed that the insecticides such as Chlorantraniliprole 18.5 SC (Coragen), Acephate 75 SP and 95 SG, Buprofezin 25 SC(Applaud), Dinetofuran 20 SG(Token), Imidacloprid17.5 SL(Confidor), Thiamethoxam 25 WG (Actara), Imidacloprid + Ethioprole (Glamore 80 WG), Flubendiamide 4% + Buprofezin 20% SC (RIL-IS-109) could not inhibit the egglaying of female YSB at their recommended doses, even when released on freshly treated plants. However, it was reduced only in Buprofezin and Acephate 95 WG @ one eggmass / treatment against five eggmass in untreated control.

But when freshly hatched larvae were released on insecticide treated plants, Chlorantraniliprole, imidacloprid and thiamethoxam could kill 100% of the larvae upto 7, 5 and 5 days, respectively so that no dead heart was formed within these durations. Other insecticides could not resist larval infestation even on same day of treatment, the dead heart formation ranging from a minimum of 20.8 in Acephate 95 WG to maximum of 78.7% in Buprofezin.

Effect of *'Ek Boond'* on efficacy of insecticides

'Ek Boond' is a non-ionic organo-silicon wetting agent which was reported to provide dynamic wetting penetration by carrying the spray of chemicals to normally inaccessible areas of the plant surface thereby providing better coverage and efficiency (Sequoia Bio Solutions Pvt. Ltd., Pune). Insecticides were evaluated alone and with *Ek Boond* at its recommended dose of 0.4 ml/litre of spray fluid against YSB in during *rabi*, 2014.

The field experiment was laid with variety Naveen in CRBD design for eight treatment including untreated control, each treatment replicated thrice. the recommended agronomic practices were followed for fertilizer application and spacing. Yellow stem borer infestation started from 3rd week of January (3SMW) and continued the whole crop season, i.e., upto May, 2014 with four high brood emergence. Insecticides Chlorantraniliprole 18.5 SC, Dinetofuran 20 SG and Acephate 95 SG were applied as foliar spray with and without *Ek Boond* at 28th January, 26th Februay and 19th March coinciding with the 1st, 3rd and 4th brood emergence. Among the insecticides, chlorantraniliprole was found most effective by keeping the dead heart formation significantly low both at 30 and 50 DAT. Accordingly, the highest grain yield of 5.1 t/ha was obtained with the treatment. But when mixed with Ek Boond, no significant difference was achieved with Chlorantraniliprole and Dinetofuran in terms of dead heart / white earhead formation and grain yield. But significant decrease in YSB infestation with increase in grain yield was recorded in Acephate+Ek Boond treatment.(Table 3.8).

So, foliar spray of chlorantraniliprole was effective against YSB when applied at the brood emergence stage and the wetting agent *'Ek Boond'* did not affect the efficacy. This efficacy of the insecticide might be due to the longer persistence on plant surface with which it prevents the larvae from entering to the plant and causing dead heart.

Field evaluation of insecticides

Nine insecticides were evaluated against insect pest of rice during *rabi* 2014 out of which Fipronil 5% (Tzed) @ 1000 ml/ha was best insecticide (5.75 t/ha) and was at par with other tested insecticide Bifenthrin 10% (Marker) @ 500 ml/ha, Quinalphus 25% (Ekalux) @ 1500 ml/ha in increasing the grain yield. All the

Table 3.8. Performance of insecticides and *'Ek Boond'* against YSB in *rabi* rice.

Sl. No	Treatments	Dose/ha	% Dead heart		% WEH	Yield (t/ha)
			30 DAT	50 DAT		
1	Chlorantraniliprole	150 ml	6.29 (14.46)	5.70 (13.77)	7.28 (15.62)	5.10 a
2	Chlorantraniliprole + Ek Boond	150 ml + 200ml	6.63 (14.37)	6.07 (13.70)	5.14 (13.01)	5.08 a
3	Dinetofuran	200g	13.45 (21.39)	28.68 (32.34)	5.56 (13.51)	3.39 cd
4	Dinetofuran + Ek Boond	200g+ 200ml	12.14 (20.36)	23.86 (20.11)	6.72 (14.93)	3.84 c
5	Acephate	526g	15.09 (22.82)	25.24 (30.13)	6.15 (14.13)	3.18 d
6	Acephate + Ek Boond	526g+ 200ml	4.07 (11.52	10.55 (18.49)	6.18 (14.30)	4.44 b
7	Ek Boond	200ml	15.74 (23.33)	25.18 (30.04)	5.35 (13.37)	3.00 d
8	Untreated Control	-	20.01 (25.08)	38.07 (38.09)	8.84 (17.30)	2.96 d
	CD at 5%		5.09	6.12	3.24	0.53

tested insecticides i.e. Fipronil(Tzed) 5% @ 1000ml/ha, Bifenthrin 10% (Marker) @ 500 ml/ha, Quinalphus 25% (Ekalux) @ 1500 ml/ha, Dimethoate 30% (Tafgor) @ 830 ml/ha, Imidacloprid 17.8% (Maharaja) @ 300ml/ha, Lambda cyhalothrin 2.5% (Cheeta) @ 500 ml/ha, Thiamethoxam 25% (Kemstar) @ 100 ml/ha, Flubendimide 39.35% (Fame) @ 50 ml/ha, Acephate 75% (Hythene) @ 1000 ml/ha were very effective against stem borer, leaf folder and gundhibug. The dead heart and white ear head and gundhi bug damage was less in treatment Fipronil 5% (Tzed) @ 1000ml/ha followed by Bifenthrin 10% (Marker) @ 500 ml/ha and Quinalphous 25% (Ekalux) @ 1500 ml/ha, during *rabi* season 2014 (Table 3.9).

During *Kharif* 2014, eight pesticides (two insecticides, two fungicides and their combinations) were evaluated against insect and disease of rice out of which RIL-IS-109 @ 1.75 ml/l +Baan @ 0.6ml/l was best insecticide-fungicide combination (4.74 t/ha) and was at par with RIL-IS-109 @ 1.75 ml/l + Contaf plus @ 2 ml/l (4.13 t/ha) and were effective against stemborer and leaf folder and sheath blight in variety TN1 (Table 3.10).

Biotic stress management in rainfed upland rice ecology

Management of major diseases under different crop establishment methods in bunded uplands

Cultural management of false smut of rice under rainfed transplanted condition

Combinations of transplanting dates (three) and fertilizer doses (three) were evaluated using Hybrid

Table 3.9: Testing of some new Insecticide against insect pest of rice during *rabi*, 2014

SL. No.	Treatment	% a.i	g or ml/ha	%DH	%WEH	%LF damage	%G.bug damage	NE	Yield t/ha
1	**Fipronil(Tzed)**	5	1000	3.5 (10.78)f	3.33 (10.51)h	1.6 (7.26)f	4.2 (11.82)d	2.0cd	5.75a
2	**Bifenthrin (Marker)**	10	500	3.7 (11.09)f	3.66 (11.02)g	1.7 (7.49)f	4.3 (11.96)d	2.1bc	5.62ab
3	**Quinalphus (Ekalux)**	25	1500	3.73 (11.08)f	3.72 (11.12)g	1.4 (6.79)g	4.4 (12.1)d	2.2b	5.55ab
4	**Dimethoate (Tafgor)**	30	830	4.12 (11.71)e	3.94 (11.44)f	2.1 (8.33)e	4.7 (12.52)c	1.8e	5.5b
5	**Imidacloprid (Maharaja)**	17.8	300	4.21 (11.84)e	4.12 (11.71)e	2.3 (8.72)d	4.8 (12.65)bc	1.9de	5.45b
6	**Lambda cyhalothrin (Cheeta)**	2.5	500	4.55 (12.26)d	4.26 (11.91)de	2.5 (9.09)c	4.8 (12.65)bc	1.2h	5.15c
7	**Thiamethoxam (Kemstar)**	25	100	4.66 (12.46)cd	4.38 (12.08)d	2.4 (8.91)cd	4.9 (12.78)bc	1.3gh	5.10c
8	**Flubendimide (Fame)**	39.35	50	4.76 (12.6)bc	4.65 (12.45)c	2.8 (9.63)b	4.9 (12.78)bc	1.5f	4.84d
9	**Acephate (Hythene)**	75	1000	4.87 (12.79)b	4.88 (12.79)b	2.1 (8.33)e	5.0 (12.92)b	1.4fg	4.8d
10	**Control**	Water	500l	5.41 (13.56)a	6.5 (14.68)a	3.8 (11.19)a	6.1 (14.29)a	3.3a	4.5e
CD at 5%				0.31	0.25	0.35	0.29	0.17	0.20

Data in parenthesis are angular transformed values, DH = dead heart, WEH = white ear head, G.bug = Gundhi bug,LF=leaffolder and NE=natural enemies

Table 3.10. Testing of some pesticide against rice pest during *Kharif*, 2014

SL. No.	Treatment	Dose gm or ml/l	%DH	%WEH	%LF	%Sheath blight	NE	Yield t/ha
1	RIL-IS-109 Flubendimide4% (35g)+Buprofezin 20%(175g)	1.75	2.8f (9.63)	3.2d (10.30)	2.6e (9.27)	26.6b (31.04)	2.7ef	3.76cd
2	Sutathion (Triazophus 40%EC)	1.5	3.3e (10.46)	3.5d (10.62)	2.8de (9.63)	25.7b (30.45)	2.8e	3.82c
3	Contaf plus (Hexaconazole 5%SC	2	5.1b (13.05)	5.2b (13.18)	4.5b (12.24)	23.6c (29.06)	3.2cd	3.65cd
4	Baan (Tricyclazole 75%	0.6	5.2b (13.18)	5.1b (13.05)	4.6b (12.38)	21.3de (27.48)	2.6fg	3.56d
5	RIL-IS-109 + Contaf plus	1.75 + 2	3.3e (10.46)	3.8c (11.24)	2.6e (9.27)	22.4cde (28.24)	3.3bc	4.13b
6	RIL-IS-109 + Baan	1.75 + 0.6	3.4de (10.62)	3.9c (11.38)	2.9d (9.80)	20.8e (27.13)	3.4b	4.74a
7	Sutathion + Contaf plus	1.5 + 2	3.5cd (10.78)	4.0c (11.53)	3.4c (10.62)	22.5cde (28.31)	3.1d	3.86c
8	Sutathion + Baan	1.5 + 0.6	3.6c (10.93)	3.4d (10.62)	2.9d (9.80)	23.28cd (28.79)	2.5g	4.26b
9	Control	water	5.8a (13.93)	5.7a (13.81)	5.1a (13.18)	31.5a (34.13)	4.5a	3.26e
	CD at 5%		0.29	0.37	0.42	1.37	0.18	0.23

Data in parenthesis are angular transformed values, DH = dead heart, WEH = white ear head, LF = Leaf folder

rice variety PHB 71 (recommended for Jharkhand and susceptible to false smut) for false smut incidence under natural disease infestation. The experiment was initiated in 2013 and was repeated in 2014 for confirmation. Three dates of transplanting (early- 20 July, normal- 27 July and late- 3 August) were evaluated with combinations of fertilizer regimes (80:40:40, 100:60:40 and 120:80:40; NPK).

Both late (3 August) and earliest (20 July) transplanting significantly reduced disease intensity over that of normal transplanting date (27 July) in both the seasons (Table 3.11). But at the same time, late transplanting (3 August) significantly reduced yield over other two other dates of transplanting. Lowest disease pressure coupled with agronomic advantages (of early transplanting) under rainfed ecology resulted in significantly highest grain yield in earliest transplanting (20 July) in both the years. Among the fertilizer doses, on the other hand, 100:60:40 resulted in significantly lowest disease intensity with yield advantage. Similarly, the interactive effects of both DT and fertilizer doses revealed that early transplanting (20^{th} July) with moderate fertilizer (100:60:40) resulted in least disease and higher yield advantage with significantly higher grain yield when natural disease pressure was high (2013). The results thus, confirms that early transplanting (by 20^{th} July) under moderate fertilization (100: 60: 40) provides desirable disease protection with higher grain yield.

Developing database on virulence structure of *M. oryzae* in Eastern India and develop NILs effective against specific lineages.

Characterization of the blast pathogen population

Sixty three single spore isolates of *Magnaporthe oryzae*, collected during 2010–2013 from different cultivars in

Table 3.11. Interactive effects of transplanting date and fertilizer doses on false smut intensity and grain yield in Hybrid rice (PHB 71), wet seasons 2013 & 2014

Fertilizer ($N:P_2O_5:K_2O$)	Disease intensity (%)				Grain yield (t/ha)			
	Date of transplanting			Mean	Date of transplanting			Mean
	20 July	27 July	3 August		20 July	27 July	3 August	
2013								
80 : 40 : 40	11.04 cd	18.79 e	10.22 cd	13.35 b	7.37 bc	6.85 b	5.49 a	6.57 a
100 : 60 : 40	6.88 a	12.26 d	7.99 ab	9.04 a	8.19 d	7.72 cd	5.82 a	7.25 b
120 : 80 : 40	12.18 d	21.95 f	9.97 bc	14.69 c	8 07 d	7.30 bc	5.61 a	6.99 b
Mean	10.03 a	17.67 b	9.39 a		7.88 c	7.29 b	5.64 a	
2014								
80 : 40 : 40	6.09 cde	10.37 f	5.64 cd	7.36 b	7.34 bcd	6.97 abcd	6.15 a	6.82 a
100 : 60 : 40	3.80 a	6.77 e	4.41 ab	4.99 a	7.73 cd	7.05 abcd	6.64 abc	7.14 a
120 : 80 : 40	6.72 de	12.12 g	5.50 bc	8.11 c	7.89 d	6.69 abc	6.30 ab	6.96 a
Mean	5.54 a	9.75 b	5.18 a		7.67 b	6.90 a	6.36 a	
Mean 2013 & 2014	7.78 a	13.71 b	7.29 a		7.77 b	7.10 a	6.00 a	
LSD 5%, Yr x DT x F				**1.57**				**0.91**

the different rice growing regions of North-East and Eastern India were used for molecular diversity and mating type analysis. DNA fingerprinting was used to study the diversity among the collections of 63 isolates by using *Pot2-TIR rep*-PCR and *MGR586-TIR*. Different lineages were detected for 63 *M. oryzae* isolates by *Pot2-TIR* and eight for *MGR586-TIR* fingerprints at 75 % similarity. Among the lineages detected by *Pot2-TIR*, lineage A and I represented the maximum number of isolates, whereas other lineages represented fewer numbers of isolates. Generally all the lineages contained isolates of mixed geographical origin. Isolates from Jharkhand were distributed in all the seven lineages. The *MGR586-TIR* DNA fingerprinting detected eight lineages, out of which three (Lineages F, G, H) were site specific but were represented only by single isolate. Lineage C contained isolates of Jharkhand only. The lineage A was the largest represented 46 isolates from all the states except Madhya Pradesh.

MGR586-TIR fingerprints appeared to differentiate the isolates more strongly compared to *Pot2-TIR* as is obvious from the distance among isolates of the same lineage (Lineage A) arbitrarily grouped together at 75 % similarity. All the 63 isolates were also investigated for *MAT1-1* and *MAT1-2* mating-type distribution by PCR based molecular markers. Of the 63 *M. oryzae* isolates collected, 16 (25 %) of the isolates were the mating type *MAT1-1* while 35 (56 %) were mating type *MAT1-2*. The *MAT1-2* isolates predominated in Jharkhand and Assam while *MAT1-1* was more predominant in the isolates of Odisha. Both *MAT1-1* and *MAT1-2* were equally distributed in the isolates of Meghalaya and Tripura. Only single isolate from Jharkhand was positive for both the mating type.

Molecular screening of blast resistance gene *Pi2* in Indian rice landraces and its verification by virulence analysis

Pi2 gene is a member of a multigene family which confers resistance to strains of blast pathogen *Magnaporthe oryzae*. The gene encodes a typical *NBS-LRR* type protein which confers broad spectrum resistance to a wide range of races of blast pathogen prevalent in Eastern India. Presence *Pi2* gene in 61 landraces was determined using a pair of primers *NBS2P3* and *NBS2R* followed by restriction digestion

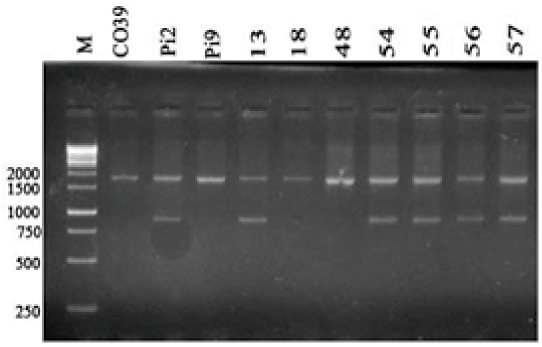


Fig. 3.19. Gel analysis of PCR products after digestion with restriction enzyme EcoR1. M: 1 kb ladder, Lanes 2 and 3 represent the susceptible control CO39 and resistant control IRBLz5CA, respectively. Lane 4: IRBL9-w (Pi9), 13 represent Brown gora, 18: Dahia, 48: Safed Gora, 54: Sanu Atte, 55: Atte, 56: Chirakey B, 57: Champae

and the results were further confirmed by pathotyping using *M. oryzae* isolates avirulent for *Pi2* gene. A monogenic line IRBLz5-CA, harbouring *Pi2* gene was used as positive control as it is resistant to *M. oryzae* isolates containing *Avr-Pi2* gene. CO39 was used as a negative control as it is susceptible to *M. oryzae* isolates containing *Avr-Pi2* gene. PCR amplification of susceptible Co39 and monogenic resistant line IRBLz5-CA and 61 landraces with *NBS2P3* and *NBS2R* primers generated monomorphic bands. However, restriction digestion of the PCR product with fast-digest *EcoR1* enzyme (Fermentas Life Sciences, Burlington, Canada) generated polymorphism between susceptible Co39 and monogenic resistant line IRBLz5-CA *(Pi2)*. Three different types of banding patterns of alleles of *Pi2* gene were observed among the landraces by NBS2P3 and NBS2R markers (Fig. 3.19). IRBLz5-CA and the landraces having *Pi2* gene produced a unique band of 850bp after restriction digestion but negative control Co39 did not have this band. Out of 61 landraces, five landraces had *Pi2* gene type banding pattern. The five landraces positive for *Pi2* gene originated from Sikkim (four) and Jharkhand (one). Thirty four landraces had Co39 susceptible type banding pattern and the remaining 22 landraces had null allele.

The five landraces identified to possess *Pi2*, based on amplification of the gene specific markers and the checks (IRBLz5CA and Co39) were inoculated with a mixture of *M. oryzae* isolates Mo-ei-118 and Mo-ei-241. The controls exhibited expected resistant and susceptible reaction for the mixture of isolates, with the Near Isogenic Line C101 A51 *(Pi2)* exhibiting resistant reaction and Co 39 showing susceptible reaction. Among the five landraces harbouring *Pi2* gene, four were resistant (Sanu Atte [Thima], Atte, Chirakey B, Champae) to the mixture of avirulent isolates but one landrace (Browngora, HRC 113) exhibited susceptible reaction even though the amplicon product was positively identified indicating the presence of *Pi2* gene (Table 3.12). Mutation in the coding region of the gene is reported to lead to loss of resistant function. Virulence analysis with avirulent isolates for *Pi2* gene however, confirmed that four

Table 3.12. Summary of disease reactions of landrace, virulence analysis against mixture of avirulent isolates for *Pi2* gene and PCR result of *Pi2* gene.

LR	HRC number	Landrace	Origin	Marker for *Pi2* gene[1]	Disease Reaction[2]	*Pi2**
13	113	Brown gora	Jharkhand	+	S	0
54	1276	Sanu Atte (Thima)	Sikkim	+	R	1
55	1291	Atte	Sikkim	+	R	1
56	1295b	Chirakey B	Sikkim	+	R	1
57	1334	Champae	Sikkim	+	R	1
		Co 39 (Control)		-	S	0
		IRBLz5CA (Control)		+	R	1

[1]Marker profile for analysis of *Pi2* gene, + indicate it contain specific band and - indicate it do not contain a specific band for *Pi2* gene. [2]Reaction against mixture of avirulent isolates for *Pi2* gene, * 1 indicate presence of *Pi2* gene, 0 indicate *Pi2* gene not present.

Table 3.13. Infestation of stem borer, leaf folder and whorl maggot in rice crops under different planting dates

Date of transplanting	Per cent dead heart	Leaf folder folded leaves (%)	Whorl maggot (0-9 scale)	Yield (t/ha)
13-08-2014	1.29	5.13	1	4.87
28-08-2014	0.79	6.43	3	4.99
11-09-2014	0.27	6.44	9	1.72

landraces of Sikkim (Sanu Atte (Thima), Atte, Chirakey B, Champae) have the functional *Pi2* gene. Presence of *Pi2* gene in independent indica landraces from the Eastern Indian region suggested that it might have originated and evolved in indica rice and exist in different allelic forms in blast endemic zones of Eastern India. The study demonstrated the usefulness of molecular markers and virulence analyses for rapid identification of resistant genes in rice landraces. These characterized landraces can be used for genetic studies and marker assisted breeding for improving blast resistance in rice.

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

Survey on the incidence of major insect pests of rice in flood-prone rainfed lowlands of Assam

Altogether eight districts of Assam, viz., Baksa, Cachar, Darrang, Dhubri, Hailakandi, Kamrup, Karimganj and Udalguri weres urveyed during *kharif* 2014 for recording the incidence of insect-pests on rice in flood prone areas. Rice leaf folder *(Cnaphalocrosis medinalis)*, stem borers (*Scirpophaga incertulas* and *S. innotata*), gundhi bug were found to be the major insect pests of winter paddy. Mealy bug {*Brevennia rehi* (Lindinger), an uncommon pest of rice in NE India was recorded causing mild to severe damage to rice in Baksa and Hailakandi districts of Assam.

Insect-pest infestations in winter rice under different dates of transplanting

Infestations of rice stem borer, leaf folder and whorl maggot on variety Naveen as winter rice was recorded under three different dates of planting commencing from the first fortnight of August at an interval of fifteen days. Per cent dead heart was found to be the lowest (0.27%) in the crop transplanted on first fortnight of September as compared to first fortnight (1.29%) and second fortnight (0.79%) of August. Per cent leaf folder infested leaves was 5.13 in first fortnight of August transplanted rice, which

Table 3.14. Management of stem borer and leaf folder in flood prone lowlands

Treatment	Insect-pests infestation			Yield (t/ha)
	DH %	WEH %	LF %	
FAME @ 50 ml/ha	3.58 (1.87)[b]	2.39 (1.54)[c]	2.75 (1.65)[b]	4.744[a]
Nursery application of carbofuran @ 33 kg/ha	4.49 (2.11)[b]	3.26 (1.80)[b]	3.37 (1.83)[b]	4.492[a]
Application of carbofuran @ 33 kg/ha at nursery and main field at 30 DAT	4.05 (2.01)[bc]	3.22 (1.79)[b]	2.94 (1.71)[b]	4.544[a]
Coragen @ 50 g *ai*/ha	3.75 (1.93)[bc]	2.49 (1.58)[c]	2.93 (1.70)[b]	4.711[a]
Pheromone trap @ 100 traps/ha	3.45 (1.86)[c]	2.01 (1.42)[d]	4.26 (2.03)[ab]	4.674[a]
Neem @ 3 ml/l at 30 DAT	4.03 (2.01)[bc]	3.35 (1.83)[b]	2.83 (1.67)[b]	4.598[a]
Beauveria bassiana @ 3 ml/l at 30 DAT	4.19 (2.04)[bc]	3.52 (1.87)[b]	2.95 (1.69)[b]	4.467[a]
Control	8.45 (2.91)[a]	7.01 (2.65)[a]	5.25 (2.29)[a]	3.778[b]
SE(d)	(0.12)	(0.06)	(0.19)	0.233
LSD (at p=0.05)	(0.24)	(0.13)	(0.39)	0.475

Values in parenthesis are square root transformed data

PROGRAMME : 4

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

This program consists of four projects. The first project relates to evaluation of rice germplasm, breeding lines and released varieties for their grain, nutritional and cooking quality, and suitability to develop value added products. The work on calibration of NIR spectrophotometer for determination of protein and amylose in rice/ rice bran is also described. Results related to identification of rice with high protein, iron and zinc have been presented. An experiment on characterization of rice cultivars for grain quality under high temperature stress is also described.

The second project relates to phenotyping of rice for tolerance to multiple abiotic stresses. The work was undertaken with a view to identify common QTLs for tolerance to multiple stresses such as submergence, anaerobic germination, salinity and drought and also unique QTLs for specific stresses. Genotypes tolerant to single/ multiple stresses were identified and physiological mechanisms conferring tolerance have been elucidated. In order to identify new source of salinity tolerance, pokkali accessions collected from coastal saline areas were evaluated. The work on probing of submergence driven changes in photosystem II on the basis of chlorophyl *a* fluorescence induction O-J-I-P transients is also described.

In the changing climatic scenario, research on drought and high temperature tolerant rice has assumed significance. Hence, the emphasis in the third project is on identifying the germplasm/ breeding lines tolerant to drought and high temperature stresses and to understand physiological mechanisms responsible for tolerance to these stresses with special emphasis on exploitation of genetic variability to identify genetic sources for component traits and superior alleles. Potential donors for vegetative stage and reproductive stage drought tolerance, and rice varieties with higher productivity and higher level of drought tolerance were identified. Twenty genotypes were identified for which the drought tolerance could be ascribed to more than one root traits.

The fourth project relates to evaluation and improvement of photosynthetic efficiency of rice. Research done on screening of germplasm /breeding lines/elite rice genotypes with higher photosynthetic efficiency under low light stress, improvement of photosynthetic efficiency, light spectral analysis in relation to physiological changes and yield potential of rice and QTL analysis for some low light adapted traits is described. The data on photosynthesis and productivity of NPT lines and performance of phytochrome sensitive *Japonica* rice mutant and wild type under low light environment are presented. With the objective to genetically engineer C_4 rice, cloning and transformation of maize NADP- malate dehydrogenase into *indica* rice was undertaken successfully.

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

Amino acid composition of some popular rice varieties including high protein rice

Brown rice samples of some popular rice varieties including high protein rice cultivars were acid digested and analyzed for individual amino acid content using high performance liquid chromatography (HPLC 1525, Waters) equipped with a C18 RP column and a fluorescence detector (2475, Waters). The amino acids were identified and quantified by comparing the retention times and peak areas of standards (WAT088122, Waters). It is evident from the data (Table 4.1) that the cultivars with high protein content namely ARC 10075 (13%) and Heera (11.5%) were richer in nearly all amino acids compared to Naveen, Ketekijoha and Swarna. Heera was found to have highest amount of threonine, which is known to help maintain the health of the digestive system lining. Heera also had the highest amount of lysine, an essential amino acid.

Table 4.1: Amino acids (g/100g fresh wt) in two high protein rice and other popular rice cultivars

Amino acids	ARC-10075	Ketekijoha	Naveen	Swarna	Heera
ASP	0.12	0.03	0.02	0.16	0.02
GLU	0.28	0.06	0.06	0.12	0.26
SER	0.23	0.10	0.21	0.37	0.47
HIS	0.08	0.04	0.08	0.16	0.19
GLY	0.24	0.26	0.40	0.67	0.53
ARG	0.17	0.29	0.18	0.30	0.42
THR	0.20	0.07	0.23	0.37	0.45
ALA	0.22	0.08	0.08	0.11	0.04
PRO	0.17	0.08	0.17	0.28	0.34
TYR	0.14	0.09	0.15	0.28	0.24
CYS	0.22	0.10	0.13	0.18	0.14
VAL	0.15	0.08	0.18	0.27	0.40
METH	0.05	0.05	0.05	0.03	0.15
LYS	0.12	0.21	0.13	0.18	0.37
ILE	0.10	0.05	0.11	0.18	0.27
LEU	0.21	0.11	0.23	0.39	0.48
PHE	0.17	0.10	0.17	0.32	0.36
Total	**2.85**	**1.79**	**2.59**	**4.36**	**5.12**

Calibration of near infra red spectroscope (NIRS) for protein and amylose in rice/ rice bran

With enhanced emphasis on economic and nutritional importance of rice grain protein and components of rice bran (RB), NIRS can be an effective tool for high throughput screening of rice germplasm for grain protein, oil, amylose and other constituents in rice breeding programme. Optimization of NIRS is prerequisite for accurate prediction of nutritional quality parameters of rice grains. In the present study, 173 brown rice (BR) and 86 RB samples with a wide range of values of nutritional parameters were used to compare the calibration models generated by different chemometrics for grain protein (GPC) and amylose content (AC) of BR and proximate compositions

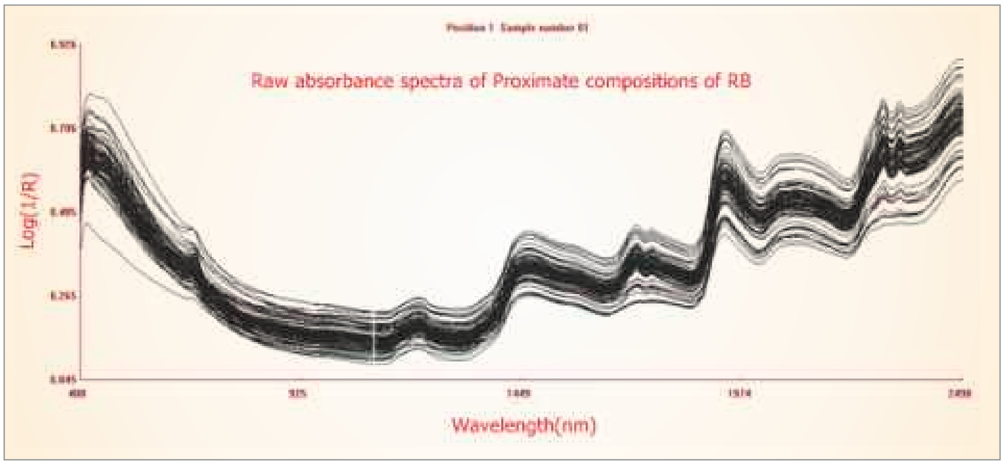


Fig. 4.1. Raw NIR absorbance spectra for proximate composition (protein, moisture, crude fiber, crude oil and ash) of Rice Bran

(protein, crude oil, moisture, ash and fiber content) of RB. Various modified partial least squares models (mPLS) corresponding with the best mathematical treatments were identified for all components (Fig. 4.1). Another set of 29 genotypes derived from the breeding programme was employed for the external validation of these calibration models.

Evaluation of rice germplasm and advanced breeding lines for grain quality and aroma under AICRIP trial

Twenty nine IVT-BT and thirty AVT-1-BT cultures from AICRIP trial (2014-15) were analyzed for grain quality parameters. Among all IVT-BT samples, the entry 2610 was found to be the best followed by 2615, 2614, 2612 and 2613 on the basis of milled kernel length, breadth, head rice recovery, volume expansion ratio, kernel length after cooking, water uptake, amylose content and alkali spreading value. In case of AVT-I-BT, the entry 2503 was found to be the best followed by the entries 2501, 2519, 2521 and 2527 in that order.

Grain quality of some popular rice cultivars and land races from Nagaland and West Bengal

Some popular rice cultivars from Nagaland and West Bengal were assessed for grain quality traits. Results (Table 4.2) indicated that the cultivar Nyakmok-V4 (Nagaland) and Kalabhat (W.B.) had very low amylose (9.59% and 5.32%, respectively). Long slender (LS) grain cv. Banskathi, which is very popular in the eastern parts of India and commands high market price showed an AC of 26.74% (high amylose rice) with GC = 38.2 mm. The other good cultivars with LS greens Kabirajisal and Dehradun Gandheswari, with intermediate AC content had GC values of 42.2 mm and 41.9 mm, respectively and hence are medium GC rice. All cultivars from W.B. were found to be good for making popped paddy (Fig. 4.2) as each of them showed good volume expansion on roasting.

Evaluation of rice cultivars for high temperature stress tolerance

Twenty seven rice cultivars were exposed to high temperature (Max./Min.=40-50°C/20-26°C) from grain filling stages to maturity. Two cultivars *viz.*, US 312 and IET 24120 performed better as they showed lower spikelet sterility% (10.17 and 7.75, respectively), then N22, reported to be high temperature tolerant earlier (Table 4.3). US 312 performed better during both years (2013 and 2014) in terms of all physiological and agronomic parameters measured.

High protein rice

In an ongoing program for screening rice cultivars for grain protein content, over 500 rice germplasm from the NRRI gene bank were screened for crude protein content. A landrace PB 104 was found to contain not less than 13.5% crude protein (per cent nitrogen x 5.95) in brown rice grains. This landrace (NRRI AC No. AC

Table 4.2: Grain quality parameters of some rice cultivars of Nagaland and West Bengal

Cultivars	Hulling %	Milling %	HRR %	Moist %	ASV	L mm	B mm	L/B	WU ml/100 g	VER	KLAC mm	ER	Amylose %	GC mm
NAGALAND														
Gwabilo SSU-V1	78.0	64.00	47.2	12.18	4	5.35	1.74	3.07	205	3.75	9.00	1.68	22.23	31.0
Nyakmok-V4	80.0	67.00	54.0	12.23	6	5.23	1.96	2.67	243	3.75	9.30	1.78	9.59	76.5
Masah (red) V6	75.0	66.00	57.0	12.33	3	4.52	1.57	2.88	185	3.75	8.00	1.77	26.21	45.5
Kshal-Chushu ghee	79.0	62.00	46.0	12.27	4	5.27	1.83	2.88	260	4.00	10.50	1.99	22.52	34.0
Apayhi	79.0	66.00	30.0	12.42	4	5.29	1.81	2.92	238	3.75	10.40	1.97	12.15	67.0
W. BENGAL														
Kalabhat	73.6	63.67	53.3	12.20	6	5.21	1.43	3.64	210	3.75	9.00	1.73	5.32	82.5
Banskathi	74.6	62.00	54.0	12.30	3	6.40	1.49	4.29	50	3.75	10.33	1.62	26.74	38.2
JP-73	72.00	60.00	40.0	12.00	3	6.20	1.58	3.93	55	3.75	10.33	1.67	21.17	41.5
Kabirajisal	76.5	65.00	60.5	12.00	5	6.67	1.61	4.13	115	4.00	11.00	1.65	22.41	42.2
Dehradun Gandheswari	74.5	60.50	46.5	12.70	4	6.30	1.42	4.44	100	4.00	10.00	1.59	22.73	41.9

ASV= Alkali Spreading Value, L= Grain Length, B= Breadth, WU= Water Uptake, VER= Volume Expansion Ratio, ER= Elongation Ratio, GC= Gel Consistency & KLAC= Kernel Length After Cooking

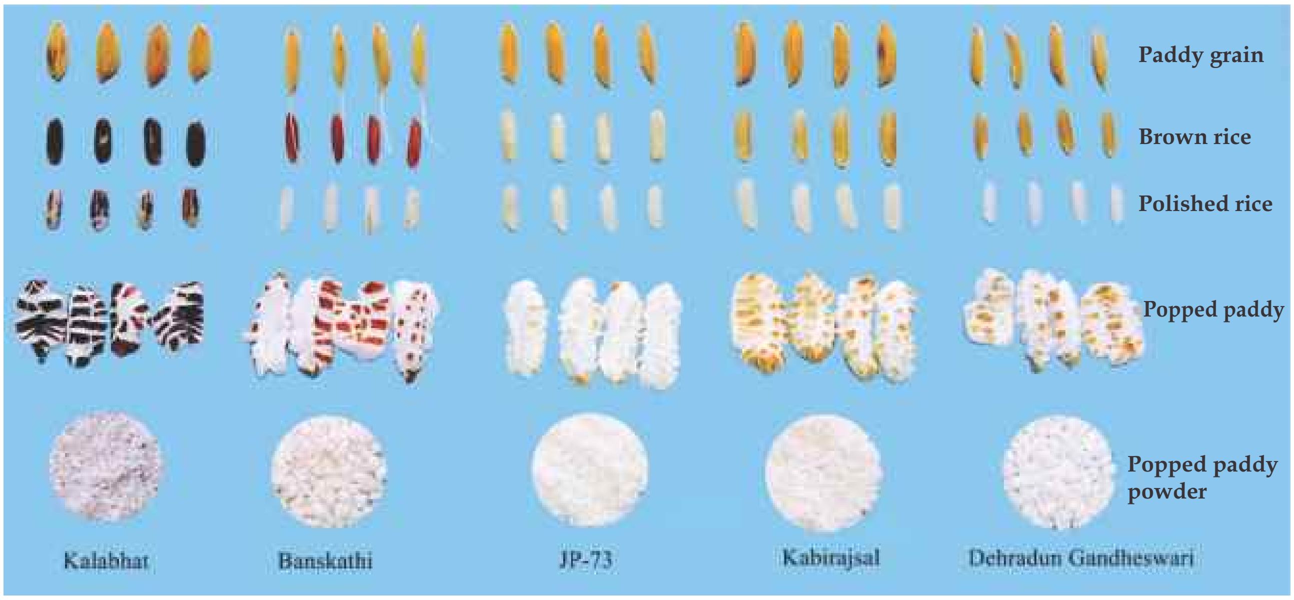


Fig. 4.2. Some rice cultivars of West Bengal found suitable for making popped paddy

Table 4.3: Effect of high temperature on some physiological and agronomic parameters of rice cultivars

Cultivars	Plant height (cm)	TDM (g)	Tillers /hill	Total grains/hill	Sterility %	1000 grain Wt(g)	Days to 50% flowering	Days to maturity
IR 64	93.00	46.00	7.33	643	61.1	22.9	79	129
MTU 1010	103.3	47.50	9.17	711	56.8	22.8	79	130
Lalat	99.7	44.50	7.50	1114	47.9	22.5	79	128
US 312	124.7	56.50	5.33	1180	10.2	21.2	81	133
N 22	135.0	28.50	4.17	504	35.3	20.3	82	133
IET 24120	110.7	36.50	6.00	1381	7.8	15.0	80	133
IET 23777	117.7	22.50	3.50	173	10.4	17.3	82	133

35048 and NBPGR IC No. 256652) was collected from village - Tunkatoli, Block - Nuagaon, District Sundargarh (Odisha) on 23 November 1999 in a collaborative exploration programme with NBPGR Base Center, Cuttack.

Micronutrient dense rice

Under the ongoing programme to screen for micronutrient dense rice, twenty five samples of brown rice of breeding lines and released varieties of rice were analyzed for iron and zinc content with X-ray fluorescence (XRF) machine. The NRRI rice cultivar CR Dhan 907 was found to be the richest in iron (20 ppm) followed by CR 3704 (14.1 ppm), the latter was also found to be rich in zinc (27.7 ppm). These two may be good source to breed for micronutrient dense rice. Some other rice cultivars also had good amount of iron and zinc (Table 4.4), though we have earlier identified better Fe & Zn rich genotypes.

Phenomics of rice for tolerance to multiple abiotic stresses

Screening of rice germplasm for submergence tolerance

The experiment was conducted with two hundred forty rice germplasm with three checks namely, Swarna, Swarna *Sub1* and FR 13A. The checks were repeated ten times. In general, none of the germplasm

Table 4.4: Iron and zinc content in brown rice samples as measured with X-Ray Fluorescence

S No.	Rice cultivar	Iron (ppm)	Zinc (ppm)
1.	Poornabhog	9.5	16.3
2.	Geetanjali	14	23.8
3.	Dhusara	12.7	20.1
4.	Kalajeera	12.6	23
5.	CR Dhan 907	20	19.6
6.	Tarori Basmati	16	23.2
7.	Pusa 1121	12.4	19.1
8.	Chinikamini	11.9	21.1
9.	Pusa Basmati	8.1	16.9
10.	CR 3704	14.1	27.7
11.	CR 3703	10.5	20.8
12.	CR 3702	12.6	18
13.	CR 3659-1	10.3	21.6
14.	CR 3659-2	11.4	20.5
15.	CR 3658-1	9.3	18.8
16.	CR 3658-2	10.4	18.3
17.	CR 3658-3	11.8	25.6
18.	CR 3700	12	21.2
19.	CR 3669	9.6	20.1
20.	CR 3702-2	10.9	25.1
21.	CR 3656	10.7	22.6
22.	CR 3648	9.1	22.3
23.	CR 3700-3	9	24.6
24.	CR 3662	11.2	20.6
25.	CR 3700-2	9.3	24.7

was better than the tolerant check FR 13A. A few germplasm namely, IC 456959, IC 459902 were at par with FR 13A (Table 4.5). However, these two cultivars were better than the other tolerant check Swarna *Sub1*.

Table 4.5: Effect of submergence on elongation ability and plant survival

Name	Plant height before submergence (cm)	Plant height after submergence (cm)	Elongation (cm)	Elongation (%)	Survival (%)
IC 461176	41.2	64.5	23.3	57	58
IC 459902	39.7	64.4	24.7	62	73
IC 461265	38.2	56.5	18.3	48	67
IC 545019	44.8	62.8	18.0	40	64
IC 459959	35.6	53.1	17.5	49	76
IC 54557	47.3	54.5	7.2	15	58
Swarna	29.1	44.4	15.3	53	0
Swarna *Sub1*	26.5	35.4	8.9	34	64
FR 13A	39.0	54.3	15.3	39	73

Screening of rice germplasm for multiple abiotic stress tolerance

The experiment was conducted with thirteen rice cultivars supplied by AICRIP centre, Hyderabad. The cultivars were tested for germination ability under 1 and 2 per cent mannitol induced drought condition, NaCl (12 ds/m) induced salinity condition and under complete submergence (anaerobic germination). The differences were significant for cultivars, whereas that for treatment and cultivar x treatment interaction varied showing either significant or non-significant differences (Table 4.6). Among the different stresses, germination% decreased drastically under submergence (Fig. 4.3). Under submergence, germination percentage was greater in Sm 686 (82.7%), followed by PHY 4 (72%) and AC 39416 (58.7%).

Evaluation of salt-tolerant rice cultivars for tissue tolerance at seedling stage

Thirteen rice cultivars were evaluated for tissue tolerance to salt stress at seedling stage by growing them at varying salinity levels (EC 0, 6, 12 and 18 dS/m). Chlorophyll and Na^+ contents of 3rd leaf from bottom were measured and then Na^+ level causing 50% reduction in chlorophyll content was computed. In general, susceptible cultivars showed greater tissue tolerance compared to tolerant cultivars. Tissue tolerance was lowest in AC 39384, a moderate salinity tolerant cultivar (12.5 mg/g leaf weight) compared to other cultivars. Medium tolerant cultivar, AC 847A showed maximum tissue tolerance, with 50% reduction in chlorophyll at Na^+ content of 25.6 mg/g leaf weight (Fig. 4.4). The data showed that most of the genotypes tolerated salinity stress by exclusion mechanism.

Table 4.6: Level of significance due to different abiotic stresses for germination % with least significant difference values at *p< 0.05

Stresses	Source of variation		
	Cultivar (d.f. = 12)	Treatment (d.f. = 1)	Cultivar x treatment (d.f. = 12)
Mannitol (1%)	3.0 **	NS	NS
Mannitol (2%)	2.4 **	0.9 *	3.4 **
Salinity	2.4 **	NS	3.4 **
Anaerobic germination	4.1 **	1.6 **	5.8 **

d.f. = Degree of freedom. Total d.f. was 77. The p of the overall ANOVA for cultivar, treatment and cultivar x treatment interaction was either *p< 0.05 or **p < 0.01. NS, non-significant.

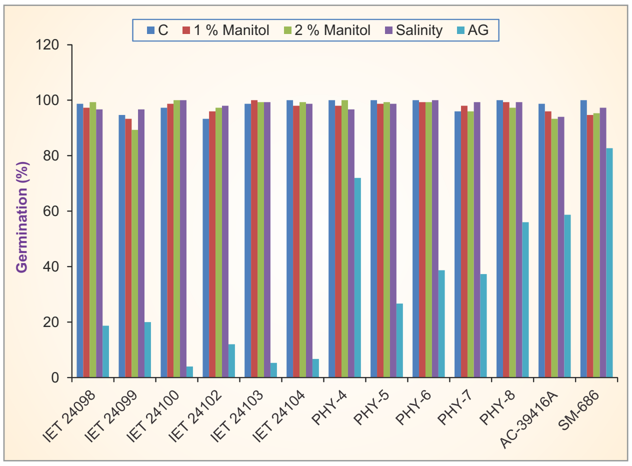


Fig. 4.3. Germination (%) of certain rice cultivars under multiple abiotic stresses

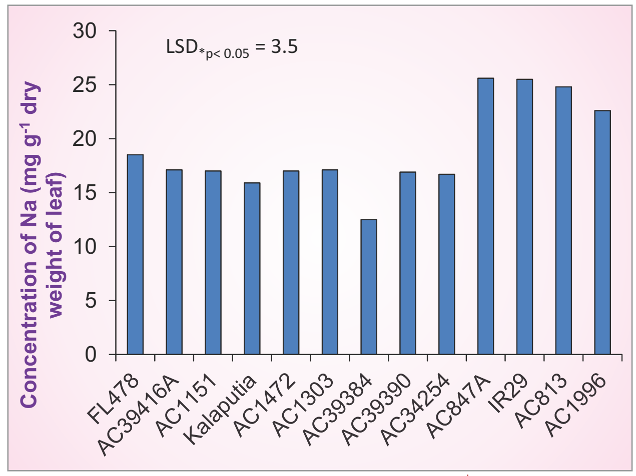


Fig. 4.4. Tissue tolerance based on leaf Na^{+} concentration for 50% reduction in chlorophyll content

Evaluation of salinity tolerant rice genotypes for drought tolerance

Twenty two salinity tolerant genotypes including susceptible checks were evaluated for drought tolerance under hydroponic condition using polyethylene glycol 6000 (-5.0 bars). The survival per centage of cultivars varied for 0 to 87.1 (Fig. 4.5). All the salinity tolerant cultivars were not tolerant to drought. Survival per centage was maximum under PEG 6000 in AC 1303B (87.1), followed by AC 1472 (78.4), AC 39293B (77.8), AC 34300 (73.3) and AC 39416A (72). The data showed that in rice germplasm pools both salinity and drought tolerant cultivars were available.

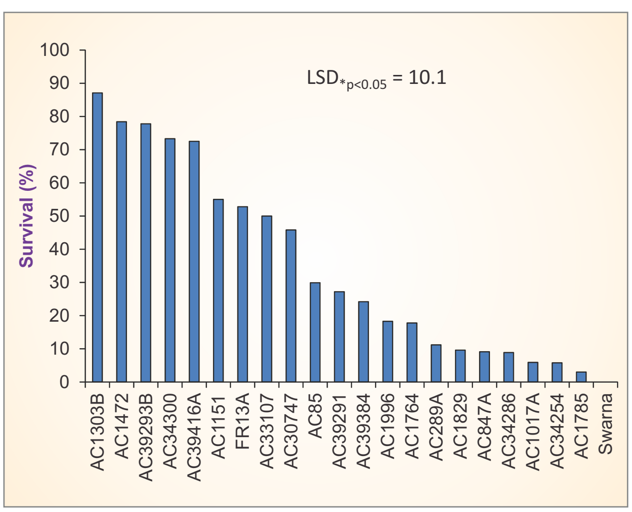


Fig. 4.5. Evaluation of salinity tolerant rice cultivars for drought tolerance

Submergence tolerant rice withstands complete submergence even with saline water

Probing of submergence driven changes of photosystem II by chlorophyll a fluorescence induction O-J-I-P transients

The present investigation characterizes the main effect of salinity and submergence on the function of PS2 in different rice cultivars as observed by the Chl a fluorescence induction kinetics (Fig. 4.6). The magnitude of fluorescence signal rose from the initial fluorescence level (O ≈ Fo) to the maximum level (P ≈ Fm) with intermediate steps J and I. O-J-I-P transient was marked only in one sample (Fig. 4.6A). A distinct treatment effects was observed in the rise of initial fluorescence level to maximum fluorescence level. The relative values of P were greater in control followed by salt stress. However, normalization of data at Fo and Fm level showed that compared to control there was a rise of fluorescence levels due to stress. The rise was greater in submerged samples compared to salt stress samples. Under salt stress the rise was more in FR 13A, followed by IR 42 and AC 39416 whereas under submergence the rise was greater in AC 39416, followed by IR 42.

The appearance of L-band was either in a negative or positive direction from the controlled condition depending on the nature of stress and cultivar x environment interaction. L-band did not appear in positive side compare to control under salt stress both

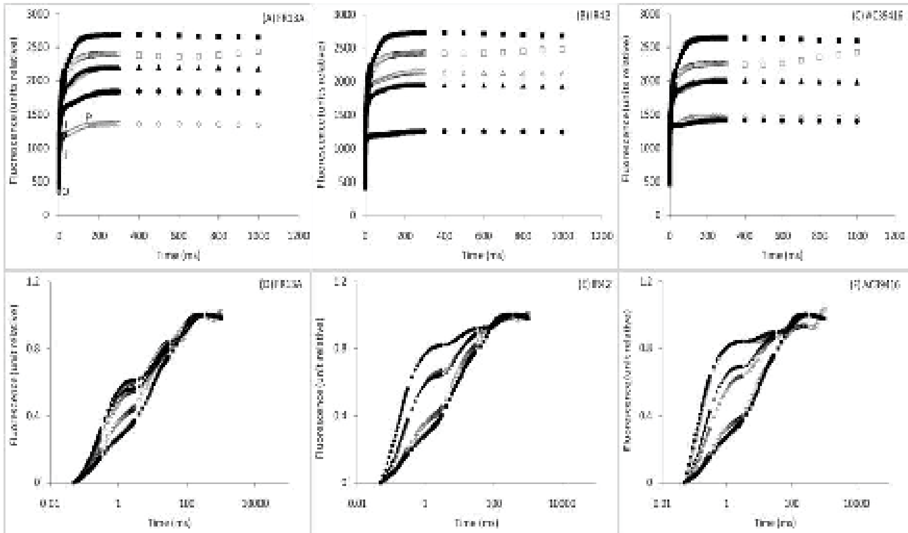


Fig. 4.6. The fast fluorescence rise in rice leaves subjected to salinity, submergence with non-saline and saline water of three cultivars namely, FR 13A (submergence tolerant, susceptible to salinity), IR 42 (susceptible to both salinity and submergence) and AC 39416 (salinity tolerant, susceptible to submergence). A typical fluorescence transient (O-J-I-P) exhibited upon illumination of a 20 min dark adapted leaf both in control and stress plant with greater reduction of maximal fluorescence (P ≈ Fm) in stress plant (A, B, C). The fluorescence at 50 µs, 2 ms, and 30 ms are known as O-, J- and I-phase, respectively. The highest peak in the curve was designated as P. Normalization at Fo and Fm revealed that a positive deviation of fluorescence rise from control to stress occurred (D, E, F), signified the damage of PS2. Control (■); Salt stress (□); Normal grown, submergence with non-saline water (▲); 12 dS/m saline treatment before submergence, submergence with non-saline water (Δ); Normal grown, submergence with 12 dS/m saline water (●); 12 dS/m saline treatment before submergence, submergence with 12 dS/m saline water (○); ms, millisecond.

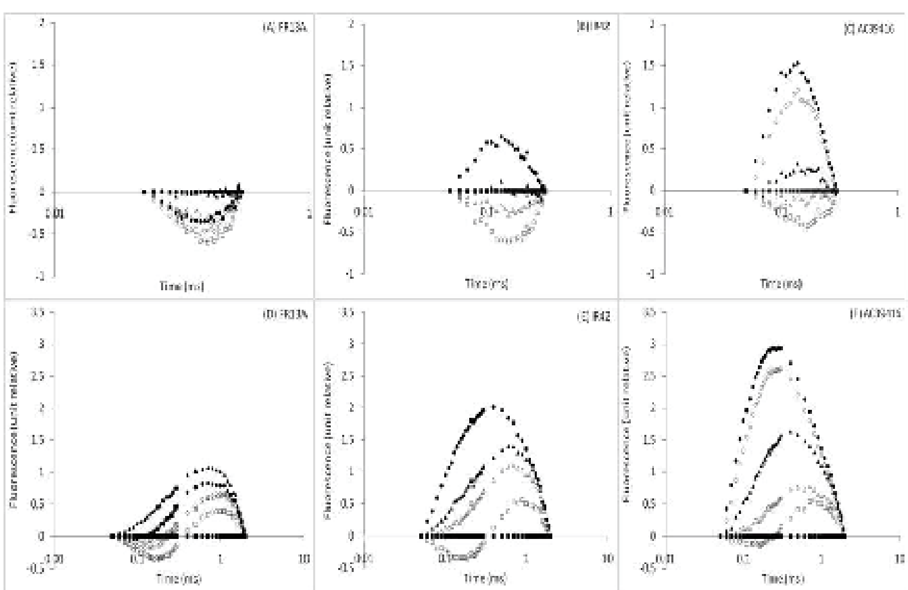


Fig. 4.7. Chlorophyll a fluorescence measured with 20 min dark adapted rice leaves. The measurements were carried out on fully expanded mature leaf, 2nd from top. The fluorescence curves were normalized between 0.05 and 0.30 ms for visualization of L-band. The fluorescence rise at 0.05-0.30 ms above the control designated as L-band (A, B, C). To visualize the K-band the fluorescence curves were normalized between Fo and Fj. The fluorescence rise at O-J phase above the control designated as K-band (D, E, F). Control (■); Salt stress (□); Normal grown, submergence with non-saline water (▲); 12 dS/m saline treatment before submergence, submergence with non-saline water (Δ); Normal grown, submergence with 12 dS/m saline water (●); 12 dS/m saline treatment before submergence, submergence with 12 dS/m saline water (○); ms, millisecond.

in salt sensitive and tolerant cultivars (Fig. 4.7A, 4.7B, 4.7C). Variations in the appearance of L-band occurred under submergence in different rice cultivars. In FR 13A, a submergence tolerant cultivar, in no cases positive deviation from control occurred, whereas in IR42, a submergence susceptible cultivar, positive deviation from control happened under submergence with saline water. In case of AC 39416 (submergence susceptible and salinity tolerant), distinct positive deviation occurred under submergence. The appearance of K-band was more prominent. The deviation was more or less in positive direction from control (Fig. 4.7D, 4.7E, 4.7F). The deviation was more positive under submergence compared to salinity. Comparison of the deviations among three cultivars under submergence revealed that in submergence tolerant cultivar FR 13A the deviations were less compared to intolerant cultivars. Submergence with saline water showed greater deviations of K-band compared to submergence without saline water in intolerant cultivars (Fig. 4.7E, 4.7F).

Evaluation of Pokkali accessions for seedling stage salinity tolerance

Thirty nine Pokkali accessions collected from coastal saline areas were evaluated for seedling stage salinity tolerance in salinity tanks at EC 12 dS/m (Fig. 4.8). Of these, one accession, AC 39417 was found more tolerant than FL 478 (tolerant check) and three accessions, *viz.*, AC 39409, AC 39394 and AC 39411 were identical in tolerance to FL 478. In contrast, two accessions, i.e. AC 39365 and AC 39370 were found more susceptible than IR 29 (susceptible check). These observations suggest that great variability exists for seedling stage tolerance even within different Pokkali accessions.

Fig. 4.8. Evaluation of Pokkali accessions for seedling stage salinity tolerance

Rice physiology under drought and high temperature stress

Identification of potential donors for vegetative stage drought tolerance

A field experiment was conducted to screen rice germplasm and breeding materials for vegetative stage drought tolerance under managed stress during *rabi* 2014. Rice gemplasm numbering 1082 (360 previously observed tolerant and 720 new) grown in augmented design were exposed to moisture stress at 30 days after sowing. Out of 360 entries, 40 observed to be highly tolerant with SES '1', 68 were moderately tolerant with SES '3 & 5', 14 moderately susceptible with SES '5 & 7' and 12 were susceptible with SES '7 & 9' in 2 replications. Twelve entries flowered quickly at the onset of stress, may be considered as drought avoidance type. Out of 720 new entries, 132 entries were identified as tolerant with SES '1' (Fig. 4.9). During the stress period, soil moisture content ranged from 9.0 to 15%, soil moisture tension from (-) 36 to (-) 51 kPa and water table depth was always below 80 cm (Fig. 4.10).

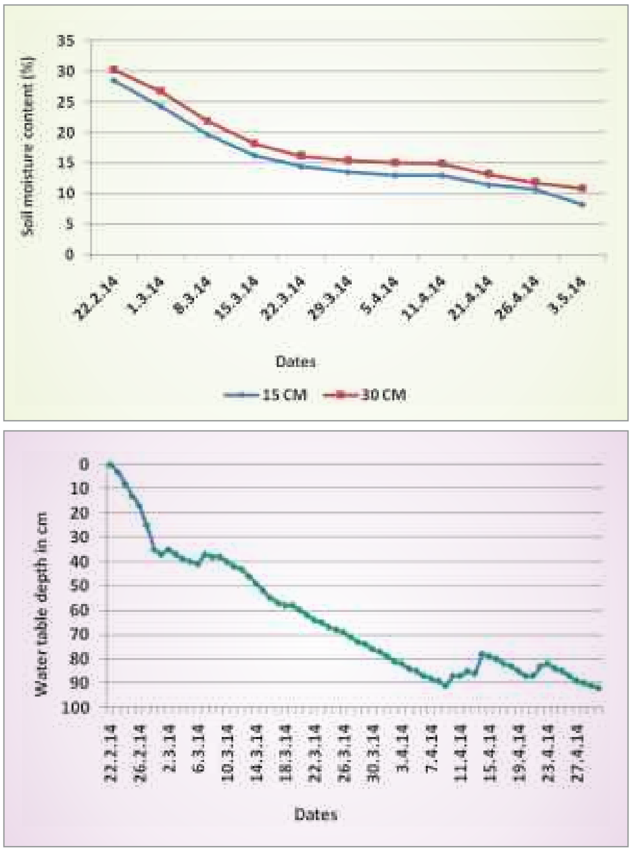


Fig. 4.9. Soil moisture content and water table depth during stress period (DS-2014)

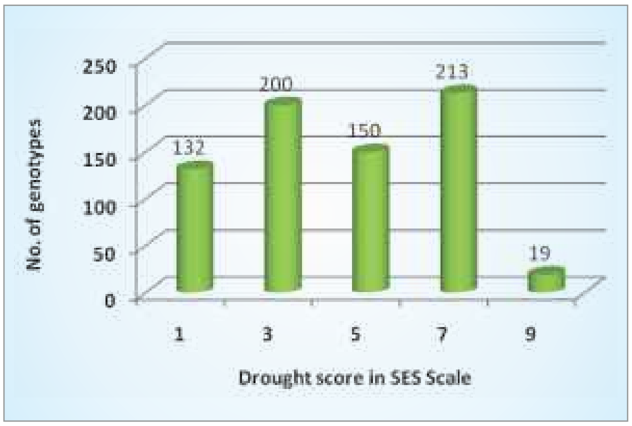


Fig. 4.10. Reaction of genotypes to drought score

Evaluation of tolerant genotypes for reproductive stage drought

Twenty selected genotypes having vegetative stage drought tolerance along with tolerant and susceptible checks (Brahman nakhi and IR 20, respectively) were evaluated for reproductive stage drought tolerance in rain out shelter during wet season 2014. The crop was irrigated normally till the booting stage; afterwards it was withdrawn till the completion of the cropping period. Among the twenty genotypes, highest yield was recorded in AC 42994 (3.77 t/ha) followed by Brahman nakhi (3.26 t/ha), AC 43006 (3.11 t/ha), Nania (2.84 t/ha) and Kalabora (2.73 t/ha) at 9.8-

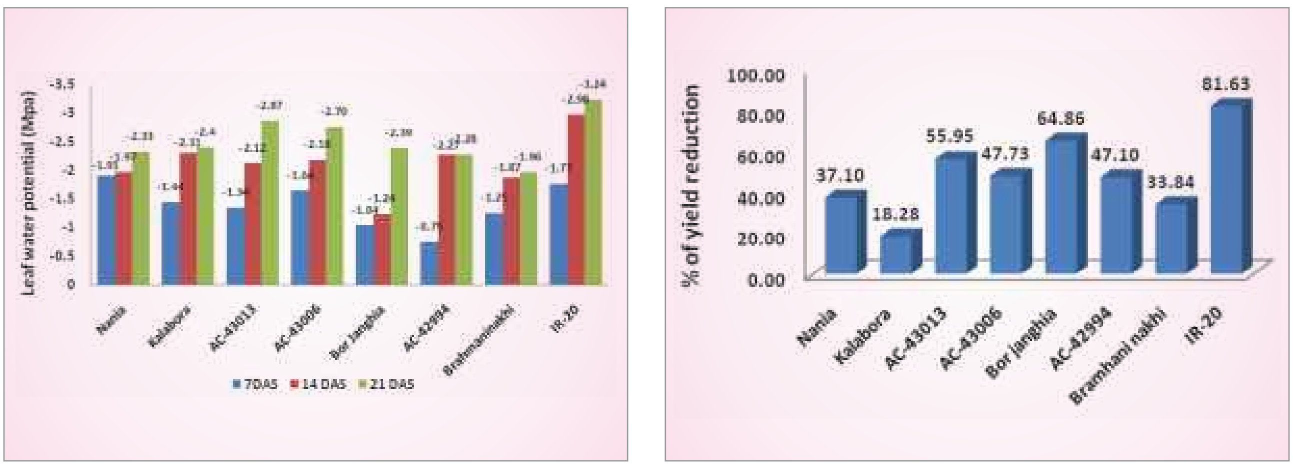


Fig. 4.11. Leaf water potential and per cent yield reduction of best performed genotypes

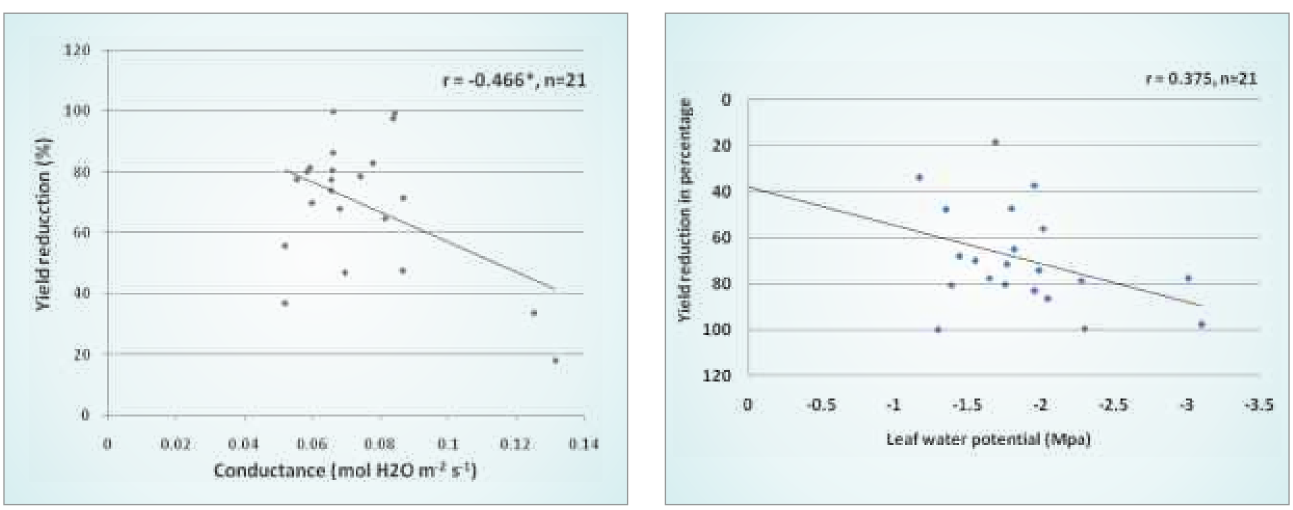


Fig. 4.12. Correlation of per cent yield reduction with stomatal conductance and panicle water potential during reproductive stage stress

13.3% of soil moisture content. But relative yield reduction was minimum in Kalabora (18.3%) followed by Brahman nakhi (33.8%), Nania (37.1%) and AC 42994 (47.1%). Susceptible check IR 20 had highest reduction in yield (81.6%). Concomitantly high water potential in flag leaf was observed in Brahman nakhi (-1.97 MPa), AC 42994 (-2.28 MPa), Nania (-2.33 MPa), Borjanghia (-2.39 MPa) and Kalabora (-2.4 MPa) (Fig. 4.11).

Minimum reduction in photosynthetic rate was observed in Kalabora (8.7%) followed by Brahmaninakhi (23.7) and AC 42994 (26.4%) at 50% flowering stage, whereas at grain filling stage it was lowest in Bor Janghia (12.5%) followed by AC 42994 (13.9%) and Kalabora (21.7%). Stomatal conductance and panicle water potential (PWP) were found to be negatively correlated with reduction in grain yield per centage (Fig. 4.12) indicating that maintenance of PWP and stomatal conductance played important role in determining grain yield.

Evaluation of elite rice varieties for drought tolerance under different moisture levels

Twenty four selected elite rice varieties were grown under three different moisture levels, control irrigated (C), moderate stress (MS) and severe stress (SS) to assess their yield performance. Stress levels

Table 4.6: Grain yield and drought susceptibility index of elite rice varieties under different moisture levels

Varieites	Grain Yield (t/ha)			RYR (%)		DSI		Grain filling (%)		
	C	MS	SS	MS	SS	MS	SS	C	MS	SS
Vandana	4.96	3.44	2.35	30.6	52.6	0.6	0.7	89.7	66.2	64.2
Vanaprava	5.55	2.38	1.74	57.0	68.7	1.2	0.9	84.0	80.2	71.4
Salumpikit	2.41	1.62	0.90	32.9	62.8	0.7	0.9	83.8	55.7	48.4
CR 143-2-2	4.67	2.83	2.46	39.5	47.4	0.8	0.6	89.6	84.1	83.3
Kalinga-III	5.47	2.53	1.73	53.7	68.4	1.1	0.9	86.5	78.1	63.2
Browngora	3.42	2.05	1.92	40.2	43.8	0.8	0.6	89.4	61.5	59.3
Zhu-11-26	5.71	2.74	2.28	52.0	60.1	1.1	0.8	92.6	84.7	79.67
Lalat	6.65	3.16	1.83	52.4	72.6	1.1	1.0	80.8	63.5	48.4
Satabdi	5.16	3.24	0.86	37.2	83.4	0.8	1.1	85.7	59.3	56.8
Kalakeri	4.14	2.60	1.75	37.3	57.8	0.8	0.8	94.9	83.2	78.8
Annapurna	5.84	4.00	1.63	31.5	72.1	0.6	1.0	92.2	83.7	60.8
N-22	3.61	1.63	1.91	55.0	47.2	1.1	0.6	90.8	80.1	69.1
Sahabhagidhan	4.91	2.51	1.99	48.8	59.5	1.0	0.8	87.8	76.8	50.3
Govind	5.09	2.57	1.02	49.5	79.9	1.0	1.1	94.2	73.9	47.2
Tulasi	5.75	2.47	1.16	57.1	79.9	1.2	1.1	93.4	76.4	45.4
Naveen	5.54	2.90	1.52	47.6	72.5	1.0	1.0	80.9	44.7	41.6
Annada	6.21	4.03	1.37	35.1	78.0	0.7	1.1	94.0	88.8	39.5
IR-36	6.28	2.80	0.81	55.4	87.1	1.1	1.2	85.9	67	11.2
IR-64	4.60	2.15	0.51	53.3	88.8	1.1	1.2	87.2	60.5	7.5
Kamesh	5.32	2.88	1.36	45.9	74.4	0.9	1.0	86.2	89.5	59.5
Rasi	5.39	4.31	0.47	20.0	91.3	0.4	1.3	92.1	85.7	56.2
Moroberekon	1.89	0.42	0.46	77.9	75.6	1.6	1.0	61.2	16.7	7.3
Azucena	5.89	0.77	0.26	86.9	95.7	1.8	1.3	78.3	14.5	0.0
IR-20	5.35	0.94	0.10	82.4	98.1	1.7	1.3	73.5	47.5	0.0
Mean	**4.99**	**2.54**	**1.35**	**49.13**	**71.57**	**1.01**	**0.97**	**86.45**	**67.60**	**47.88**
LSD at 5%	1.01	0.79	0.57	-	-	-	-	5.32	26.89	12.69

(C- control, MS – moderate stress, SS – severe stress, RYR – relative yield reduction DSI- drought susceptibility index) were maintained MS: -30 to -40 kPa and SS: -50 to -60 kPa during PI to milky white stage. Highest grain yield was obtained in Lalat (6.65 t/ha) under control, Rasi (4.3 t/ha) under moderate stress and CR 143-2-2 (2.4 t/ha) under severe stress condition. Relative yield reduction (RYR) was lowest in Rasi (20%) and Brown gora (44%) under MS and SS, respectively. Nine genotypes had < 40% RYR in MS and only three genotypes had <50% RYR in SS. However, drought susceptibility index (DSI) was lower in these genotypes (<1.0) with better grain filling (> 50%) even under SS. Lowest DSI was recorded in CR 143-2-2 (0.6) with highest grain filling (83%) indicated tolerance to stress level of (-)50 to (-)60 kPa (Table 4.6).

Root trait characterization of drought tolerant lines

Two hundred twenty rice germplasms and breeding lines of longer duration (for rainfed lowland condition) previously observed to be drought tolerant were germinated in petri dishes lined with moist filter paper. After 3 days of germination, the seedlings were transferred to a perforated thermocol base placed on trays containing Hoagland solution with pH adjusted to 5.7. Nutrient solution was replaced at weekly interval and pH was maintained regularly. Thirty days old seedlings were taken from the medium to measure root morphological traits such as root length (RL), shoot length (SL), root number, root dry weight (RDW) and shoot dry weight (SDW). Twenty best genotypes Kalakeri, Mahulata, Zhu-11-26, CR 143-2-2, Lalnakanda-41, Annapurna, RR 433-2, Samba Mahsuri, EC 306321, CR 2430-4, RMP-1, RR 366-5, AC 26774, Sasyashree, Salumpikit, Lektimachi, AC 26773, Khitish, IET 18817, IC 5165130 were observed to have higher values for more than one root trait indicating that the tolerance of genotypes to vegetative stage drought may be based on different root traits.

Evaluation and improvement of photosynthetic efficiency of rice

Impact of low light on the photosynthetic rate and chlorophyll accumulation efficiency in wild species of genus *Oryza*

A study was conducted to characterize thirteen species of wild relatives of genus *Oryza* for their photosynthetic efficiency (P_N), transpiration rate, stomatal conductance, internal CO_2 concentration, chlorophyll accumulation efficiency and biomass production under normal and reduced light intensity (50% of normal light).

The result revealed maximum P_N in *O. nivara* followed by *O. australiensis* and *O. rufipogon* under normal light condition. However, under low light condition, the maximum P_N was observed in *O. nivara* followed by *O. rhizomatis* and *O. eichingeri* (Fig. 4.13). The stomatal conductance and the transpiration rate followed the same trend under both light regimes. The internal CO_2 concentration increased under low light environment, irrespective of the species, indicating the scope of further improvement of photosynthesis under low light. Considering accumulation of more chlorophyll b and consequently low *Chl a/b* ratio under low light environment as the selection criteria for selecting the varieties for low light tolerance, *O.rufipogon, O.punctata, O.barthii, O.eichingeri* and *O.nivara* showed tolerance to low light environment due to higher accumulation of chlorophyll b (Fig. 4.14), and lower *Chl a/b* ratio. These species may be used as donors in the rice breeding programme to develop low light tolerant rice varieties.

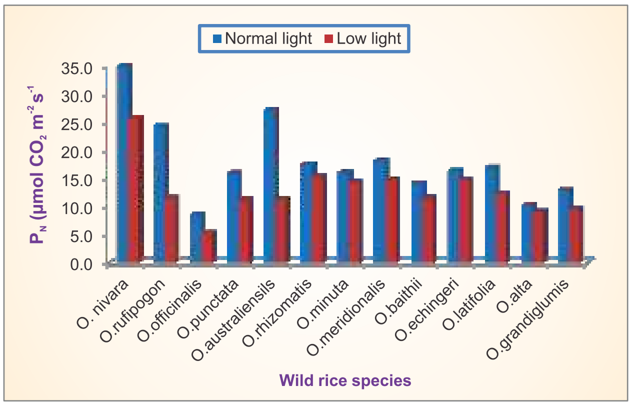


Fig. 4.13. Photosynthetic efficiency of wild rice species under low light

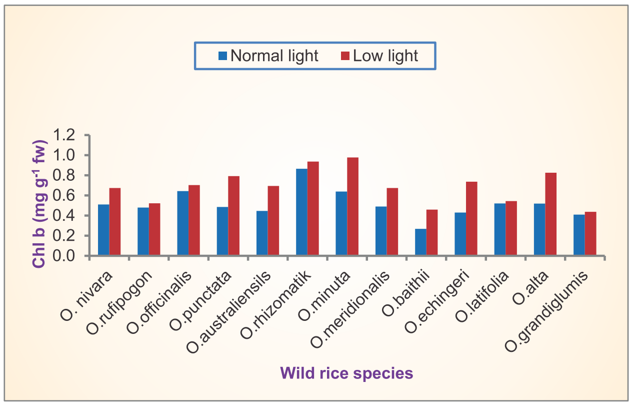


Fig. 4.14. Chlorophyll b accumulation in wild rice species under low light

Table 4.7: Photosynthesis and chlorophyll accumulation efficiency (average value) of rice genotypes of different duration groups as influenced by low light

Duration of variety	PN($\mu molCO_2 m^{-2}s^{-1}$)		Chl b (mg g^{-1}fw)		Total Chl. (mg g^{-1}fw)		Chl a/b ratio	
	NL	LL	NL	LL	NL	LL	NL	LL
<100 days	24.793	15.738	0.692	0.922	2.890	3.558	3.18	2.86
100-120 days	26.643	16.439	0.637	0.856	2.646	3.222	3.15	2.78
121-135 days	31.605	18.115	0.540	0.790	2.165	2.885	3.32	2.88

Variation in photosynthesis and chlorophyll accumulation in some elite rice genotypes grown under two different light regimes

A study was carried out to find out the relationship between photosynthetic efficiency and chlorophyll accumulation in selected rice genotypes of different duration groups, viz., <100 days, 100-120 days and 121-135 days under low light (50% of normal light). The rate of photosynthesis and chlorophyll a/b ratio was found to be significantly reduced under low light environment in all rice genotypes, irrespective of their duration. At the same time chlorophyll b and total chlorophyll content were apparently high in the cultivars under low light compared to that in normal light condition. It was found that 121-135 days duration genotypes showed better photosynthesis and more chlorophyll b content in low light (Table 4.7). Among these rice genotypes, photosynthesis and chlorophyll b accumulation was more in Kalinga II followed by Konark and Satyakrishna.

Performance of phytochrome sensitive *Japonica* rice mutant and wild type under low light environment

A study was conducted on the effect of low light intensity (25% of natural light) at different growth stages and subsequent exposure to natural light to assess for various agronomically important traits in two *Japonica* rice cultivars namely, Akitokomachi and its phytochrome A mutant, A0410, under field condition. The dry matter accumulation was affected significantly in phytochrome A mutant under shading in comparison to the wild type at all the growth stages. Under shade condition, the net photosynthesis in the flag leaf of the phytochrome A mutant was 27.7% less than that of the wild type (A 0401= 12.91 μmol CO_2 m^{-2} s^{-1}, Akitokomachi = 17.86 μmol CO_2 m^{-2} s^{-1}), whereas under normal light condition the net photosynthesis in the mutant was 8.7% less than that in the wild type (A0401= 24.74 μmol CO_2 m^{-2} s^{-1}, Akitokomachi= 27.11 μmol CO_2 m^{-2} s^{-1}) (Fig. 4.14). The grain yield of the mutant was found to be less than that observed in wild type. The plants under the shade condition showed lower yield in comparison to the plants under normal light condition. The mutant under the shade condition showed reduction in yield by 18% in comparison to the wild type under similar condition. Under normal light condition, the mutant showed 9.4% reduction in yield (Fig. 4.16). Under low light intensity, the tiller number, leaf area index, dry matter production, panicle number, grains/panicle and grain yield were also reduced in the phytochrome A mutant, A 0410. The data suggest that phytochrome A has a major role in regulating the agronomically relevant traits and grain yield in rice.

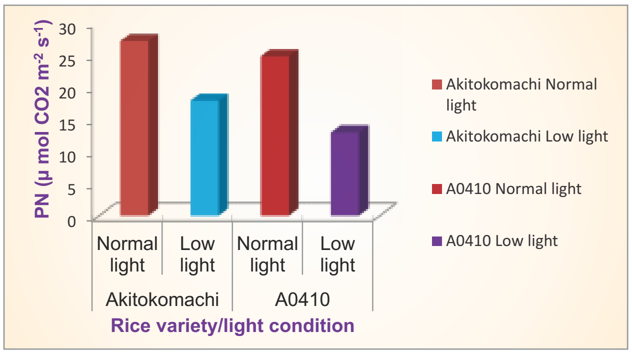


Fig. 4.15. Photosynthetic efficiency of Japonica rice mutant and wild type under low light environment

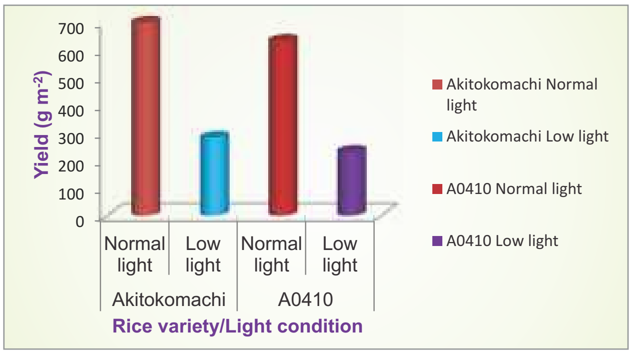


Fig. 4.16. Grain yield of Japonica rice mutant and wild type under low light environment

Table 4.8: Photosynthesis, yield and yield attributing parameters of NPT lines

NPT lines	PN ($\mu molCO_2$ $m^{-2}s^{-1}$)	LAI	Total Chl (mg g^{-1}fw)	TDM	Grain yield (t ha^{-1})	Tillers (m^{-2})	Panicle (m^{-2})	HI (%)	Sterility (%)
CR3697-1-13-1-1-1	23.56	8.03	2.09	1828.2	8.95	263.3	245.0	48.95	19.22
CR Dhan 307	19.51	6.07	1.92	1445.7	6.27	215.0	211.7	43.37	22.38
CR 3697-4-4-4-3-1-1	18.89	9.34	1.93	2037.3	6.39	280.0	273.3	31.34	17.51
CR 2683-7-1-1-1-1	15.45	7.75	1.96	1426.7	2.96	156.7	143.3	20.74	24.32
CR 2683-1-3-1-2	22.47	8.23	2.02	2248.3	8.74	225.0	215.0	38.86	11.79
CR 2682-1-1-5-2-1	14.51	7.63	2.02	2256.7	5.69	223.3	211.7	25.21	17.12
Swarna	23.87	7.94	2.07	1842.3	9.08	330.0	328.3	49.26	17.28
CD at 5%	**1.6**	**0.48**	**0.10**	**458.2**	**0.52**	**15.8**	**16.3**	**3.45**	**1.31**

PN- Photosynthesis, LAI- Leaf Area Index, TDM- Total Dry Matter, HI- Harvest Index

Photosynthesis and productivity of NPT lines

Six NPT lines along with the check (Swarna, a HYV) were assessed for their photosynthetic efficiency and productivity. None of the NPT lines showed superiority over the check. There was no significant difference in grain yield of two NPT lines viz. CR 3697-1-13-1-1-1 and CR 2683-1-3-1-2 compared to the check. Swarna recorded highest grain yield (9.08 t/ha) compared to CR 3697-1-13-1-1-1 and CR 2683-1-3-1-2 which yielded 8.95 and 8.78 t/ha, respectively. Swarna also recorded highest photosynthetic rate (23.87 µ mol CO_2 m^{-2} s^{-1}) followed by CR 3697-1-13-1-1-1 and CR 2683-1-3-1-2. The other yield attributing characters also correlate with the respective lines (Table 4.8).

Cloning and transformation of C_4 photosynthetic maize NADP- malate dehydrogenase into *indica* rice

Maize NADP- malate dehydrogenase was cloned into binary vector.

A) Amplification of NADP-*mdh* from maize cDNA

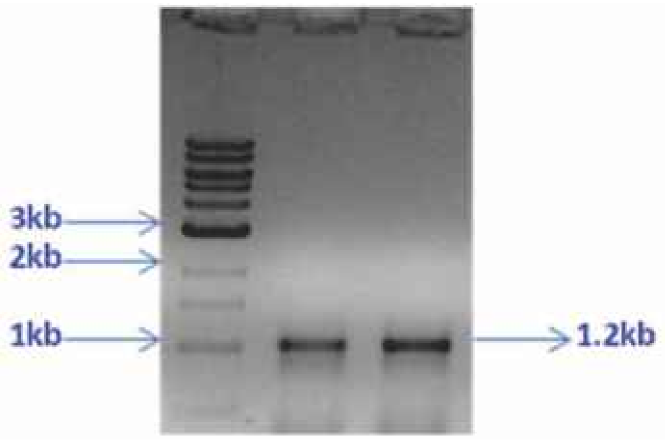


Fig. 4.17. PCR amplification of maize NADP-Malate dehydrogenase (1.2 kb) using 0.8% agarose gel

B) Cloning of NADP- MDH into PGEMT- EASY

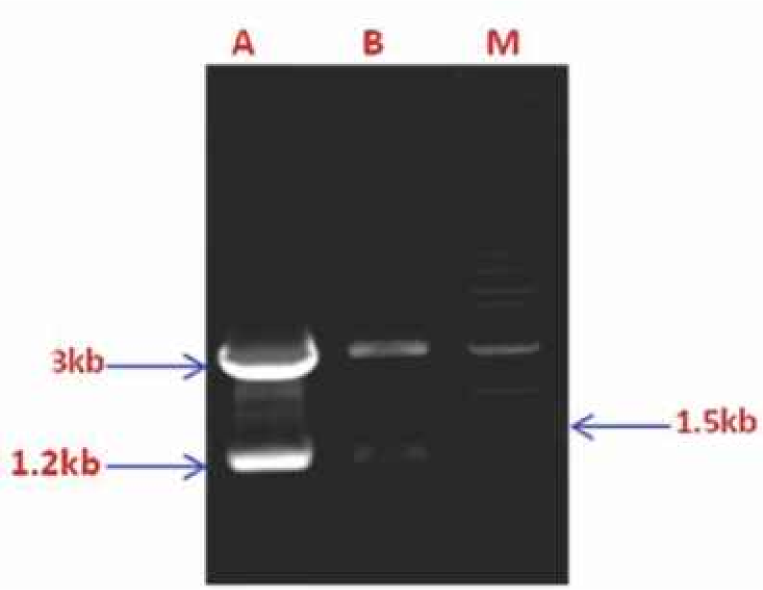


Fig. 4.18. Restriction digestion of recombinant pGEMT-Easy by EcoR1 Lane M. 1 kb Molecular weight marker; Lane A & B: digestion by EcoR1

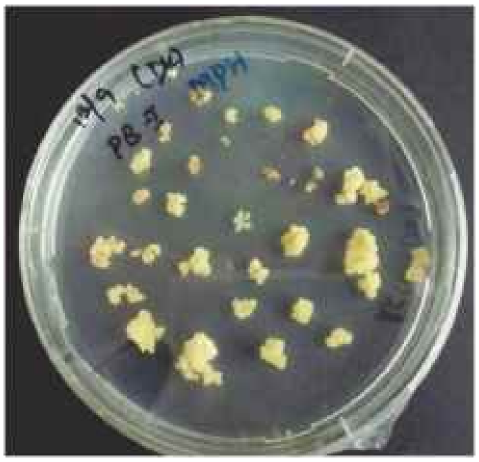


Fig. 4.19. Agrobacterium mediated transformation of maize NADP-Malate dehydrogenase gene into rice callus.

PROGRAMME : 5

Socio-economic Research and Extension for Rice in Developments

As per the objectives of the programme 5, significant development was observed in model village cluster with respect to coverage of NRRI varieties as well as change in attitude of the participating farmers of the cluster. The model village is mainly rainfed, therefore, animal husbandry was introduced for strengthening the livelihoods. Similarly, thirteen technologies were tested for their suitability for farmwomen under activity 'Designing and testing of gender sensitive approaches in rice farming'. It was observed that farmwomen could make more profit from the land allotted to them by men folk which may further improve the accessibility of farmwomen to land. Farmers of various areas reported problems in rice such as availability of quality HYV and hybrid seeds, timely irrigation, mechanization and custom hiring, procurement facility, demonstration of new generation technology, agri-preneurship, capacity building, single-window grievance redressal system and inter departmental coordination.

Dissensus delphi method was used to finalise resources for further characterisation of resources and innovations with revised methodology. As per the result, majority of the experts advocated mapping physical, biological, socio-personal, economic and infrastructural aspects in relation to rice farming.

Analysis of spread of NRRI varieties revealed that in Uttar Pradesh the NRRI variety Sahabhagidhan was grown. The NRRI hybrids-Ajay, Rajalaxmi and CR Dhan 701 were found to be grown in Bihar. While in Gujarat, NRRI varieties Jaya and Mahsuri were being grown. In another activity, it was found that cost of cultivation per hectare had increased over the years, whereas profit margin had not increased commensurately. Human labor accounted for 35.8 per cent of the total cost of cultivation and 53.1 per cent of the operational cost of cultivation and thus, it is the single largest item in the total cost structure.

In order to make easy access to scientists, a user-friendly database on data from 1961 to 2012 regarding state-wise area, production and yield of rice in India was constructed.

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

Development of model village, evaluation of interventions and recommendations

In continuation to the efforts made earlier to develop rice based model village in a rainfed area namely, Gurujang-Guali cluster, Tangi-Choudwar block of Cuttack district, emphasis was laid during 2014-15 to improve the livestock of the households. In the process of strengthening the livelihood of farmers, ten newly released rice varieties of NRRI were

Demonstration of newly released varieties 'CR Dhan 303' and 'CR Dhan 305' in the model village

A farmer with the demonstration of rice hybrid 'Ajay' in model village

A farmer in the model village being trained in operating reaper

demonstrated in five acres of land. Besides, 10 hectare Front Line Demonstration (FLD) was organized to popularize hybrid rice cultivation.

The yield of *kharif* rice revealed that hybrid rice Rajalaxmi produced highest average grain yield of 6.32 t/ha followed by CR Dhan 305 (5.8 t/ha), CR Dhan 303 (5.7 t/ha) and CR Dhan 304 (5.6 t/ha). The varietal substitution interventions produced remarkable result in the cluster in terms of coverage. Out of 161 hectares of available rice land in the cluster 101 hectares were under NRRI varieties, which accounts for 63 per cent of the total rice area. In the medium land ecology, the coverage of Swarna *Sub1* was found to be highest followed by Naveen and Pooja. In the lowland ecology, Varshadhan had full coverage. A small sample (30) study conducted in the cluster to assess the direction of changes by using Mc Nemar test revealed that significant positive changes have taken place with respect to attitude towards hybrid rice, knowledge on high yielding varieties, knowledge on rice cultivation, soil nutrient management, pest control and mechanization. The vegetable farming in the unbunded upland in *kharif* and in the backyard rice fields during *rabi* were taken up to sustain the livelihood of the household mostly through the of the participation of the women. Vegetables seed packets of desired varieties of bean, cucumber, okra and pumpkin were supplied to 20 farmwomen and 15 farmers.

Considering the opportunities and interests of households in livestocks, an effective coordination between the livestock Subject Matter Experts of KVK and state government under convergence actions yielded many successes for extension of livestock in the cluster. Two training programmes, two animal health camps, deworming vaccination, quick disease diagnosis and treatment through mobile veterinary unit were undertaken to improve the productivity

Animal health camp is in progress in the Model village

A woman beneficiary with the ducklings being supplied for livelihood and nutritional security

Presentation during 'Institute level stakeholders meet' on developing rice-based model village

Interactions during 'village level stakeholders meet' on developing rice-based model village

and quality of livestock. Livestock demonstrations on poultry (Banaraja-100 birds), duck rearing (40 birds) and pisciculture (three ponds) were taken up to promote transfer of knowledge and skills on livestock management.

A study was conducted to assess the credit needs of small scale rice farmers, major determinants and related information from two villages. Primary information was collected by focus group discussion as well as face to face interview of thirty small scale rice farmers using structured interview schedule. Profile of the respondents, credit demand, access to credit information, etc. were estimated and a multiple regression analysis was done to identify the factors determining demand for credit, considering various socio-economic factors as independent variables. The results indicated that access to information on institutional credit services were very low (57%) as banks/financial institution (FIs) merely conduct any promotional/awareness programmes in the area. The immediate demand for credit estimated to be Rs. 47, 350 and the respondents preferred cooperative societies as better institutions over banks due to less cumbersome procedure of loan application and prompt delivery. Its share in total credit demand was estimated to be 47%. About 53% of the respondents desired to use the loan to create assets like farm machineries, land reclamation/ development, purchase of livestock, etc. The regression analysis indicated that age of the respondent, family size, land holding, operational bank account, current liabilities and gross family income were significant determinants of credit demand by small scale rice farmers. The study advocated for concerted efforts to augment the flow of credit to farm through regular visiting of bank officials for creation of awareness, opening of bank accounts and simplification / promptness of credit delivery mechanism.

As part of agreed upon village development programme, the block development officer (BDO) has implemented the septic latrine program for all households as an important step for health and hygiene of villagers. Institute level stakeholder meeting was held on 9 June 2014 with participation of ten development agencies and an action plan for 2014-15 was formulated. Another village level workshop by involving different agencies and villagers was held on 4 March 2015 to assess the progress and understand the village level difficulties. Renovation of water harvesting structure, a long standing need of the villagers, has not yet been effected and the concerned agencies were requested for quick actions in this regard.

Designing and testing of gender sensitive approaches in rice farming

Under the project activity, 'Designing and testing of gender sensitive approaches in rice farming', socio-economic, technological and institutional interventions were continued and evaluated in Sankilo village of Cuttack district. During this year, demonstrations on six NRRI rice varieties, viz., Shatabdi, Naveen, CR Dhan 303, CR Dhan 304, Pooja and Ketakijoha (aromatic) were conducted by thirty adopted farmwomen in half-an-acre area by each during *kharif* 2014-15. Apart from varietal demonstrations, method demonstrations on raising of mat-type nursery, seed treatment, line transplanting,

Director inaugurating the women development group 'Ananya Mahila Bikash Samiti' in Sankilo

Farmwomen displaying traditional rice-based value added food products during the workshop

2 & 4-row manual rice transplanters, 4-row drum seeder, finger weeder, split application of balanced fertilizer, need based plant protection measures and safe spaying of pesticides, mechanized and drudgery reducing post-harvest processing technologies like, NRRI mini parboiling unit and rice husk combustor for meeting domestic fuel need from rice husk were also organized and their responses collected. Since, input arrangement and management play an important role for maximization of profit in rice farming, information on those were collected from all the adopted farmwomen.

- An expanded group of forty women farmers including all the thirty adopted women were formally registered in the name of *'Ananaya Mahila Bikash Samiti'* for supporting and accelerating their all round development. The group has opened a saving account in local bank for undertaking income generating group activities.
- An one-day Workshop-cum-Training programme on 'Designing and testing of gender sensitive approaches in rice farming' was organized on 11 August 2014 coinciding with important field operations with the participation of over eighty participants including women participants from neighbouring villages. Scientists from various disciplines conducted demonstrations and participated in women farmers-scientists interactions. The participating farmwomen showcased their traditional skills and displayed over hundred rice-based value-added products (VAPs), many of which were having good commercial value and marketability through linking with value chain.
- Apart from close monitoring and providing technical backstopping during the crop seasons, emphasis was given on rapport building, establishing trustworthiness, social harmony, family relationship and their exposure to the developing world throughout the project period.

Dr. JS Chauhan, ADG (FFC & Seeds), ICAR visiting the rice-based vegetable farming and interacting with the adopted farmwomen

- Crop cutting experiments were organized for *kharif* rice in the presence of all adopted farmwomen as well as their male counterparts to show them the benefits of new varieties and integrated crop management practices. The average fresh grain yields recorded for the demonstrated varieties were, Shatabdi - 3.36 t/ha, Naveen - 5.04 t/ha, CR Dhan 303 - 6.8 t/ha, CR Dhan 304 - 6.8 t/ha, Pooja - 5.4 t/ha and Ketakijoha - 4.32 t/ha. It was found that newly released CR Dhan 303 and CR Dhan 304 outperformed the widely grown variety of Swarna with average grain yield of 5.0-6.5 t/ha in the village.
- During *rabi* 2015, demonstrations on vegetable crops, viz., broccoli, capsicum, red cabbage, China cabbage, cherry tomato, carrot, potato, garlic, cauliflower, knol khol, cabbage, pumpkin, coriander and amaranthus were demonstrated. High yielding and hybrid seeds were provided as critical inputs. Apart from domestic consumption, these high value vegetables were sold in the local market and sent to nearby urban markets. This helped them in earning about 15-20 per cent additional profit.
- Several rounds of discussion and interactions were made among the Director, project personnel, concerned scientists, *Ananya Mahila Bikash Samiti*, seed companies, rice millers and processors to establish a rice-value chain thorough signing a memorandum of understanding (MOU) before the ensuing *kharif* season. This would help the women rice growers to link themselves to the market, to ensure sale of paddy at remunerative price and to earn more profit.

Data recorded on participation, experience with new knowledge and access of farmwomen to inputs in rice farming were analyzed. The summary of the findings is given below.

Six major project activities were undertaken during 2014-15, which included training programmes (7), demonstrations (12), exposure visits (4) including NRRI, village level field visits/ field days (12), meeting with experts (8), and monthly group meeting among the group members (12). Regarding the extent of participation of the thirty adopted farmwomen in various project activities, data in Table 5.1 reveals very high participation (80-100%) in training programmes (83.33%), followed by demonstrations (76.66%), meetings with experts (73.33%), and monthly group meetings among members (66.67%). However, the participation in exposure visit programmes was observed almost equal (20.00, 23.33, 30.00 & 26.67%) at all levels of participation (very high, high, moderate & low). It may be added here that nobody was complete absent in any of those activities.

Attempts were made to know the specific reasons of their absence which are presented in Table 5.2. It can be observed that the reason 'important household works' ranked first (35.66% weightage) followed by various 'festivals and social functions' (20.97%), 'illness of self' (16.09%) and 'illness of family members' (11.21% weightage), respectively. This indicates

Table 5.1: Participation of farmwomen in the project activities during 2014-15 **(N=30)**

Sl. No.	Project activities	Frequency of activities (f)	Extent of participation			
			Very high attendance (80-100%)	High attendance (60-80%)	Moderate attendance (40-60%)	Poor attendance (< 40%)*
1.	Training programme	7	25 (83.33)	4 (13.34)	1 (3.33)	0 (0.00)
2.	Meeting with experts	8	22 (73.33)	4 (13.33)	2 (6.67)	2 (6.67)
3.	Demonstration	12	23 (76.66)	2 (6.67)	3 (10.00)	2 (6.67)
4.	Exposure visit	4	6 (20.00)	7 (23.33)	9 (30.00)	8 (26.67)
5.	Field visits/ Field days	12	16 (53.33)	6 (20.00)	4 (13.33)	4 (13.33)
6.	Monthly group meeting among members	12	20 (66.67)	5 (16.66)	3 (10.00)	2 (6.67)

(Figures in the parentheses indicate percentages)
(* Nobody was found complete absent in any of the above activities)

Table 5.2: Reasons for not having cent percent attendance in the project activities **(N=30)**

Sl. No.	Reasons	Total weighted score	Weighted score in percentage	Rank
1.	Important household works	122	35.06	I
2.	Festivals and social functions	73	20.97	II
3.	Illness of self	56	16.09	III
4.	Illness of family members	39	11.21	IV
5.	Weather not favourable to travel	25	7.18	V
6.	Absent in the farming on the day	21	6.03	VI
7.	Uneasiness during long travelling	12	3.45	VII

Table 5.3: Experience of farmwomen with the new knowledge in rice farming **(N=30)**

Sl. No.	New Knowledge	Nature of experience with new knowledge			Appropriateness of the new knowledge as perceived by farmwomen		
		Doing by self	Experiencing in others field	No Experience	More appropriate	Moderate appropriate	Less appropriate
1.	Rice Variety						
	i. Shatabdi (120d)	2 (6.67)	28 (93.33)	0 (0.00)	5 (16.67)	10 (33.33)	15 (50.00)
	ii. Naveen (120d)	6 (20.00)	24 (80.00)	0 (0.00)	21 (70.00)	9 (30.00)	0 (0.00)
	iii. CR Dhan 303 (130d)	3 (10.00)	27 (90.00)	0 (0.00)	17 (56.67)	8 (26.67)	5 (16.67)
	iv. CR Dhan 304 (130d)	1 (3.33)	29 (96.67)	0 (0.00)	19 (63.33)	10 (33.33)	1 (3.33)
	v. Pooja (150d)	26 (86.67)	4 (13.33)	0 (0.00)	25 (83.33)	5 (16.67)	0 (0.00)
	vi. Ketakijoha (150d)	4 (13.33)	26 (86.67)	0 (0.00)	12 (40.00)	17 (56.67)	1 (3.33)
2.	Raising of Mat type seedling	4 (13.33)	26 (86.67)	0 (0.00)	30 (100.0)	0 (0.00)	0 (0.00)
3.	Line transplanting	30 (100.0)	0 (0.00)	0 (0.00)	27 (90.00)	3 (10.00)	0 (0.00)
4.	Recommended dose of fertilizers	25 (83.33)	5 (16.67)	0 (0.00)	25 (83.33)	5 (16.67)	0 (0.00)
5.	Application of need-based pesticides	4 (13.33)	11 (36.67)	15 (50.00)	10 (66.67)	3 (20.00)	2 (13.33)
6.	Seed treatment	30 (100.0)	0 (0.00)	0 (0.00)	30 (100.0)	0 (0.00)	0 (0.00)
7.	2-row manual transplanter	4 (13.33)	26 (86.67)	0 (0.00)	4 (13.33)	11 (36.67)	15 (50.00)
8.	4-row manual transplanter	4 (13.33)	26 (86.67)	0 (0.00)	7 (23.33)	14 (46.67)	9 (30.00)
9.	4-row manual drum seeder	2 (6.67)	26 (86.67)	2 (6.67)	16 (57.14)	9 (32.14)	3 (10.71)
10.	Finger weeder	5 (16.67)	22 (73.33)	3 (10.00)	19 (70.37)	6 (22.22)	2 (7.40)
11.	Rice parboiling unit	8 (26.67)	15 (50.00)	7 (23.33)	7 (30.43)	12 (52.17)	4 (17.40)
12.	Rice husk combustor	10 (33.33)	11 (36.67)	9 (30.00)	18 (85.71)	3 (14.28)	0 (0.00)
13.	Paddy straw mushroom cultivation	10 (33.33)	16 (53.33)	4 (13.33)	23 (88.46)	3 (11.54)	0 (0.00)

(Figures in the parentheses indicate percentages) pressure on farmwomen due to multiple roles and responsibilities..

During *kharif* 2014, some new technologies (Table 5.3) were given through demonstrations and training on package of practices for increasing rice production and productivity. Among the six varieties, 'Pooja' was rated most appropriate by the farmwomen (83.33%) followed by 'Naveen' (70.0%), 'CR Dhan 304' (63.33%) and 'CR Dhan 303' (56.67%) mainly because of their better productivity, local adaptability and marketability. 'Shatabdi' was found less suitable by majority (50.0%) due to low productivity, while the scented variety 'Ketakijoha' was reported moderately appropriate by 56.67% farmwomen.

Interestingly, all farmwomen (100.0%) found 'raising of mat-type seedlings' for mechanical transplanting as appropriate, even though only four of them practiced this technology. Similarly, other recommended packages like, seed treatment (100.0%), line transplanting (90.0%), recommended dose of fertilizers (83.33%) and application of need-based pesticides (66.67%) were found very appropriate among the practicing farmwomen, and all of them (100.0%) adopted seed treatment and line transplanting as per the recommendation.

Among the women-friendly farm machineries demonstrated, rice husk combustor, finger weeder and 4-row manual drum seeder were perceived as more appropriate by 85.71%, 70.37% and 57.14% farmwomen, respectively. Majority opined rice parboiling (52.17%) and 4-row manual rice transplanter (46.67%) as moderately appropriate, while half of them (50.0%) said 2-row manual transplanter was less appropriate. The 4-row transplanter was preferred over 2-row as it could cover double the area in unit time. Paddy straw mushroom cultivation as an income generating activity by using available straw was also rated as more appropriate by 88.46% farmwomen.

Since socio-economic and technological empowerment of farmwomen largely depends on accessibility to farm inputs and take decisions to use

Farmwomen with the demonstration of rice varieties 'CR Dhan-304' and 'Ketakijoha' (aromatic) in the gender project village

Farmwomen operating 4-row rice transplanter and 4-row rice drum seeder in the presence of the Director, NRRI

Table 5.4: Access of farmwomen to farm inputs in rice farming during 2014-15 (N=30)

Sl. No.	Name of the inputs	Class of the inputs	Source		Who Arranged			Access to Inputs #		
			Own	Hired/ NRRI*/ Borrowed/ Purchased/	Self	Self + Family members	Family members	Full access input	Moderate access	Little access
1.	Land	0.5 acre (Demo.)	18 (60.00)	0 (0.00)	9 (50.00)	6 (33.33)	3 (16.67)	18 (100.00)	0 (0.00)	0 (0.00)
		0.6 - 1 acre	5 (16.67)	2 (6.67)	1 (14.29)	2 (28.57)	4 (57.14)	5 (71.43)	2 (28.57)	0 (0.00)
		> 1 acre	3 (10.00)	2 (6.67)	0 (0.00)	2 (40.00)	3 (60.00)	3(60.00)	2 (40.00)	0 (0.00)
2.	Money	Up to Rs. 2500	11 (36.67)	0 (0.00)	4 (36.36)	3 (27.27)	4 (36.36)	5 (45.45)	5 (45.45)	1 (9.00)
		Rs. 2501 - 5000	9 (30.00)	2 (6.67)	1 (9.00)	8 (72.72)	2 (18.18)	5 (45.45)	4 (36.36)	2 (18.18)
		> Rs. 5000	4 (13.33)	4 (13.33)	0 (0.00)	6 (75.00)	2 (25.00)	2 (25.00)	5 (62.50)	1 (12.50)
3.	Seeds	10 kg. (Demo.)	0 (0.00)	18 (60.00)	18 (100.0)	0 (0.00)	0 (0.00)	18 (100.0)	0 (0.00)	0 (0.00)
		> 10 kg.	5 (16.67)	7 (23.33)	5 (41.67)	5 (41.67)	2 (16.67)	7 (58.33)	3 (25.00)	2 (16.67)
4.	Fertilizer	For 0.5 acre (Demo.)	0 (0.00)	18 (60.00)	18 (100.0)	0 (0.00)	0 (0.00)	18 (100.0)	0 (0.00)	0 (0.00)
		For > 0.5 acre	5 (16.67)	7 (23.33)	4 (33.33)	8 (66.67)	0 (0.00)	7 (58.33)	3 (25.00)	2 (16.67)
5.	Pesticide	Used (2 - 5 kg)	4 (13.33)	0 (0.00)	1 (25.00)	3 (75.00)	0 (0.00)	2 (50.00)	2 (50.00)	0 (0.00)
6.	Water	Bore well	2 (6.67)	0 (0.00)	0 (0.00)	1 (50.00)	1 (50.00)	2 (100.00)	0 (0.00)	0 (0.00)
		Canal water	0 (0.00)	30 (100.0)	9 (30.00)	10 (33.33)	11 (36.67)	13 (43.33)	8 (26.67)	9 (30.00)
7.	Labour	Family member	--	--	16 (53.33)	4 (13.33)	10 (33.33)	16 (53.33)	12 (40.00)	2 (6.67)
		Hired labour	--	--	0 (0.00)	4 (30.76)	9 (64.23)	4 (30.76)	5 (38.46)	4 (30.76)
8.	Machine	Tractor	0 (0.00)	5 (16.67)	0 (0.00)	4 (80.00)	1 (20.00)	0 (0.00)	3 (60.00)	2 (40.00)
		Power tiller	1 (3.33)	24 (80.00)	3 (12.00)	17 (68.00)	5 (20.00)	1 (4.00)	15 (60.00)	9 (36.00)
		Transplanter	0 (0.00)	2 (6.67)	2 (100.0)	0 (0.00)	0 (0.00)	1 (50.00)	1 (50.00)	0 (0.00)
		Drum seeder	1 (3.33)	2 (6.67)	2 (66.67)	1 (33.33)	0 (0.00)	1 (33.33)	2 (66.67)	0 (0.00)
		Cono weeder	5 (16.67)	2 (6.67)	7 (100.0)	0 (0.00)	0 (0.00)	7 (100.0)	0 (0.00)	0 (0.00)
		Finger weeder	1 (3.33)	4 (13.33)	4 (80.00)	1 (20.00)	0 (0.00)	5 (20.00)	0 (0.00)	0 (0.00)
		Thresher -cum-winnower	1 (3.33)	23 (76.67)	4 (16.67)	8 (33.33)	12 (50.00)	5 (20.83)	13 (54.16)	6 (25.00)

(Figures in the parentheses indicate percentages) (*Seeds & fertilizers required for 0.5 acre demonstration were provided by NRRI)
(**# Full access to inputs** : Women independently make their decisions on when, how and where to use the inputs;
Moderate access to inputs : Women, while making decisions, consult the family members and influenced by their advice and suggestions;
Little access to inputs : Women have almost no access to inputs and use inputs as per decision of others)

the farm inputs in rice farming, *viz.*, land, money, seeds, fertilizers, pesticides, water, labour and machines. Data on above aspects were collected and analyzed. As critical inputs, only 10 kg of paddy seeds and required quantity of chemical fertilizers for 0.5 acre demonstration were provided by NRRI.

A perusal of data in Table 5.4 shows that apart from half acre NRRI demonstration, seven farmwomen (23.33%) had cultivated upto one acre and five farmwomen cultivated in more than one acre land on their own during 2014-15. This expansion of area under the control of farmwomen signifies more trust and confidence on women farmers by their male counterparts and a positive impact of the project. Regarding, accessibility to 'land', it can be seen, full accessibility by 100.0% farmwomen over 0.5 acre demonstration land, 71.43% on 0.6-1 acre land and full accessibility by 60.0% farmwomen on more than one acre land (i.e., a deceasing trend of full accessibility with the increase in acreage). Similar trends were also observed in case of 'money' (45.45%, 45.45%, & 25.0%), 'seeds' (100.0% & 58.33%), and 'fertilizers' (100.0% & 58.33%), respectively.

Only four farmwomen had applied 'need-based pesticides', which were arranged mostly with the help of family members (75.0%) and had moderate (50.0%) to full accessibility (50.0%) by them. Only two farmwomen (6.67%) were having their own bore wells and also had full accessibility, while majority (43.33%) of women were having full access to canal water for irrigation purpose.

In case of labour, majority (53.33%) had full access to family labour, but had moderate access (38.46%) to hired labour. With regard to farm machineries, most of them were hiring their implements like, power tiller (80.0%), thresher-cum-winnower (76.67%) and tractor (16.67%), which were mostly arranged in consultation with or by family members. Majority were found having moderate accessiblity to tractor (60.0%), power tiller (60.0%), transplanter (50.0%), drum seeder (66.67%) and thresher-cum-winnower (54.16%), except cono winnower there 100.0% were found full accessible.

An analysis was done to assess the benefits in terms of returns over operational expenses in rice cultivation for each of the half acre demonstration plots with the women farmers. It was observed that average net returns during 2014-15 increased by about 26% over the first year of demonstration (2013-14). It was also reported by the respondents that they acquired knowledge, skill and demonstrated the technologies in other areas as well. Further, cultivation of vegetable and pulses boosted and other livelihood opportunities like animal husbandry activities have also been intensified which effected in increasing annual income of the households. A multiple regression analysis was carried out to identify the factors which influences the variation in net returns amongst the women farmers. The results indicated that education of the women farmers, number of workable persons in the family and level of their participation in different demonstration activities influenced significantly towards accrual of net returns from rice cultivation.

Crop cutting experiments being organized in the presence of participating farmwomen and their male counterparts

Table 5.5: Estimates of factors which influences net returns from rice cultivation (N=30)

Variables	*Coefficients*
Age	-0.016
Education	0.291*
Labour force	0.834*
Cultivated land	-0.055
Participation level	0.160**
Adjusted R Square	0.630

*Coefficient significant at 10% level;
** Coefficient significant at 1% level

Rice yield performance stability in demonstration plots of NRRI

Twelve rice varieties grown in five consecutive years from 2009-10 to 2013-14 in *kharif* season were used to identify the stable rice varieties. AMMI Stability Index (ASI) was used to identify the varieties. The result shows that Ajay was the most stable rice variety followed by Abhisek, Naveen, Hazaridhan, Ketekijoha, Satyakrishna, Rajalaxmi, Geetanjali, IR 64 *Sub1*, Kamesh, Lalat MAS and Chandan. Rajalaxmi was the highest grain yielding variety on an avarage but it ranked seventh in yield stability across the five years. Although, Hazaridhan was lowest in grain yield but ranked fourth in grain yield stability. At the other end, Chandan was very unstable in grain yield but ranks fourth in grain yield (Table 5.6). Further, each variety was grouped according to their duration and ranked which is evident from the table.5.6 & 5.7. In addition, the fig. 5.1 indicates that three varieties *viz*., Ajay, Naveen & Satyakrishna were found to be highly stable and with higher yield.

During *rabi* season eleven rice varieties grown in five consecutive years from 2009-10 to 2013-14. The result shows that Hazaridhan is the most stable rice variety followed by IR64 *Sub1*, Rajalaxmi, Ajay, Sadabahar, Chandan, Geetanjali, Satyakrishna, Kamesh Naveen, Hazaridhan and Lalat MAS. Ajay is the highest grain yielding variety but it ranks fourth in yield stability across the five years, whereas Sadabahar was lowest in grain yield but ranks fifth in grain yield stability. However, Lalat MAS was very unstable with rank eleven but ranks sixth in grain yield (Table 5.6 & 5.7).

Further, each variety was grouped according to their duration and ranked which is evident from the table 5.7. In addition, the fig. 5.2 indicates that four varieties *viz*., Hazaridhan, IR 64 *Sub1*, Rajalaxmi and Ajay were found to be highly stable and with higher yield. Therefore, it is concluded that only Ajay was found to be highly stable with higher yield in both the seasons.

Developing approaches for paddy seed self sufficiency among the farmers

The main objective of this project to develop the self sustaining seed system (4S) for the rice growers. Since last three years this Institute is taking steps to produce the paddy seeds by the farmers by utilizing their own resources and procuring breeder seeds from the NRRI. The villages in the Cuttack and Kendrapara district wherein the participatory 4S model was taken up by the Institute as well as by the BPD unit (Entrepreneurship development program) of the Institute were surveyed and the response of the seed growers were collected.

During the interview with the seed growers of Cuttack and Kendrapada, it was ascertained that 100 per cent of the seed growers were happy about the participatory self sustaining seed system taken up by the Institute. The seed growers could sell their seeds at expected price i.e., Rs. 20/- per Kg. In the first year total area was 30 acres (660 q) while the same increased to 50 acres (1100 q) and 100 acres (1680 q) during 2nd and 3rd year, respectively.

The strength of this program as expressed by the farmers were availability of breeder seeds from NRRI, proper seed treatment with bavistin, line transplanting by useing transplanter, timely taking up the plant protection measures to control pests and diseases, proper rouging, threshing separately by the thresher and proper drying up to 12% moisture level which helped them to sell at comparatively higher price. The threat of this program as expressed by them were timely water availability in the canal, availability of fertilizer at proper price and good seed availability in nearby locality.

It was further ascertained that the seed growers were ready to continue this program in an entrepreneurial mode by establishing seed processing unit if they get some financial assistance by the Government or any other financial agencies. The marketing aspect could be managed by some of the entrepreneurs who can

Table 5.6: Variety name along with its grain yield, ASI value and its rank (WS)

Name	Duration	AGY*	AGY ranking	ASI*	Overall ASI Rank	Group ASI Rank
Naveen	120	4.48	6	1.535	3	1
Hazaridhan	120	3.78	12	1.561	4	2
Kamesh	110	3.88	10	4.803	10	3
Abhisek	125	4.00	7	0.663	2	1
IR 64 Sub 1	125	3.94	9	4.260	9	2
Lalat MAS	130	4.52	5	4.986	11	3
Chandan	125	4.70	4	5.712	12	4
Ajay	135	6.72	2	0.105	1	1
Ketekijoha	145	4.00	8	1.751	5	2
Satyakrishna	135	5.72	3	2.789	6	3
Rajalaxmi	135	6.90	1	3.055	7	4
Geetanjali	135	3.80	11	3.720	8	5

*AGY= Average Grain Yield and ASI=AMMI Stability Index

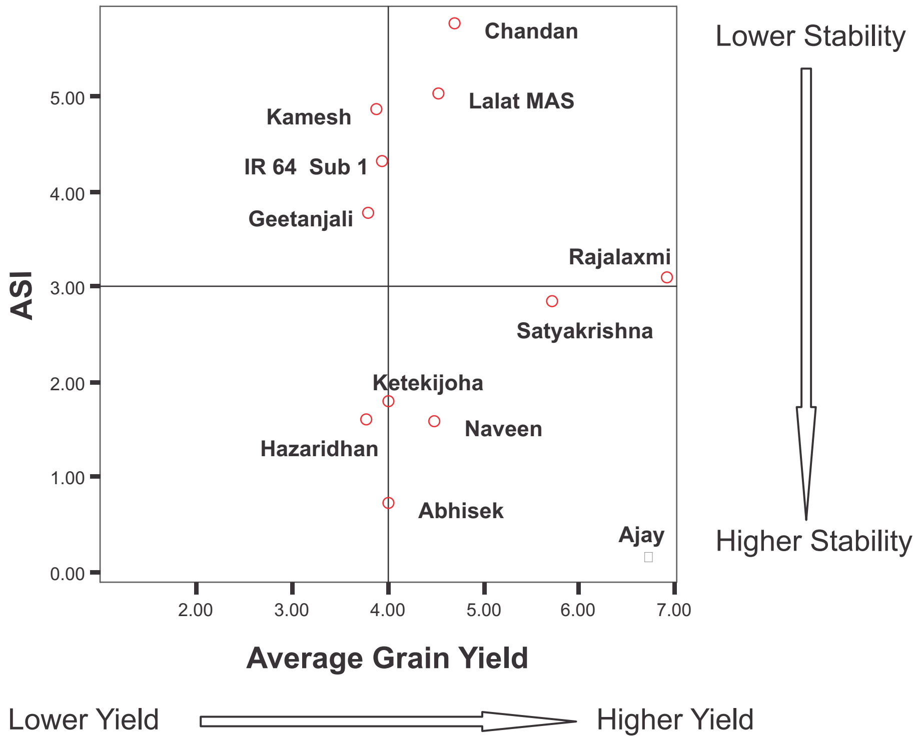


Fig. 5.1. Grain yield and ASI value of NRRI varieties in kharif

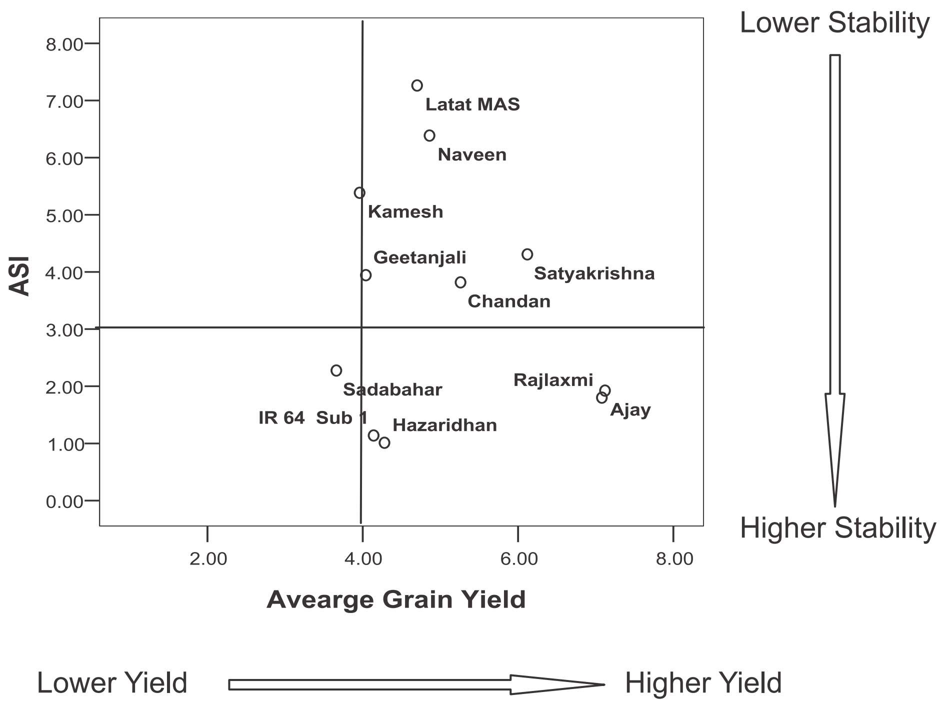


Fig. 5.2. Grain yield and ASI value of NRRI varieties in rabi

Table 5.7: Variety name along with its grain yield, ASI value and its rank (DS)

Variety	Duration	Mean grain yield	Yield rank	ASI	ASI rank	Group ASI Rank
Hazaridhan	120	4.28	7	1.011	1	1
Sadabahar	105	3.66	11	2.275	5	2
Kamesh	110	3.96	10	5.385	9	3
Naveen	120	4.86	5	6.385	10	4
IR 64 *Sub 1*	125	4.14	8	1.138	2	1
Chandan	125	5.26	4	3.818	6	2
Lalat MAS	130	4.7	6	7.262	11	3
Rajalaxmi	135	7.08	2	1.8	3	1
Ajay	135	7.12	1	1.923	4	2
Geetanjali	135	4.04	9	3.944	7	3
Satyakrishna	135	6.12	3	4.307	8	4

sell their seeds in the nearby locality depending upon the farmers demand. This model (4S) can be successfully taken up by the entrepreneurs if they can be trained and developed in seed production enterprise.

Standardize participatory training modules for the KVKs to disseminate rice technology

In order to assess the need of standardized participatory training modules for KVKs to disseminate rice technology, data was collected from 45 KVKs regarding various training programmes being conducted by them. It was found that on an average a KVK was organizing 67 training programmes on various topics out of which 15 (22 per cent) training programmes were on rice technology with maximum of 61.4 per cent to minimum of 3.85 per cent. The detail presentation of the percentage training being conducted by KVKs on rice technology is given below (Fig. 5.3).

Region wise, western Odisha KVKs conduct only 13.86 per cent training programme on rice while coastal Odisha KVKs recorded 24 per cent barring Puri District which recorded only 4.76 per cent training programme on rice. This shows that in order to popularize rice technologies of NRRI, a standard participatory training manual is required. Therefore, data was collected on need for training manual on rice production technologies and it was found that majority of the respondents (77.77%) agreed for its need, while only 4.4% respondents didn't need training manual by NRRI to impart training on rice production technologies. Remaining 17.77 per cent respondents were undecided.

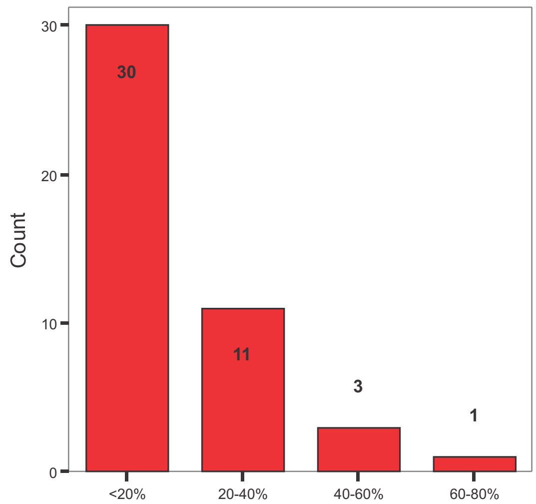


Fig. 5.3. Percentage of training programmes on rice conducted by KVKs

Feedback on rice production technologies (RPTS) as perceived by the different stakeholders

Feedback data on the performance of different rice production technologies and government sponsored programmes and schemes collected from 120 progressive rice farmers from 29 districts of Odisha through a structured interview schedule brought out the following findings.

Change in productivity due to BGREI activities: Analysis of data revealed that they were supplied with different varieties, *viz.*, Pooja, Pratiksya, MTU 1001, MTU 1010, Swarna *Sub1*, Ranidhan, Naveen, and Sahabhagidhan during 2013 and 2014 under BGREI demonstration programme. As per the yield data provided by the farmers, the average grain yield of BGREI demonstration plots was found to be 5.81 t/ha as against the average yield of non-BGREI plots of same or similar duration varieties at 4.51 t/ha, a significant jump of about 28.82% in average productivity.

Sale price of paddy by farmers: With regard to minimum support price (MSP) farmers reported that majority (49.17%) of them sold their surplus paddy at MSP of Rs. 1360/- per quintal at government Mandis/ LAMPS, followed by 41.67% at 'less than MSP' (Rs. 1000-1356/- per quintal) to middlemen/ traders or at Mandis, and 2.50% farmers did not sell their produce. More importantly, 6.67 % framers sold their paddy as seeds to Odisha State Seed Corporation (OSSC) at above MSP, ranging from Rs. 1400 - 1860/- per quintal.

Reasons for low adoption of rice transplanters/ drum seeders: Only 5% of the respondent farmers adopted machines for transplanting or sowing, which they opined very satisfactory. The major reasons cited by non-adopters in order of importance were, (i) unaware about the technology and skill to handle, (ii) high cost of equipments, (iii) unavailability of equipments, (iv) apprehension of failure due to unfavourable weather condition during sowing or transplanting operation, and (v) fear of unavailability of post-sale services and spare parts. Therefore, there is a need to popularize farm mechanization with a suitable awareness and extension strategy at the back ground of severe labour shortage in farming activities.

Responses received from farmers on suitable rice variety: Feedback responses of over two hundred

Table 5.8: Sale price of paddy by the respondent farmers (N=120)

Less than MSP (Rs./Qtl.)				MSP	More than MSP	Not Sold
Up to 1000	1001 - 1100	1100 - 1200	1201- 1359	1360	> 1360	
1 (0.008)	14 (11.67)	15 (12.50)	20 (16.67)	59 (49.17)	8 (6.67)	3 (2.50)
50 (41.67)				**59 (49.17)**	**8 (6.67)**	**3 (2.50)**

(Figures in the parentheses indicate percentages)

farmers across various states were collected through accidental sampling and personal interaction to know the type of rice varieties they grew and their future expectations during participation in various exhibitions and other agricultural events. Following generalized responses were recorded.

a) Farmers from states like Madhya Pradesh, Chhattisgarh, Maharashtra, Tamil Nadu, Gujarat, Bihar, Jharkhand and Punjab were more interested in fine quality rice hybrids with productivity of above 8.0 t/ha.

b) Farmers from states like Maharashtra, Madhya Pradesh, Bihar, Jharkhand and Chhattisgarh showed interest in short duration (80-120 days) and superfine HYV paddy varieties having high productivity of above 6.0 t/ha.

c) Farmers from northern states like Punjab, Haryana, Uttar Pradesh and Delhi were found more interested in aromatic rice having export quality to substitute Pusa Basmati-1121 and Pusa Basmati-1509, having potential of above 5-6 t/ha.

d) Most of the farmers from Vidarbha region of Maharashtra were growing three export quality rice varieties namely, HMT, Jay Sriram & Indrayani mainly because, (i) the average grain productivity was above 6-7 t/ha, (ii) superfine quality of rice that fetches good market price, i.e., paddy @ Rs. 2,500/Qtl & rice @ Rs.5,000/Qtl. and (iii) resistant to various pests and diseases. Such farmers were interested in still better productive and remunerative varieties.

e) Farmers from Konkon region of Maharashtra showed interest in NRRI machineries and in superfine and short duration (80-100 days) scented as well as non-scented paddy varieties having high production potential, better than the most widely grown popular variety Ratna.

Perceived problems and suggestions of rice farmers: The major problems as emerged from the discussion among one hundred fifty rice farmers from Odisha and suggestions provided by them for increasing rice production and productivity in the state are as follows.

a) **Production and supply of quality HYV seeds:** Non-availability of sufficient quantity of foundation and certified seeds to farmers was pointed out unanimously as the major reason for marginal growth in production and productivity of rice despite having enormous potential. It was emphatically suggested that, 'Participatory seed village programme for self-sufficiency at village level' needs to be encouraged by providing sufficient quantity of foundation seeds to farmers to produce certified seeds.

b) **Special effort for production and distribution of hybrid seeds:** At present about 95 per cent of hybrid seeds are produced by private sector and the cost of hybrid seed varies between Rs, 250-300 per kg which is too high for farmers to afford and also not easily available at village level. Therefore, efforts should be made to supply subsidized hybrid seeds to farmers at their door step. Capacity building and awareness programme on hybrid rice and seed production technology should be integral to the action plan of the state agriculture department.

c) **Procurement and payment of seed price:** Odisha State Seed Corporation (OSSC) should ensure procurement of certified seeds from farmers at prescribed price and must pay the seed price to farmers in time for continued interest of farmers in seed production. Also, the OSSC should install Seed Processing Plant at least at block level for quality seed production and local supply.

d) **Strengthening irrigation infrastructure and timely water supply:** About 50 per cent area of the state is irrigated as per record. However, due to defunct irrigation infrastructure in many districts, the percentage would be far below in reality. That is the reason why farmers are not getting irrigation water in time during June to mid July. Arrangement for irrigation facilities through the use of solar energy should be explored. In addition to increasing new irrigation infrastructure, the defunct ones should be repaired on priority.

e) **Mechanized farming and custom hiring:** Labourer shortage during peak season of farm operations was found as a major concern and the availability of subsidized rice at rupees one per kg was mainly blamed for the crisis. Therefore, it was suggested to popularize farm mechanization with development and supply of subsidized farm implements suitable for both small and large land holdings, and for both men and women farmers. Custom hiring of large implements through Farmers Interest Groups (FIGs) should be encouraged as part the agriculture policy at every Panchayat level.

f) **Improved *Mandi* and procurement cacility:** Poor marketing facilities, poor storage infrastructure, delayed opening of *Dhan Mandis* and limited procurement from farmers resulted in distress sale of paddy. Similarly, lack of storage go downs for quality seeds resulted high cost of seeds. Necessary corrective measures are essential.

g) **Demonstration of new generation technologies:** Strategy required for demonstration and polarization of agro-technologies of direct seeded rice (DSR) by using machines (seed drill/ drum seeder), rice transplanter machine even in lowland situation with tall seedlings, combine harvester and crop diversification.

h) **Subsidized power in agriculture:** Cost of electricity for irrigation is high. There should be provision for free or subsidized electric supply for irrigation purpose.

I) **Mainstreaming rural youths and encouraging agri-preneurship:** Special attention is required for development of entrepreneurship in rice farming to attract educated youth through lucrative enterprises like production and marketing of value added products; seed production and marketing, value-chain establishment and custom hiring by proving easy credit facility and capacity training.

j) **Capacity building:** Competencies of extension functionaries and capacity building of farmers and farmwomen on various aspects of latest production technologies including organic farming and market information need to be improved through training and exposure.

k) **Single-window grievance redressal system:** The system is required to facilitate inputs, electricity, water and cooperative credit to farmers to save time and cost. It was also suggested to simplify the loan and subsidy procedure. It is to be ensured that inputs like seeds, fertilizers, and pesticides etc. should made available at proper time.

l) **Inter-departmental coordination:** Emphasis on proper coordination among different government line departments such as Agriculture, Horticulture, Animal Husbandry and Fisheries, Soil Conservation, Water Resources, Irrigation and Power etc. to adequately address the concerns of the farmers by removing bottlenecks.

Dissemination of rice production technology through KVKs

KVK, Cuttack

OFTs (On-farm trials)

On-farm trials were conducted on 'assessment of recently released rice var. CR Dhan 303 and CR Dhan 304 in transplanted condition' in Mangarajpur (Badamba), Guali (Salipur) and Sankilo (Nischintakoili) villages involving five farmers from each village for each variety. The varieties were found performing well from vegetative stage to maturity at all three locations even though there was Hoodhud (storm) on 12 October 2014 during last *kharif*. On an average variety CR Dhan 303 yielded 6.3 t/ha which was 31.25% more than local variety Laxmisagar (4.8 t/ha) of similar duration (130-135 days) while the variety CR Dhan 304 yielded 6.5 t/ha which was 34.38 per cent higher than similar local variety. On-farm trial on 'paddy straw of NRRI released rice varieties as substrate for mushroom cultivation' was conducted in village Uchhapada of Tangi-Choudwar block involving 13 farmers and farmwomen. It was found that mushroom yield was highest (1.12 kg/bed) from the paddy straw of Sarala, followed by 0.92 kg/bed from paddy straw of Pooja and lowest of 0.80 kg/bed from paddy straw of Varshadhan. Another OFT on

'Assessment of IPM module against leaf folder in rice' was conducted in Sankilo (Nischintakoili) village involving 15 farmers during *kharif* 2014. The IPM techniques which were applied in farmers field were seed treatment, application of Cartap 4G in rice nursery at 5-7 days before uprooting seedlings, surveillance of leaf folder, crop canopy management by need based application of insecticide. Lower infestation (0.5 leaf/hill) of leaf folder was observed in experimental plots in comparison to check (3.2 leaf/hill). On an average the yield in treated plots was 4.53 t/ha which was 7.34 per cent higher than check (4.22 t/ha)

FLDs (Front line demonstrations)

Front line demonstrations on high yielding rice varieties Sahabhagidhan in two ha, Varshadhan in one ha, Swarna *Sub 1* in one ha and Poornabhog in one ha was conducted involving all total 25 farmers and farmwomen. The variety Sahabhagidhan yielded 4.2 t/ha which was 60.2% higher than the farmer variety Khandagiri (2.6 t/ha). These varieties have faced partial water stress during their vegetative growth stage in *kharif* 2014. The variety Varshadhan yielded 4.8 t/ha which was 24.9% higher than local variety Budha thengua (3.8 t/ha). The variety Swarna *Sub1* yielded 5.3 t/ha which was 10.8% higher than local check Swarna (4.8 t/ha). During the growth period there was no occurrence of flood but infestation of sheath blight was found in Swarna variety. Poornabhog was demonstrated at village Brahmansila (Kantapada) which yielded 3.2 t/ha which was 40.4% higher than Haldigundi (2.3 t/ha), a local short grain variety with good aroma.

Trainings

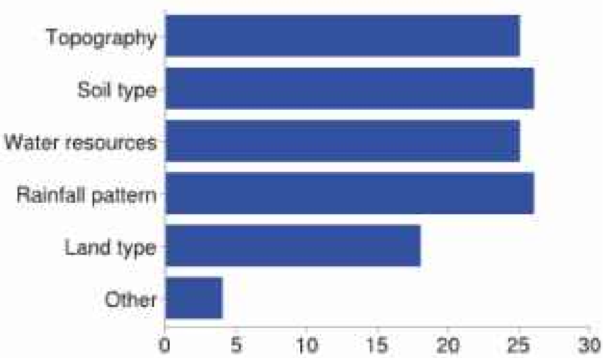
A total of 17 off-campus training programmes were conducted related to rice covering the topics 'Scientific nursery raising for healthy seedlings', 'Integrated nutrient management', 'Integrated weed management', 'Integrated pest management' and 'Integrated pest management in rice nursery' involving 425 farmers / farmwomen and rural youths of different villages of Cuttack.

Characterization of resources and innovations to aid rice research and develop extension models

Based on the recommendations of IRC, a thorough review of literature was done regarding mapping of resources. At first, delphi method was used to determine the various resource factors which would be considered for mapping. An online digital questionnaire was prepared and circulated among rice scientists of NRRI, IIRR and AICRIP centres for data collection. A total of 44 responses were received and analyzed, which are presented below.

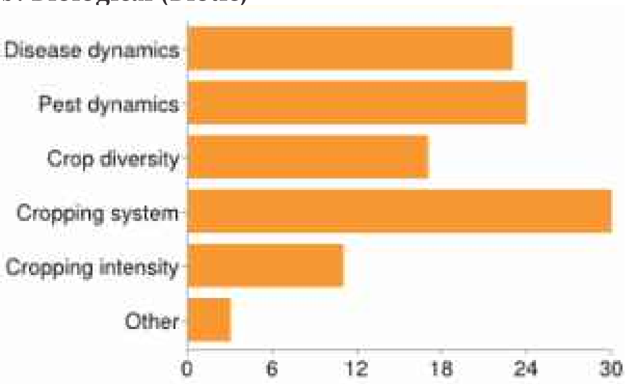
As per the results, majority of the experts advocated for mapping topography, soil type, water resources & rainfall pattern among physical/abiotic factors; disease dynamics, pest dynamics & cropping system among biological/biotic factors; labour availability among socio-personal factors; land holding and income pattern among economic factors and market linkage and technology support agencies among infrastructural factors. The other factors suggested by respondents are physical/abiotic factors: temperature both low and high, agro-ecology, weather variables

a. Physical (Abiotic)



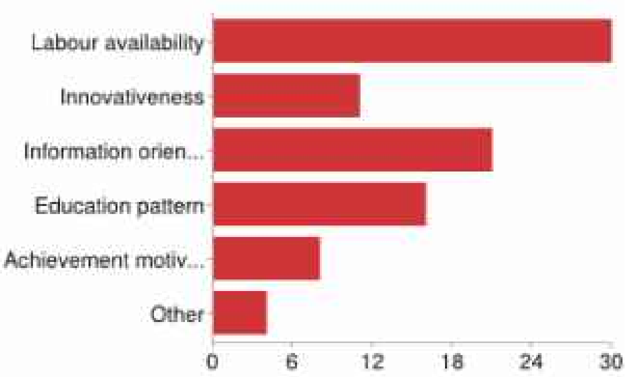
Factor	Number	Percentage
Topography	25	(56.8%)
Soil type	26	(59.1%)
Water resources	25	(56.8%)
Rainfall pattern	26	(59.1%)
Land type	18	(40.9%)
Other	4	(9.1%)

b. Biological (Biotic)



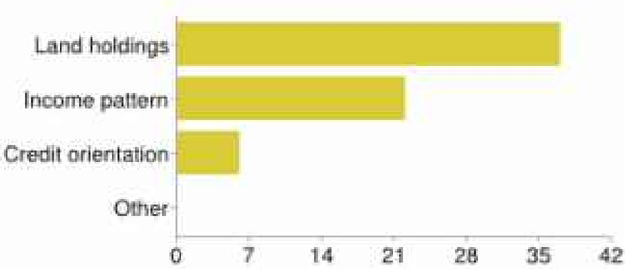
Factor	Number	Percentage
Disease dynamics	23	52.3%
Pest dynamics	24	54.5%
Crop diversity	17	38.6%
Cropping system	30	68.2%
Cropping intensity	11	25%
Other	3	6.8%

c. Socio-personal



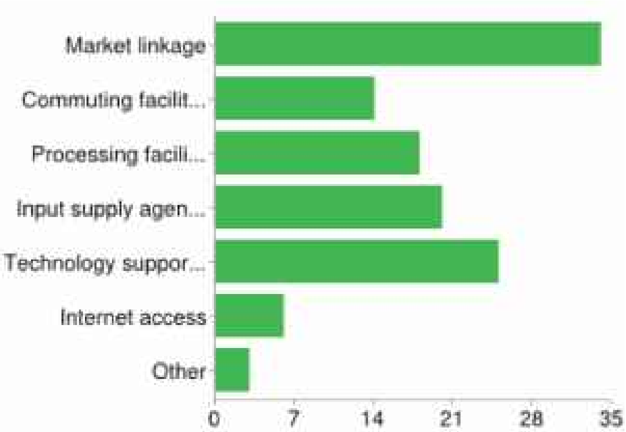
Factor	Number	Percentage
Labour availability	30	68.2%
Innovativeness	11	25%
Information orientation	21	47.7%
Education pattern	16	36.4%
Achievement motivation	8	18.2%
Other	4	9.1%

d. Economic



Factor	Number	Percentage
Land holdings	37	84.1%
Income pattern	22	50%
Credit orientation	6	13.6%
Other	0	0%

e. Infrastructure



Factor	Number	Percentage
Market linkage	34	77.3%
Commuting facilities and accessibility	14	31.8%
Processing facilities	18	40.9%
Input supply agencies	20	45.5%
Technology support agencies	25	56.8%
Internet access	6	13.6%
Other	3	6.8%

Fig. 5.4-5.8. Distribution of responses towards different factors under physical, biological, socio-personal, economic and infrastructure categories

and cropping system; biological/ biotic factors: biotic community; socio-personal factors: gender orientation; economic factors: labour engagement pattern and migration; infrastructural factors: storage facility; and other factors: duration of water availability, varietal preferences and specific characters of rice (Fig. 5.4-5.8).

Accordingly, resource characterization will be done through well established planning and spatial decision process which includes concepts related to spatial decision making process, phases and steps in a structured or semi-structured spatial decision process, typical workflows in spatial decision process. The sub-categories of planning and spatial decision process are i) participation/collaboration specific activities during a spatial decision process ii) planning and spatial decision process workflows and iii) spatial decision process phases and steps.

Impact analysis and database updation in relation to policy and programmes on rice

Estimation of area under NRRI varieties in different states

The HYV area and variety wise seed distribution information are used to estimate the area under different high yielding rice varieties in three states *viz.*, Uttar Pradesh, Bihar and Gujarat.

Data analysis revealed that the mega varieties (with area coverage more than one lakh ha) in the state of Uttar Pradesh are NDR 359, Sarjoo 52, BPT 5204, MTU 7029, PR 113, PR 114, Pant 10, Pant 12, PR 115, Swarna *Sub 1* and Pusa Sugandh 2. The hybrid rice area covered about 328,400 hectare and accounted for 5.9% of the total HYV rice area in Uttar Pradesh. The NRRI variety Sahabhagidhan was found to be grown in an area of 41, 950 hectare in the state.

The mega varieties of Bihar state are MTU 7029, Rajendra Mahsuri, Swarna *Sub 1*, Sarjoo 52, BPT 5204 and Arize 6444. The hybrid varieties were grown to the extent of 507, 418 ha (16.2% of HYV area) in the state. The single largest variety of the state was MTU 7029, which covered 38.6% of the total HYV area under rice. Two NRRI inbred varieties *viz.*, Abhishek and Sahabhagidhan was found to be grown to the extent of 9542 ha and 7580 ha, respectively. NRRI hybrids Ajay, Rajalaxmi and CR Dhan 701 were found to be grown to the extent of 2513 ha, 3063 ha and 5506 ha, respectively in the state.

The varieties with larger area coverage in the state of Gujarat were Gurjari, Jaya, GR 11, GAR 13 and Mahsuri. The variety Gurjari was extensively grown in the state and covered 51.9% of the total HYV rice area. Hybrid rice was grown to the extent of 9% of the total HYV rice area.

Rise in wages is the main factor behind increasing cost of cultivation and eroding profit

Detailed cost of cultivation data of rice for 18 states of India for two years (2010-11 and 2011-12) was digitalized and analysis of data was carried out taking last 32 years data (1980-81 to 2011-12) to find out the main factor behind increasing cost of cultivation and decreasing profit. Price indices were used for converting all the cost and return figures at constant 2011-12 prices for comparison over years. Analysis of data revealed that cost of cultivation per ha has increased over years and profit margin has not increased commensurately (Table 5.9). The average C_2 cost of cultivation per ha at all India level has increased from Rs. 24573 to Rs. 39985 per ha between early 1980s (1980-84) and the five year average ending 2011-12. Though the C_2 cost of cultivation has increased by 63% (Rs. 15412 per ha), the profit has increased only by 35% (Rs. 1452 per ha) during the above period. However, the average profit over operational cost of cultivation has increased from Rs. 13098 to Rs. 19474

Table 5.9: Average cost of cultivation and profitability of rice in India **Figures in Rs./ha**

Particulars	Period						
	1980-84	1985-89	1990-94	1995-99	2000-04	2005-09	2007-11
Cost of cultivation(C_2)	24573	27513	30729	32820	37909	38656	39985
Operational cost of cultivation	15573	17597	19278	21006	25255	24924	26061
Profit over C_2 cost	4098	5117	5589	4395	822	5454	5550
Profit over operational cost	13098	15033	17040	16209	13475	19186	19474

per ha i. e. an increase of 49% in the same period. Human labor accounts for 35.8% of the total cost of cultivation and 53.1% of the operational cost of cultivation and thus, is the single largest item in the total cost structure (Fig. 5.9 and 5.10). The other important cost items are land rent (27.0%), machine labour (7.9%), fertilizer (5.9%) and animal labour (5.4%) in the total cost of cultivation of rice.

The increase in nominal and real wage growth rate per year was 10.49% and 3.24%, respectively between 1980-81 and 2011-12 and therefore, contributed significantly to rise in cost of cultivation. It was observed that there were sharp rise in wages in the recent period in the comparison to the previous periods (Fig. 5.11). Disaggregated data analysis revealed that the nominal growth rate in wage was 10.60%, 12.79%, 8.09%, and 18.50% during 1980s, 1990s, 2000s and the recent period (2006-11), respectively. However, when the real growth rate was computed at constant price the growth rates were different. The real wage rate increase was 7.22% per year in the recent period (Fig. 5.12) in comparison to the increase of 3.61% during 1980s, 3.85% during 1990s and 1.72% during 2000s.

State wise analysis of growth rate in real wages for the recent period (2006-07 to 2011-12) revealed that more than 5% growth was observed in 13 out of 18 states and they were Karnataka, Punjab, Uttarakhand, Andhra Pradesh, Gujarat, Odisha, Bihar, Tamil Nadu, Chhattisgarh, Uttar Pradesh, Madhya Pradesh, West Bengal and Kerala (Fig. 5.13). Least growth rate in real wage was observed in Haryana state. This increase in wage rates coupled with higher cost of animal labor (Fig. 5.14) has induced increase in machine use in various operations of rice cultivation in different states. Due to increase in animal labour cost, its use had reduced to even one to two hours in the states of Kerala, Haryana and Punjab. The machine labor use was observed to be more in states like Tamil Nadu, Kerala, Andhra Pradesh, Karnataka, Punjab, Haryana, Maharashtra and Gujarat (Fig. 5.15) and helped in overall cost reduction.

Creation of database on area, production, yield of rice and forecasting rice area and production

A database of state-wise area, production and yield of rice in India has been constructed (Fig. 5.16). The data used in the database has been collected from the website of 'Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India' during different time period in the last five years. In database, the area and production has been given in thousand hectares and yield has been given in kg/ha. User can retrieve state-wise-data on area, production and yield of rice from 1961 to 2012. An example is given below to search the data of West Bengal from 2005-2012.

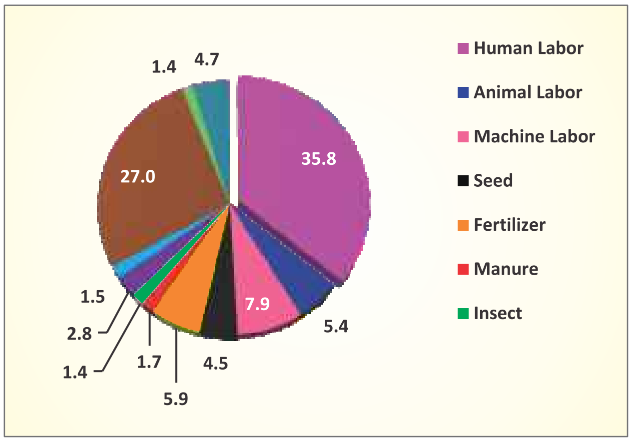


Fig. 5.9. Share of different components in total cost of cultivation of rice in India

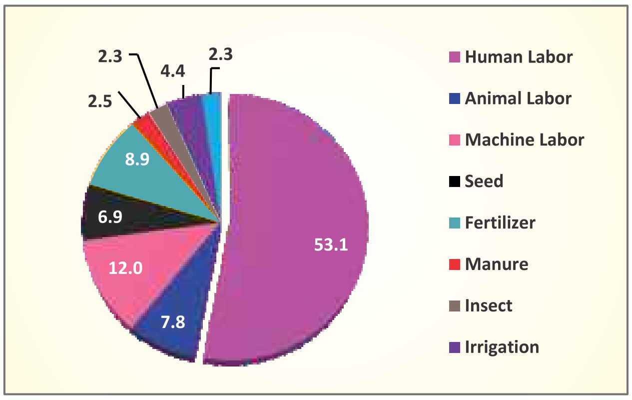


Fig. 5.10. Share of different components in operational cost of cultivation of rice in India

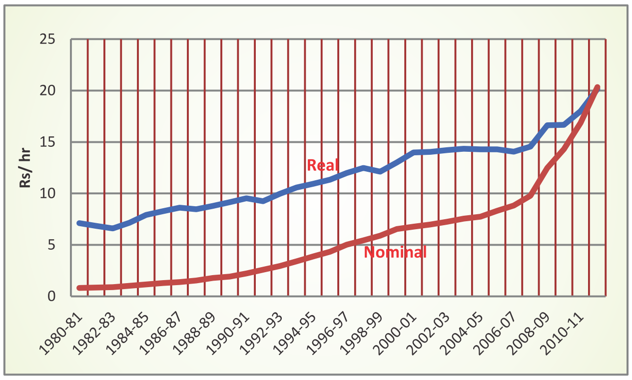


Fig. 5.11. Trends in rice wage rates (1980-2011) of India

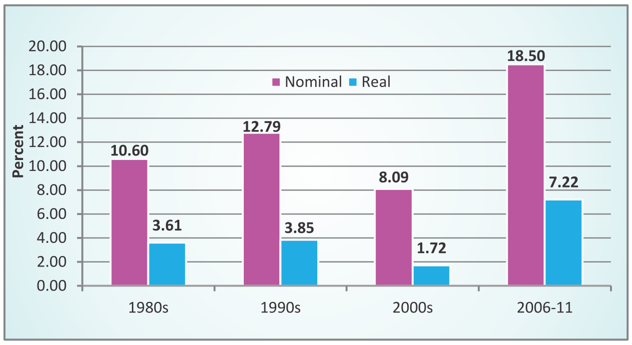


Fig. 5.12. Growth rate of rice wages in India during different periods

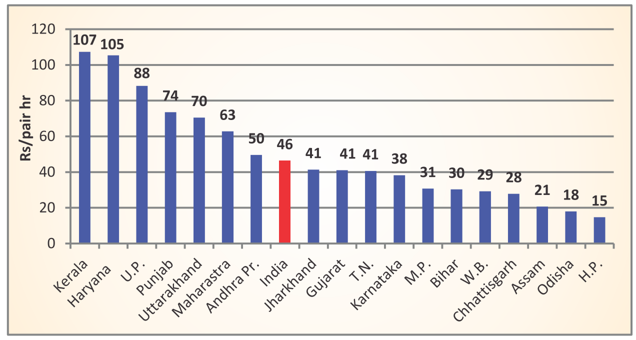


Fig. 5.14. Animal labor cost at constant price in different states of India (2007-11)

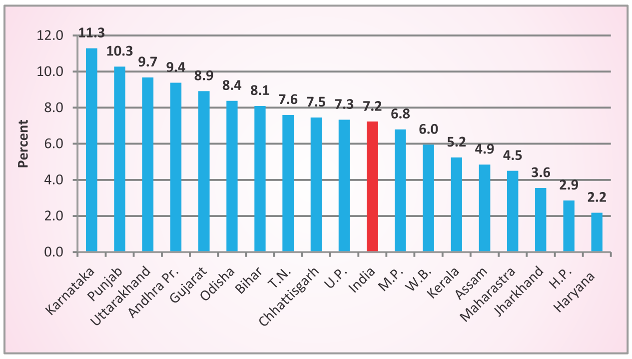


Fig. 5.13. Growth rates in real rice wages in different states of India (2006-11)

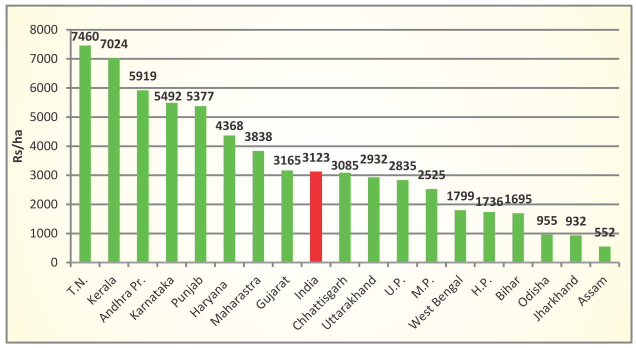


Fig. 5.15. Average machine use at constant prices in different states of India (2007-11)

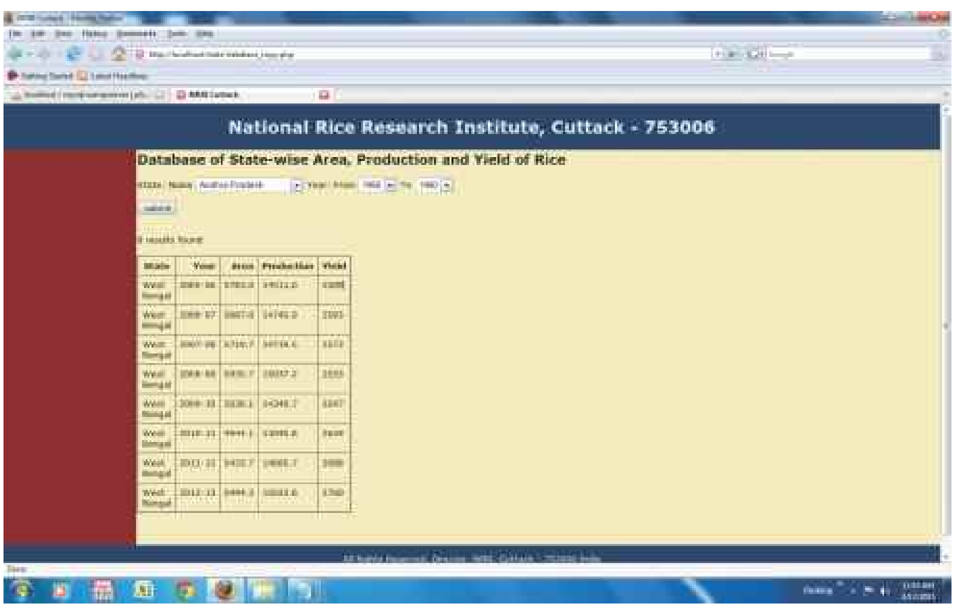


Fig. 5.16. Database of state-wise area, production and yield of rice in India

The Odisha data of area under rice and production of rice was analyzed for long term analysis. It was found that AR (1)-ARCH (3) provides the better fit. The area and production has been forecasted for 2020. The forecasted value for area is 4587 thousand hectares with a standard error of 458 thousand hectares and the forecasted value for production is 7653 thousand tonnes with a standard error of 765 thousand tonnes.

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Singh CV, Maiti D, Mandal NP, Kumar Y, Anantha MS, Variar M and Singh VK. 2014. Crop diversification in upland rice areas. CRURRS Technical Bulletin Series No. 1, Hazaribag, Jharkhand, India. p. 28.

Singh CV, Maiti D, Mandal NP, Kumar Y, Anantha MS and Variar M. 2014. वर्षाश्रित क्षेत्रों सीधी बोवाई (डी एस आर) विधि से धान उत्पादन. CRURRS Technical Bulletin Series No. 2, Hazaribag, Jharkhand, India.

Kumar Y, Singh CV, Anantha MS, Mandal NP, Maiti D and Variar M. 2014. वर्षाश्रित उपराऊँ एरां मध्यम भूमि के लिए धान की प्रमुख किस्में तथा उत्पादन तकनीक. CRURRS Technical Bulletin Series No. 3, Hazaribag, Jharkhand, India.

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Policy Paper

M Din, Mehta CR, Annamalai SJK, Singh M, Behera D and Paikray PK. 2014. Road map for mechanization of rice cultivation. CRRI Policy paper No. 2, Cuttack, India p.52.

Extension Bulletins

Chourasia M, Behera KS, Das KM, Prasad SM, Sahoo TR, Sarangi DR and Sethy S. 2015. "धान में कीट एवं रोग नियन्त्रण"(Management of rice pests and diseases). CRRI Extension Bulletin No. 3, Cuttack, India, p. 76.

Chourasia M, Behera KS, Das KM, Prasad SM, Sahoo TR, Sarangi DR and Sethy S. 2015. Management of rice pests and diseases. CRRI Extension Bulletin No. 4, Cuttack, India, p. 76.

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Berliner J, Pokhare SS, Mishra CD, Sahu SC and Prakash A. 2015. *Rice nematodes and their management*. CRRI Technology Bulletin No. 104, Cuttack, India.

Dash SK, Pradhan SK, Kar MK, Patnaik SSC, Behera L, Meher J, Anandan A, Marndi BC, Lenka S, Chottopadhyay K, Singh ON and Mohapatra T.2015. *CRRI rice varieties for diverse ecologies*, CRRI Technology Bulletin No.106, Cuttack, India.

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Marndi BC, Chattopadhyay K, Singh DP, Saha S, Sen P, Mahato KR, Sasmal S and Singh ON. 2015. *High yielding rice varieties of CRRI for coastal saline areas*. CRRI Technology Bulletin No. 105, Cuttack, India.

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Technology Bulletin No. 102, Cuttack, India.

Rao RN, Ratho SN, Panda D, Rao KS, Sarkunan V, Behera KS, Patnaik SSC, Mohanty SK, Das S, Swain P and Das KM. 2015. *Production technology for hybrid rice- Rajalaxmi* (Hindi). CRRI Technology Bulletin No. 103, Cuttack, India

Sharma SG and Mishra P. 2015. *A farmers' guide to proper storage and improving out turn ratio (OTR) of paddy rice* (Hindi). CRRI Technology Bulletin No. 100, Cuttack, India.

Swain P, Mohanty S, Bhattacharyya P, Baig MJ, Chattopadhyay K, Singh ON and Sarkar RK. 2014. *Rice cultivation in rainfed upland and drought prone areas under changed climate*, CRRI Technology Bulletin No. 101, Cuttack, India.

Book

Other Publications

Anonymous. 2014. CRRI Annual Report 2013-14. Central Rice Research Institute, Cuttack, India.

Anonymous. 2014-15. CRRI Newsletters *viz.*, April-June 14: 35(2), July-September 14: 35(3), October-December 14: 35(4), January-March 15: 36(1). Central Rice Research Institute, Cuttack, India.

Television and Radio Talks

- ❖ TR Sahoo delivered a radio talk on "ଅଦିନିଆ ପନିପରିବା ଚଷ"*(Off season vegetable cultivation)*" on 9 July 2014 at AIR, Cuttack.
- ❖ RK Mohanta delivered a talk in a special Q/A programme on "ବର୍ଷାଦିନେ ଗାଈ ଗୋରୁଙ୍କ ଯତ୍ନ"*(Care and management of livestock in rainy season)*" in "*Pallimancha*" broadcasted by Prasar Bharati on 25 July 2014.
- ❖ RK Mohanta delivered a radio talk on "ବନ୍ୟା ସମୟରେ ଗାଈ ଗୋରୁଙ୍କ ଯତ୍ନ" *(Care and management of livestock during flood)*" recorded Prasar Bharati, Cuttack on 25 July 2014.
- ❖ S Sethy delivered a radio talk on "କୃଷି କାର୍ଯ୍ୟରେ ମହିଳା ମାନଙ୍କର ଶ୍ରମ ଲାଘବ ପାଇଁ କୃଷି ଯନ୍ତ୍ରପାତିର ବ୍ୟବହାର"*(Use of agricultural machinery for drudgery reduction in farm women)*" broadcasted by Prasar Bharati, Cuttack 8 September 2014.
- ❖ DR Sarangi delivered a radio talk on "ପନିପରିବା ଚଷରେ ଅଣୁସାରର ବ୍ୟବହାର"*(Use of micro-nutrients in vegetable crops)*" recorded and broadcasted by AIR, Cuttack on 24 November 2014.
- ❖ RK Mohanta delivered a talk on "ଅଧିକ କ୍ଷୀର ଉତ୍ପାଦନ ପାଇଁ ଦୁଧିଆଳୀ ଗାଈକୁ ସନ୍ତୁଳିତ ଗୋଖାଦ୍ୟ" *(Balanced feeding for getting more milk from cows)*" which was broadcasted by AIR, Cuttack on 09 February 2015.
- ❖ S Sethy delivered a talk on "ଫଳ ଓ ପନିପରିବାର ମୂଲ୍ୟଯୁକ୍ତ ଦ୍ରବ୍ୟ ପ୍ରସ୍ତୁତି"*(Value added products from fruits and vegetables)*" which was broadcasted by AIR, Cuttack on 11 February 2015.

Events and Activities

IMC, RAC, IRC, IJSC and SAC Meetings

Institute Management Committee

The XXVIth and XXVIIth Institute Management Committee (IMC) meetings of the NRRI were held on 4 September 2014 and 31 January 2015, respectively at Cuttack under the chairmanship of Dr. T Mohapatra, Director, NRRI. Matters related to infrastructure development, budgetary provisions, construction works and production of NRRI seed varieties in farmers' field were discussed.


Chairman & members IMC discussing issues

Research Advisory Committee

The XXth meeting of the Research Advisory Committee (RAC) of NRRI was held at its campus from 10 to 11 November 2014 under the chairmanship of Dr. VL Chopra, Chairman, RAC. Dr. AK Singh, Dr. VK Dadhwal, Dr. (Mrs.) Krishna Srinath, Dr. BV David, Shri Kulamani Rout and Shri Utkal Keshari Parida were present during the meeting. The Chairman along with the members conducted a pre-meeting briefing with the Director followed by an open session. Dr. T Mohapatra, Director, NRRI presented the highlights of the research achievements and infrastructural developments since the last RAC meeting followed by presentations of the Programme Leaders/Co-Leaders, Dr. (Mrs.) Mayabini Jena, Dr. BN Sadangi, Dr. ON Singh, Dr. AK Nayak and Dr. SG Sharma. During the meeting, one technology bulletin was released by the Chairman and members of the RAC. The RAC members also visited different Divisions and had discussions with the scientists of concerned disciplines. The Chairman and members of the new RAC appreciated the contribution made by the last Research Advisory Committee headed by Prof. RB Singh, Ex. President NAAS and Former Member, National Commission for Farmers. Through the guidance of the previous RAC, the institute made significant progress. Last year eight new varieties were released by CVRC. Besides, three more varieties were also identified by VIC for release.


Chairman, RAC releasing NRRI Publication

Institute Research Council

The XXXIIIrd meeting of the Institute Research Council (IRC) was held from 14 to 19 July 2014 for presentation of results of 2013 and work plan for 2014-15 under the chairmanship of Dr. T Mohapatra, Director, NRRI. Project wise presentation of results of all projects for the year 2013 were made by all PIs. The following external members of IRC attended the meeting and evaluated the results (RPP II) of each project discipline-wise:

Programme 1 (Crop Improvement) : Dr. JK Roy and Dr. SR Das

Programme 2 (Crop Production) : Dr. PK Mohapatra and Dr. D Panda

Programme 3 (Crop Protection) : Dr. SK Panda and Dr. SK Mohanty

Programme 4 (Crop Physiology and Biochemistry) : Dr. PK Mohapatra (Sambalpur University)

Programme 5 (Social Science) : Dr. C Satapathy and Dr. Dibakar Naik

Institute Joint Staff Council

The IV[th] IJSC meeting was held on 21 March 2015 at NRRI, Cuttack under the chairmanship of Dr. T Mohapatra, Director, NRRI. Various administrative and financial matters were discussed and finalized.

SAC meeting of Krishi Vigyan Kendra

KVK, Santhapur

The XVI[th] Scientific Advisory Committee meeting of Krishi Vigyan Kendra was held on 15 November 2014 at its Santhapur campus under the chairmanship of Dr. T Mohapatra, Director, NRRI, Cuttack. Dr. SM Prasad, programme coordinator welcomed the chairman and the members and presented the Action Taken Report of last SAC meeting along with the brief presentation of report on achievements of KVK, Cuttack. The activities namely, trainings, OFTs, FLDs etc. taken up during kharif, 2014 and proposed activities for rabi 2014-15 in the area of Agronomy, Home Science, Soil Science, Plant Protection and Animal Science were presented by the concerned SMSs of the KVK. After each presentation, discussion was held on different aspects and suggestions for improvement were sought. Members from ICAR Institutes, State Departments i.e. Agriculture, Horticulture, Forestry, Fishery, Soil Conservation and Veterinary, AIR, Cuttack, farmers and farmwomen, Head of the Divisions of NRRI provided their valuable suggestions.

Director, NRRI discussing during the SAC Meeting of KVK, Santhapur

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

Attended the 49th Annual Rice Group Meeting at IIRR, Hyderabad from 4 to 8 April 2014	Drs. T Mohapatra, KB Pun, M Variar, NP Mandal, CV Singh, Yogesh Kumar, S Lenka, T Singh, K Pande, JN Reddy, SK Pradhan, P Swain, MK Kar, SSC Patnaik, SK Dash, K Chhatopadhya, J Meher and RK Sahu
Attended the third review meeting of DBT India-IRRI Network Project "From QTL to variety: marker assisted breeding of abiotic stress tolerant rice varieties with major QTLs for drought, submergence and salt tolerance" at New Delhi on 22April 2014	Dr. SK Pradhan
Attended the 24th Annual Group Meeting of AICRP-NSP (Crops) at S.K. University of Agriculture & Technology, Srinagar (J & K) from 24 to 26 April 2014	Mr. RK Sahu
Attended the meeting on "Interactive Conference of the Vice Chancellors and Directors" at New Delhi on 28 April 2014	Dr. T Mohapatra
Attended the "XII Plan EFC Memo of Main Scheme, NRRI (NRRI, DRR, AICRP-rice and CRP Biofortification) – PAMD appraisal note" at New Delhi from 30 April to 1 May 2014	Dr. T Mohapatra

Attended the Research Advisory Committee (RAC) meeting at DRR, Hyderabad on 2 May2014	Dr. T Mohapatra
Visited different blocks of Darjeeling, Cooch Behar and Uttar Dinajpur districts of West Bengal for monitoring BGREI program from 6 to 9 May 2014	Dr. S Saha
Attended the Workshop of "STRASA phase II and launching of STRASA Phase III at NASC Complex, New Delhi from 20 to 23 May 2014	Drs. JN Reddy, KB Pun, M Variar, NP Mandal, Anantha MS and Yogesh Kumar, SSC Patnaik and RK Sahu
Delivered a lecture on "Genetic diversity in cultivated/wild/weedy rice of Odisha" on the occasion of Celebration of International Day for biological diversity at Hotel New Marrion, Bhubaneswar on 22 May 2014	Dr. BC Patra
Attended IFPRI-NAIP workshop on "Priority Setting, Monitoring and Evaluation in National Agricultural Research System: Status, Experiences and Way forward" at NASC Complex, Pusa, New Delhi on 27 May 2014	Dr. T Mohapatra
Attended the National Symposium on "Plant Pathology in Genomic Era" held at IGKV, Raipur during 26-28 May 2014 and delivered an oral presentation on Arbuscular Mycorrhiza and chaired the combined technical session: (V) Advances in understanding the biology of plant viruses and (VI) Climate change and emerging plant diseases on 27 May 2014	Dr. D Maiti
Attended the Review Meeting on Finalization of Agro climate wise common Action Plan (OFTs) of Odisha jointly organized by Zonal Project Directorate, Zone-VII, Jabalpur and Directorate of Extension Education, OUAT from 27 to 28 May 2014	Dr. SM Prasad
Attended the meeting on "Sharing of data of studies concerning arsenic contamination in rice & to initiate systematic scientific study" at Nabanna, 325 Sarat Chatterjee Road, P.S. Shibpur, Howrah, Kolkata on 30 May 2014	Dr. T Mohapatra
Attended the Zonal Workshop of Zone II, held at NIRJAFT, Kolakata from 2 to 3 June 2014	Dr. VK Singh
Attended the Foundation Day programme of the National Academy of Agricultural Sciences at New Delhi on 5 June 2014	Dr. T Mohapatra
Attended a Seminar jointly organized by Orissa Environmental Society (OES) and Indian Science Congress Association (ISCA) at Bhubaneswar on the occasion of World Environment Day on 5 June 2014	Dr. BC Patra
Attended NAIP-IFPRI workshop on "Impact of capacity building programmes under NAIP" at NASC Complex, New Delhi on 7 June 2014	Dr. T Mohapatra
Attended the '*Review meeting*' at Directorate of Agriculture, Kolkata with State Agriculture Department, Government of West Bengal on different issues related to BGREI Program on 10 June 2014	Dr. S Saha
Attended *kharif* workshop organized by ATMA, Koderma held on 10 June 2014	Dr. VK Singh
Attended Regional Workshop on 'Integrated Farming System' organized by PDFSR, Modipuram at ICAR-RCER, Patna on 11 June 2014	Dr. VK Singh
Attended 7th PAC meeting at INSA, New Delhi on 12 June 2014	Dr. T Mohapatra

Attended Technical Committee Meeting held under NFSM program organized by SAMITI, Department of Agriculture, Government of Jharkhand on 14 June 2014	Dr. Yogesh Kumar
Attended Annual Group Meet on Soybean held at Birsa Agricultural University, Ranchi on 15 June 2014	Dr. Yogesh Kumar
Participated in the Brain Storming session on "Take it to Farmers -the Farmers' Rights through Awareness" organized by PPV&FRA at NASC Complex, New Delhi on 24 June 2014	Dr. BC Patra
Attended 10th Meeting of General Council (GC) of National Food Security Mission (NFSM) at Krishi Bhawan, New Delhi on 25 June 2014	Dr. T Mohapatra
Attended 'XXVII Extension Education Council Meeting of Birsa Agricultural University, Ranchi held at Krishak Bhawan of the University on 25 June 2014	Mr. Bhoopendra Singh
Attended ICAR Regional Committee Meeting-II at CIFRI, Barrackpore, Kolkata from 27 to 28 June 2014	Dr. T Mohapatra
Attended 3rd Annual Review and Planning Workshop of NICRA Project at NAAS Complex, New Delhi from 3 to 5 July 2014	Dr. P Swain
Attended the Scientific Advisory Committee meeting held at KVK, Ram Krishna Mission, Jharkhand on 10 July 2014	Dr. Yogesh Kumar
Visited demonstration blocks of paddy in Mahasamund and Balod Districts of Chhattisgarh State under BGREI program from 24 to 25 July 2014	Dr. M Din
Attended project work "ICAR-IRRI collaborative program on STRASA" at International Rice Research Institute (IRRI), Philippines from 28 July to 8 August 2014	Dr. MS Anantha
Attended 86th Foundation Day & Award Ceremony 2014 of ICAR, New Delhi in the A.P. Shinde Auditorium of NASC Complex, New Delhi on 29 July 2014	Dr. T Mohapatra
Attended Vice-Chancellors and Directors' Conference in A.P. Shinde Auditorium, NASC Complex, New Delhi on 30 July 2014	Dr. T Mohapatra
Attended pre-review meeting of KVKs at ZPD Unit, Jabalpur on 4 August 2014	Dr. S M Prasad
Attended Regional Consultation for the Asia- Pacific region on "Role of Family Farming in the 21st Century: Achieving the Zero Hunger Challenges 2025" at M.S. Swaminathan Research Foundation, Chennai from 7 to 10 August 2014	Dr. T Mohapatra
Attended 'IPv6 workshop for Enterprises' at C-DAC, Bangalore on 8 August 2014	Dr. B Mondal and Mr. Santosh Sethi
Attended Pre-Zonal Workshop of KVKs at OUAT, Bhubaneswar on 12 August 2014	Dr. M Chourasia
Attended a workshop on 'Biosafety and Detection of GM Crops' at NBPGR, New Delhi from 11 to 16 August 2014.	Drs. S. Samantaray and MJ Baig
Attended KVK Interface Workshop at NASC, New Delhi on 20 August 2014	Dr. T Mohapatra
Attended the KVK Interface Workshop on "Interventions in Tribal areas and efficiency enhancement" at NASC Complex, New Delhi from 19 to 20 August 2014	Dr. SM Prasad
Attended India Rice Conference on "Strengthening Rice Production, Processing & Sustaining Food Security" at HHI, Kolkata from 21 to 22 August 2014	Dr. T Mohapatra

Participated in meeting of KVKs of Jharkhand under chairmanship of Shri Radha Mohan Singh, Hon'ble Minister of Agriculture, Govt. of India at IINRG, Ranchi on 25 August 2014	Dr. VK Singh
Delivered keynote address on the topic "Towards Second Green Revolution & Rice with a Vision" at STI (P), AIR & Doordarshan, Bhubaneswar on 27 August 2014	Dr. T Mohapatra
Visited demonstration blocks of paddy in Jangir-champa District of Chhattisgarh State under BGREI program and delivered a talk on 28 August 2014	Dr. M Din
Delivered the first Dr. SN Patnaik memorial lecture on "From Genetics to Genomics: A Journey of Exciting Science and Enabling Technologies" at PG Department of Botany, Utkal University on 5 September 2014	Dr. T Mohapatra
Participated in XXI Zonal workshop of KVKs, Zone-VII at IGKV, Raipur and installed an exhibition stall with farmers varieties of paddy, pulses, oilseeds, vegetables and root crop for registration under PPV & FRA from 5 to 7 September 2014	Drs. SM Prasad and M Chourasia
Attended and delivered a lecture on "NRRI Technologies for Field Application in Zone VII States" in XXI Zonal Workshop of KVKs at IGKV, Raipur on 7 September 2014	Dr. T Mohapatra
Attended and delivered a talk on "The Genetic Revolution: Past, Present and Future" in the National Conference on "Biotechnology for Sustaining Agriculture" at Biotechnology Centre, JNKVV, Jabalpur on 8 September 2014	Dr. T Mohapatra
Participated in *Kisan goshti* organized by District Agricultural Officer, Ranchi at Village-Sagatoli, Block-Ormanjhi which was Chaired by Dr. BN Singh, National Consultant (NFSM & BGREI), Hazaribag under BGREI programme on 9 September 2014	Dr. Yogesh Kumar
Attended and delivered a lecture on "Advances in Rice Genomics" in Winter School on the same theme area at DRR, Hyderabad on 10 September 2014	Dr. T Mohapatra
Attended and delivered a lecture on the topic "Mutants in rice Genetics and Breeding" in the training programme on "Rice Breeding: recent developments, emerging challenges and future needs" at ICRISAT, Hyderabad on 10 September 2014	Dr. T Mohapatra
Attended the Project formulation workshop for developing project on the accepted concept note for NFBSFARA (ICAR) under NRM theme organzed at NAARM, Hyderabad from 9 to 11 September 2014	Dr. D Maiti
Attended 'GARUDA-NKN Partners Meet' at Bangalore from 19 to 20 September 2014	Drs. B Mondal, N Umakanta and Mr. Soham Ray
Attended District Level Monitoring Team (DLMT) meeting of BGREI at ATMA, Cuttack on 20 September 2014	Drs. SM Prasad and M Chourasia
Delivered a lecture on "Use of Molecular Markers: Lessons from the Past for Future Strategic Crop Breeding" in the ICAR Winter School on "Novel Genomic Tools and Breeding Approaches for Sugar Crop Improvement" at IISR, Lucknow on 23 September 2014	Dr. T Mohapatra
Joined the Monitoring team for coordinated trials (DRR) as nodal scientist for monitoring of upland rice trials at BAU, Ranchi and trials for saline soils at CSSRI research station, Lucknow from 25 to 27 September 2014	Dr. NP Mandal
Participated and delivered talk in *rabi* workshop at Koderma organized by Dept. of Agriculture, Koderma on 13 October 2014	Dr. VK Singh

Participated and delivered a talk in *rabi* workshop at Koderma organized by Dept. of Agriculture, Koderma on 13 October 2014	Dr. VK Singh
Attended the "4th International Rice Congress (IRC2014)" and presented keynote on "Indian Rice Outlook" at the Bangkok International Trade and Exhibition Centre (BITEC), Thailand from 27 October to 1 November 2014	Dr. T Mohapatra
Participated in the National Symposium on 'Management options for enhancing farm productivity and livelihood security under changing climate' from 29 to 31 October 2014 at OUAT, Bhubaneswar	Dr. SD Mohapatra and Shri BS Satapathy
Participated in Institute Management Committee meeting of National Centre for Integrated Pest Management, New Delhi on 30 October 2014	Dr. KB Pun
Attended one day Review Workshop of the project Phenomics of Moisture Deficit and Low Temperature Stress Tolerance in Rice at IARI, New Delhi on 31 October 2014	Dr. P Swain
Attended *National Symposium* on "Management Options for Enhancing Farm Productivity & Livelihood Security under Changing Climate" from 29 to 31 October 2014 at OUAT, Bhubaneswar	Drs. R Raja, BB Panda, B Lal and P Gautam
Participated in the XVIII Workshop of the AICRP on RES at the G.B. Pant University of Agriculture & Technology, Pantnagar from 29 October to 1 November 2014	Dr. SP Patel
Participated in the International Seminar on 'Integrating Agriculture and Allied: Prioritizing Future Potentials for Secure Livelihoods' organized by Crop and Weed Science Society, BCKV, Kalyani, West Bengal from 6 to 9 November 2014	Dr. T Singh
Attended the meeting on Vision 2050 at Mahatma Jyotiba Phule Hall (CR-I), Krishi Bhawan, New Delhi on 10 November 2014	Dr. T Mohapatra
Attended and delivered an invited lecture on 'Rice IPM – Biodiversity Implication' in the National Symposium on 'Entomology as Science and IPM as Technology–The way Forward' organized by Entomological Society of India at College of Horticulture and Forestry, CAU, Pasighat, Arunachal Pradesh from 14 to 15 November 2014	Dr. SD Mohapatra
Participated in the National Symposium on 'Agriculture diversification for sustainable livelihood and environmental security' at PAU, Ludhiana from 18 to 20 November 2014	Dr. T Singh
As a Member of the National Level Monitoring Team visited Howrah and Purba Medinipur districts of West Bengal for monitoring of NFSM (Rice) programme during 17-18 November 2014 and Baksa and Nagaon districts of Assam for the monitoring of BGREI (Rice) programme from 19 to 20 November 2014	Dr. KB Pun
Attended the Annual Shuttle Breeding Selection Activity and EIRLSBN Workshop at RARS, Titabar, AAU, Assam from 19 to 20 November 2014	Dr. SK Pradhan and Mr. SSC Patnaik
Attended the 'National Plant Physiology Conference 2014' held at OUAT, Bhubaneswar, Odisha from 23 to 25 November, 2014 and delivered a talk on "Chlorophyll a fluorescence based phenotyping under salt stress in rice"	Dr. RK Sarkar
Attended and delivered inaugural lecture in National Conference of Plant Physiology at OUAT, Bhubaneswar on 23 November 2014	Dr. T Mohapatra
Attended and delivered a talk in the seminar on "Evolving Plant Biology: From Chromosomes to Genomics" at Bose Institute, Kolkata from 28 to 29 November 2014	Dr. T Mohapatra
Participated in Review Workshop of NICRA and International Plant Nutrient Institute (IPNI) at ICAR-Zonal Project Directorate, Zone II, Kolkata from 21-22 November 2014	Dr. VK Singh

Attended workshop on 'Open Access to Agricultural Knowledge for Inclusive Growth and Development' at NAARM, Hyderabad from 29 to 30 October 2014	Dr. B Mondal
Attended 3rd NKN Annual Workshop at IIT, Guwahati from 15 to 17 December 2014	Drs. B Mondal, N Umakanta and Mr. SK Rout
Attended National Conference of Plant Physiology (NCPP–2014) at OUAT from 23 to 25 November 2014	Drs. P Swain and MJ Baig
Attended 28th National Conference on Agricultural Marketing at Sardar Patel University, Anand, Gujarat from 4 to 6 December 2014.	Dr. P Samal
Attended the Research Advisory Committee (RAC) meeting at IIVR, Varanasi, Uttar Pradesh from 17 to 18 December 2014	Dr. T Mohapatra
Attended the Review meeting of foreign aided projects at Krishi Bhawan, New Delhi 22 December 2014	Dr. SK Pradhan
Attended Soil and Water Networking National workshop at IIT, Kharagpur from 4 to 7 January 2015, jointly organized by IIT Kharagpur and the University of Sydney	Mr. A Kumar
Participated in VII Annual Convention and National Seminar on "Sustainable Rural Livelihood: Technological & Institutional Perspective" and presented a research paper entitled '*Farmer-led innovation of Sugarcane Cultivation for rural prosperity in Koderma, Jharkhand*' at Sher-e-Kashmir University of Agricultural Sciences & Technology, Jammu from 8 to 10 January 2015	Dr. VK Singh
Attended a meeting on "Formulating price policy report on *kharif* crops for the year 2015-16" at Krishi Bhawan, New Delhi on 10 January 2015	Dr. P Samal
Attended in National Conference on "Indigenous Innovation and Foreign Technology Transfer in Fertilizer Industry: Needs, Constraints and Desired Simplification" organized by the Society of Fertilizers and Environment and Raman Centre for Applied and Interdisciplinary Sciences in collaboration with ICAR-CRIJAF, Kolkata on 17 January 2015	Mr. Manish Kumar
Attended and delivered lead lectures on Blast of rice and AM-fungi for upland rice respectively in National Symposium on "Advances in Phytopathological Research in Globalized Era with Reference to Eastern Region" at Department of Botany, Ranchi University on 29 January 2015	Drs Mukund Variar and Dipankar Maiti
Delivered a lecture on 'Frontier Technology for profit maximization in rice' in '*Agriculture Varta*' organized by CSR unit, TATA Steel, Jamshedpur, Jharkhand on 29 January 2015	Dr. Yogesh Kumar
Attended National Symposium on "Agrochemicals for Food and Environment Safety" and presented a paper on 'Effect of rice husk biochar and fly ash on fipronil sorption' at IARI, New Delhi from 28 to 30 January 2015	Dr. T Adak
Attended the SAC of KVK Nawada (8-9 January) and KVK, Hazaribag (9 February 2015) as ICAR representative	Dr. M Variar
Attended Scientific Advisory Committee meeting of Krishi Vigyan Kendra, Assam Agricultural University, Nalbari on 30 January 2015	Drs. KB Pun and T Singh
Attended the XII Agricultural Science Congress at NDRI, Karnal from 3 to 6 February 2015	Drs. T Mohapatra, Lipi Das, B Mondal and Smt. Sujata Sethy

Attended HRD programme for scientists of Home Science, Animal Science and Fisheries in KVKs of Odisha at OUAT, Bhubaneswar from 6 to 8 February 2015	Dr. RK Mohanta
Attended SAC meeting of KVK (Holy Cross), Hazaribag on 9 February 2015	Dr. VK Singh
Attended International Conference on "Natural Resource Management for Food Security and Rural Livelihoods" at New Delhi from 10 to 13 February 2015 and presented a paper entitled "Transformation of Zn in rice soil and its availability and uptake to rice crop under flooded and aerobic moisture regime"	Dr. M Sahid
Attended an Interaction and Inspiration Programme of Odisha Bigyan Academy for +2 Science Lecturers and Students of Odisha and delivered a lecture on "Food Security" at Utkal University, Vanivihar, Bhubaneswar on 12 February 2015	Dr. T Mohapatra
Attended a workshop in the training institute of Agriculture Department and delivered a lecture on "Women's Role and Responsibility in Managing Natural Resources" at Training Institute, Minor Irrigation & Water Use, Baramunda, Bhubaneswar on 13 February 2015	Dr. T Mohapatra
Attended the 4th International Global Social Science Conference-2015 and presented papers in the Global Social Science Conference (GSSC-2015) on the theme "Management of Sustainable Livelihood Systems" at OUAT, Bhubaneswar from 14 to 17 February 2015	Drs. T Mohapatra, BN Sadangi, SK Mishra and Lipi Das
Attended the Agricultural Genomics Symposium and delivered a lecture on "Our Experience in Rice Genomics: Structure to Function" at TNAU, Coimbatore on 16 February 2015	Dr. T Mohapatra
Attended the 5th International Conference on Next Generation Genomics and Integrated Breeding for Crop Improvement and delivered a lecture on "Exploring Salinity Tolerance in Rice by Genome wide Approaches" at ICRISAT, Hyderabad from 19 to 20 February 2015	Dr. T Mohapatra
Attended the 17th Indian Agricultural Scientists and Farmers' Congress on "Agri-Innovation for Enhancing Production and Rural Employment" at Bioved Research Institute of Agriculture & Technology, Allahabad from 21 to 22 February 2015	Drs. T Mohapatra and B Lal
Attended the 17th Annual Conference of the Society of Statistics, Computer and Applications and delivered a lecture on "Genome wide Analysis using Bioinformatic Tools: Adding Value to Rice Genomic Resources" at Birla Institute of Management Technology, Bhubaneswar on 23 February 2015	Dr. T Mohapatra
Attended the 17th Annual Conference of the Society of Statistics, Computer and Applications at Birla Institute of Management Technology, Bhubaneswar from 23 to 25 February 2015	Drs. P Samal, GAK Kumar, B Mondal and NN Jambhulkar
Attended Institute Management Committee meeting of NRCPB, New Delhi on 25 February 2015	Dr. T Mohapatra
Delivered a lecture on 'Measuring the impact of watershed development programmes: scopes and limitations'. In: 17th Annual Conference of Society for Statistics and Computer Applications', Birla Institute of Management Technology, Bhubaneswar from 23 to 25 February 2015	Dr. B. Mondal
Attended Institute Management Committee meeting of National Centre for Integrated Pest Management, New Delhi on 24 February 2015	Dr. KB Pun
Attended a workshop on 'Training Needs Assessment' for HRD Nodal Officers of ICAR at NAARM, Hyderabad on 26 February 2015	Dr. S Samantray

Attended ISEE National Seminar Extension Innovations and Methodologies for Market–led Agricultural Growth and Development at RVSKVV, Gwalior from 26 to 28 February 2015	Dr. VK Singh
Attended RPSC meeting of AIR, Cuttack on 27 February 2015	Dr. SM Prasad
Attended a 3 day training programme organized at Block Office, Tangi-Choudwar for selected farmers/farm women and delivered lectures on "*Role of Goat Nutrition in Profitable Goat Farming*" on 27 to 28 February 2015	Dr. RK Mohanta
Attended the workshop organized as a part of National Science Day celebration by the Dept. of Botany, Vinoba Bhave University, Hazaribag and delivered key note address on the focal theme: "Developing winning research project proposals" on 28 February 2015	Dr. D Maiti
Participated in project launching workshop on 'Livelihood food security for Churchu block' organized by SUPPORT and CINI at Hotel Canary Inn, Hazaribag, Jharkhand on 3 March 2015	Dr. Yogesh Kumar
Attended and delivered a lecture in the First SRM Genetics Congress at Department of Genetic Engineering, SRM University, Kattankulattur, Chennai on 4 March 2015	Dr. T Mohapatra
Attended BGREI meeting, at ATMA, Koderma, Jharkhand on 11 March 2015	Mr. B Singh
Attended the meeting on preparation of Action Plan of BGREI for the year 2015-16 at Directorate of Agriculture and Food Production, Bhubaneswar on 17 March 2015 as a member of DLMT for Koraput district of Odisha	Dr. S Lenka
Attended two days workshop on 'Attracting and retaining Youth in Agriculture (ARYA) project', at NAARM, Hyderabad from 11 to 12 March 2015	Dr. VK Singh
Delivered a talk on "Beneficial microbes: A sustainable solution for food security "in National seminar at M.S. Swaminathan School of Agriculture (CUTM), Paralakhemundi, Odisha on 28 March 2015	Dr. U Kumar

Participation in Exhibitions

The institute participated in the following exhibitions for showcasing the NRRI technologies:

- 68th NRRI Foundation Day celebration at NRRI, Cuttack on 23 April 2014
- World Food Day 2014 celebration by Odisha Krushak Samaja at Bhubaneswar on 16 October 2014
- 3rd Interface Meet of the ICAR institutes-SAU–State Departments for the year 2014-15 for Odisha at NRRI, Cuttack from 21 to 22 October 2014
- 10th Indian Fisheries and Aquaculture, organized at NBFGR, Lucknow from 12 to 15 November 2014
- 3rd Agriculture Education Day celebration at NRRI, Cuttack on 14 November 2014
- Women in Agriculture Day celebration at NRRI, Cuttack on 3 December 2014
- Jawan-Kisan Mela-2015 at Astaranga, Puri from 6 to 7 December 2014
- Global Social Science Conference-2015 on "Management of Sustainable Livelihood Systems" at OUAT, Bhubaneswar from 14 to 17 February 2015.

Dr. S. Ayyappan, Secretary, DARE & DG, ICAR visiting NRRI stall during 10th IFAF at NBFGR, Lucknow

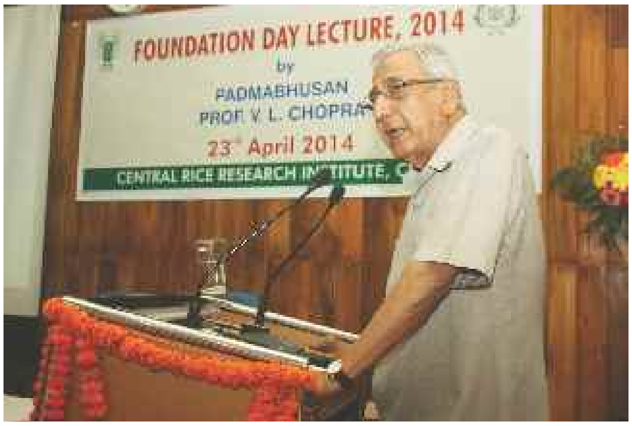
- Eastern Zone Regional Agriculture Fair on 'Rural Livelihood Security for Eastern Plains of India' at Central Potato Research Station, Patna, Bihar from 19 to 21 February 2015.
- Odisha State Agriculture Fair 'Krishi Mahotsav-2015' at Janata Maidan, Chandrasekharpur, Bhubaneswar from 5 to 8 March 2015.

Organization of Events, Workshops, Seminars and Farmers' Day

68th Foundation Day and Dhan Diwas

The National Rice Research Institute (NRRI), Cuttack observed its "68th Foundation Day and Dhan Diwas" on 23 April 2014. Padma Bhushan Professor VL Chopra, Former Secretary, DARE, Govt. of India and Director General, ICAR delivered the Foundation Day Lecture on "Enhancing Livelihoods through Technology" and graced the occasion as chief guest. Speaking on the occasion, Professor Chopra recalled the glorious past and immense contributions of the institute in the upliftment of the farming community of the country. Padmashri Dr. SVS Shastry, former Project Coordinator, All India Coordinated Rice Improvement Project (now, Indian Institute of Rice Research), Hyderabad was the special guest of the function. Padmashri Professor Priyambada Mohanty Hejmadi, former Vice Chancellor of Sambalpur University and a proponent of classical odishi dance and a renowned practitioner, graced the function as guest of honour along with Mr. P Krishna Mohan, IFS, Director of Fisheries, Govt. of Odisha. Dr. T Mohapatra, Director of the institute highlighted the eight recently released and notified varieties during last one year by CVRC and also three varieties identified recently by the VIC. The programme was attended by over three hundred farmers and farmwomen from Assam, Jharkhand and Odisha apart from invited dignitaries and staff of the institute.

Chief Guest Prof. VL Chopra inaugurating the "Foundation Day and Dhan Diwas" along with Special Guest Padmashri Dr. SVS Shastri and Padmashri Dr. Priyambada Mohanty Hejmadi



Padma Bhushan Prof. VL Chopra, Former Secretary, DARE and DG, ICAR & Chief Guest of the function delivering the Foundation Day Lecture

86th ICAR Foundation Day

The 86th ICAR Foundation Day was celebrated at National Rice Research Institute, Cuttack on 16 July 2014. The programme was presided over by Dr. T Mohapatra, Director, NRRI. Dr. Debaraj Panda, former Director, WALMI, Odisha and Dr. PK Mohapatra, former Dean, College of Agriculture, OUAT graced the occasion as chief guest and guest of honour, respectively. Scientists from NRRI main campus as well as Regional Research Stations, technical staff, administrative staff, research fellows and students attended the programme. Ten progressive farmers from different villages of Cuttack district participated in this programme and they were felicitated for their involvement in field trials as well as innovativeness in farm productions.

Stakeholders' Meet

The stakeholders' meeting on Rice-based Model Village was held on 9 June 2014 under the chairmanship of Dr. T Mohapatra, Director, NRRI, Cuttack and was attended by 10 representative farmers & 10 representative farmwomen of the cluster, 10 officials from state developmental departments and farmers' organization apart from scientists and technical staff of the project. Dr. BN Sadangi, Head, Division of Social Sciences & programme leader apprised the house about the project objectives, activities, major problems of the cluster and interventions carried by NRRI so far; and relevance of various stakeholders for the success of the project. He gave a brief account of the socio-economic environment of the cluster and technological interventions made by the institute during kharif-2013-14 and rabi-2014. Dr. T Mohapatra, Director, NRRI & chairman of the session highlighted some of the initiatives by project personnel in resolving the problems and hastening the developmental activities in the area.

Interface Meet

The 3rd "Interface Meet of the ICAR Institutes-SAU-State Departments" for the year 2014-15 for Odisha was organized at NRRI, Cuttack from 21 to 22 October 2014. The two-day meet was chaired by Prof. (Dr.) Manoranjan Kar, Vice-Chancellor, OUAT, Bhubaneswar. Inaugurating the meet, he appreciated the initiative of the Secretary, DARE and DG, ICAR to hold this meet to bring all stakeholders on a single platform to discuss various issues concerning agricultural growth and development in the state. He emphasized on crop diversification, low-cost technologies and integrated farming system for economic and livelihood security of small and marginal farmers of the state. Chief Guest of the function Shri Rajesh Verma, IAS and Principal Secretary (Agriculture and Cooperation), Government of Odisha, emphasized on strengthening and institutionalizing the linkages among all stakeholders and organizations at grassroot levels. KVKs of all districts can be the central platforms at district level and all other stakeholders should work hand-in-hand with KVKs to demonstrate and disseminate agricultural technologies and information. At the outset, Dr. T Mohapatra, Director, NRRI and convener of the meet briefed about the objectives of the meet and presented the action taken report. There was a intense discussion involving all concerned particularly young entrepreneurs and farmers.

Farm Innovators Day

ICAR- National Rice Research Institute, Cuttack observed "Farm Innovators Day and BGREI Scientists-Farmers Interaction Meet" on 27 January 2015 in its premises. Shri Ranglal Jamuda, IAS, Special Secretary, DAC, MOA, Govt. of India graced the occasion as chief guest and inaugurated the event. He emphasized on 'Seed, Soil and Water' for sustaining agricultural production in the state. The Guest of Honour Dr. PK Meherda, IAS, Commissioner-cum-Director, Department of Agriculture and Food Production, Govt. of Odisha said that progress in agriculture sector was impossible without seeds of improved varieties, technologies, farm machineries and efforts of our farmers. Dr. T Mohapatra, Director and chairman highlighted the significant achievements of the institute, especially the recently released varieties and their suitability for diverse ecologies. He spoke on the objectives of the porogramme, inspired the farmers and summarized the suggestions for taking further actions. Apart from central and state government officials, the programme was attended by over 250 innovative/progressive farmers and state department officials from 29 districts of Odisha.

Chief Guest Shri Rajesh Verma, IAS, Principal Secretary (Agril.) Govt. of Odisha addressing the gathering

Dr. PK Meherda, IAS, Commisioner-cum-Director, Dept. of Agriculture and Food Production, Govt. of Odisha and Guest of Honour speaking on the occasion

Agriculture Education Day

The National Rice Research Institute, Cuttack celebrated 3rd "Agriculture Education Day" on 14 November 2014 in its premises with the participation of 200 students of class VIII to XII standard from 18 Schools and Junior Colleges around the city along with their teachers. Chief guest of the inaugural function Prof. UC Mohanty, Emeritus Professor, IIT, Bhubaneswar and President of Odisha Bigyan Academy inaugurated the programme. He also inaugurated the Agricultural Science Exhibition showcasing the projects developed by the students of all the participating schools and colleges on the theme "Rural Agricultural Production Systems for Livelihood Security". Speaking on the occasion, he stressed on the need for research on green energy and agricultural biodiversity resources and their optimal use for bringing sustainable development and prosperity to the society. Prof. SP Adhikary, Vice-Chancellor, Fakir Mohan University, Balasore and the chief speaker described evolution of agriculture since the pre-historic era and domestication of crops. The Chairman of the inaugural function Dr. T Mohapatra, Director, NRRI briefed about importance and relevance of various horizons of agricultural sciences namely, education, research and extension. On this occasion, the chief guest released one educational bulletin entitled "Marvels of Agricultural Science" for the benefits of the students.

Release of the educational bulletin "Marvels of Agricultural Science" on the occasion

DG, ICAR Inaugurated Office Building at NRRI Regional Station, Gerua

Dr. S Ayyappan, Hon'ble Secretary, DARE & Director General, ICAR visited NRRI Regional Station, Gerua (Assam) on 8 March 2015. Dr. Ayyappan inaugurated the newly constructed Office-cum-Laboratory building of NRRI Regional Station, Gerua. Altogether 238 farmers from different districts of Assam participated in a farmers' meet out of which 96 were farmwomen. Since inauguration day coincided with the International Women's Day, progressive farmers, particularly farmwomen, were felicitated and provided with 5 kg mini kits of rice variety 'Chandrama' to mark the occasion. Hon'ble DG, ICAR in his address emphasized upon adoption of rice-based farming and cropping system for sustainable food and nutritional security. Dr. T Mohapatra, Director, NRRI highlighted the rice and rice based technologies available with NRRI to cater to the needs of the rice farming community and urged the farmers to remain in touch with different research and extension institutions located in the region in order to update with recent technological developments and to harness their benefits. Dr. SV Ngachan, Director, ICAR Research Complex for North Eastern Hill Region, Umiam (Meghalaya) emphasized upon crop diversification and utilization of rice fallow with inclusion of short duration pulses and oilseed crops for higher crop productivity and farm income. Dr. DK Sarma, Director, National Research Centre on Pig, Rani (Assam) suggested integration of piggery in rice-based production system for ensuring high income level to rice farmers.

Hon'ble DG takes note of traditional rice germplasm

Dr. Gopinath Sahu Memorial Lecture

The 23rd Dr. Gopinath Sahu Memorial Lecture was jointly organized by the Association of Rice Research Workers (ARRW), Dr. Gopinath Sahu Memorial Trust (GSMT) and National Rice Research Institute, Cuttack on 24 November 2014. Dr. SK Sopory, Vice

Participants of cleanliness awareness campaign congregating at the NRRI main building

Chancellor, Jawaharlal Nehru University, New Delhi was the guest speaker and Dr. PK Mohapatra, Member, GSMT and Executive Editor of the popular Odia daily, The Samaja was the guest of honour. Dr. SK Sopory delivered the memorial lecture on "Glyoxalase pathway: Role in stress tolerance in plants". He elaborated on the work that was carried out in his laboratory over a decade on understanding glyoxalase system, the genes involved and their functional significance. The guest of honour, Dr. PK Mohapatra described the challenges due to climate change and described some adaptation and mitigation strategies. Dr. T Mohapatra, Director, NRRI, presided over the function.

Awareness Campaign on "Swachh Bharat Abhiyan"

A public awareness campaign on cleanliness was organized by National Rice Research Institute (NRRI), Cuttack in collaboration with NRRI High School on 25 October 2014 under the "Swachh Bharat Abhiyan" being implemented at the institute. The day-long programme was started with a morning rally (Prabhat Pheri), where over 200 students, school teachers and NRRI staff led by Dr. T Mohapatra, Director of NRRI and Mrs. Ranjita Pradhan, Head Mistress of NRRI High School participated. The participants carrying banners and placards on cleanliness (Swachhta) walked through the neighbouring villages Kanheipur and Bhadimul, and the NRRI campus enchanting the slogans. The villagers also showed their enthusiasm on this noble cause.

Academic Program for Knowledge and Skill Development

With a view to enhance skills and knowledge of scientific staff and research scholars and to keep them abreast with new developments in rice science, the Director, NRRI, Dr. T Mohapatra convened a meeting of Heads of Divisions, Scientists, Research Scholars and research project workers on 15 September 2014 to deliberate upon the issue. After a thorough discussion, it was decided to initiate an 'Academic Program for Knowledge and Skill Development' by holding lecturers on various topics covering all major disciplines of rice science. The course content covering fourteen different areas was prepared. This program was formally launched on 8 October 2014 with the Vice Chancellor of OUAT, Bhubaneswar, Professor M Kar as the chief guest. The Dean College of Agriculture, OUAT and Dean Life Sciences, Ravenshaw University, Cuttack were invited to the function as guests of honour. On this occasion, Prof. Kar, gave an inaugural lecture on the "Physiology of Drought Tolerance in Plants".

Official Language Implementation Committee

Dr. T Mohapatra, Director, NRRI chaired the quarterly meeting of the Official Language Implementation Committee (OLIC) of the Institute for the quarter ending April-June, 2014 held on 27 June 2014. All the Heads of Divisions, the Chief Finance & Accounts Officer, Senior Administrative Officer, Administrative Officer are the members of this committee attended the meeting. The Director reviewed the status of the progress of Official Language at the Institute. He urged the importance of compliance of various rules and regulations of Official Language. A number of decisions were made to implement the Official Language policy effectively at the institute.

Hindi Fortnight

The Hindi Fortnight was celebrated at NRRI, Cuttack from 8 to 23 September 2014. During this period five Hindi competitions *viz.*, Correct and Speed Writing, Reading, Hindi Shabd antakshari, General Knowledge, Noting & Drafting were conducted for non-Hindi speaking staff. The closing ceremony of Hindi Fortnight-2014 was organized on 26 September 2014 in the auditorium of the institute. Shri Sanjeev Arora, IPS, Deputy Commissioner of Police, Cuttack graced the occasion as the chief guest. Dr. T Mohapatra, Director, NRRI presided over the function. Dr. Ajay Kumar Patnaik, Visiting Professor, Department of Hindi, Ravenshaw University, Cuttack and Shaukat Rashidi, Poet, Cuttack were invited as guests of honour.

Winter School

NRRI organized a Winter School sponsored by Indian Council of Agricultural Research, New Delhi on "Advanced Techniques for Assessment of Soil Health, GHG emissions and Carbon Sequestration in Rice under Changing Climatic Scenario and Mitigation Strategies" from 11 November to 1 December 2014 for the officers in the cadre of scientists/assistant professors or equivalents and above.

Prof. VL Chopra, Ex-DG, ICAR and Secretary, DARE, New Delhi inaugurated the programme. The inaugural programme was also attended by the guests of honour Dr. VK Dadhwal, Director, NRSC (ISRO), Hyderabad and Dr. AK Singh, Head, Division of Genetics, IARI, New Delhi. In his address as chief guest, Prof. VL Chopra highlighted the importance of sustainable management of soil under the climate change scenario. Dr. VK Dadhwal delivered lead lecture on the use of remote sensing for the assessment of soil health. Dr. AK Singh highlighted the importance of the healthy soil for improved production and maintaining environmental quality. Dr. T Mohapatra, Director, NRRI in the opening remarks welcomed the guests and elucidated the current research needs and future strategies for enhancing rice production.

World Food Day

World Food Day was observed on 16 October 2014 at Agrahat village of Tangi-Choudwar block, Cuttack, Odisha by Krishi Vigyan Kendra, Santhapur, Cuttack on the theme: "Family Farming". Three hundred farmers and farmwomen from the locality and 150 school children participated in the programme. Dr. T Mohapatra, Director, NRRI and the chief guest inaugurated the main function and released a leaflet on "Family Farming" for awareness of the farming community. He called upon the stakeholders to focus on family farming for all-round prosperity of the villages including nutritional security. Shri SC Sahoo, DDA, Cuttack, the chief speaker and Shri HK Swain, BDO, Tangi-Choudwar block and Shri PK Das, Headmaster of the Agrahat High School, the guests of honour addressed the gathering.

A lady farmer sharing her experience about family farming

Women in Agriculture Day

Krishi Vigyan Kendra, Cuttack, a unit of ICAR-NRRI, Cuttack observed the "Women in Agriculture Day" on 3 December 2014 at NRRI, Cuttack on the theme "Harnessing the potential of women in agriculture through group approach". Smt. Snehangini Chhuria, Honourable Minister of State (Independent Charge), Handloom, Textile and Handicrafts, SC/ST Development and Women and Child Development (Mission Shakti), Government of Odisha, inaugurated the programme as chief guest and released an extension leaflet in Odia entitled "Baigyanika Upayare Sasya Sanrakhyna". In her address, the chief guest emphasized on the role of self-help groups (SHGs) in promoting women empowerment in social and economic spheres.

Dr. Neelam Grewal, Director, DRWA, the guest of

Hon'ble Minister looking at the farm products exhibited by the farmers in the stall

Guests on the dais listening to the participants

honour explained the opportunities available to the women SHGs. Dr. T Mohapatra, Director, NRRI and chairman of the function, highlighted the importance of group efforts in women empowerment. Eleven SHGs consisting of 120 farmwomen participated in the programme and successful women SHGs were awarded prizes and certificates.

NRRI-NABARD Interaction Meet

A NRRI-NABARD Interaction-cum-Exposure Meet was organized on 26 March 2015 in the institute in collaboration with NABARD Regional Office, Bhubaneswar, which was attended by four DGMs, over thirty District Development Managers-cum-AGMs (DDMs/AGMs) of NABARD from Odisha, all HODs and scientists of the institute. Shri SK Kale, CGM, NABARD, Bhubaneswar in his presidential address highlighted the activities and achievements of NABARD in augmenting agricultural production in the state through its credit support in rural sector, promotional activities, regulatory roles and supervisory mechanisms. Gracing the occasion as the chief guest and inaugurating the meet, Director, NRRI Dr. T Mohapatra said that rice is core to the development of the country, more so in eastern parts of the country and particularly in Odisha. He emphasized on NABARD's role in farm mechanization, custom hiring, and value-chain establishment. All the HODs presented a brief account of disseminable technologies on rice for the benefit of the NABARD officials.

Workshop on Rice Production

The institute organized a "Workshop on Rice Production" on 6 March 2015 at the 'Institute for Management of Agricultural Extension' (IMAGE), Bhubaneswar in the side line of the state "Krishi Mahotsav" celebrated from 5 to 8 March 2015 at Bhubaneswar. The workshop was attended by over hundred rice farmers from various districts of Odisha, apart from fifty state Agriculture Officers and scientists from NRRI. The main objective of the workshop was to understand their problems in rice production and suggest recommendations. The workshop was inaugurated by Dr. T Mohapatra, Director, NRRI and Shri A Sethi, Director, IMAGE. Addressing the gathering in the opening session, Shri Sethi said that the workshop is an excellent platform to bridge the existing information gap in order to empower the ultimate users, i.e., "farmers". Dr. T Mohapatra, Director and chairman emphasized on 'crop diversification' in view of the frequent natural disasters like drought, cyclone and flood being received by the state almost every year.

Workshop on 'Hybrid Rice and Innovative Technology for Enhancing Rice Productivity'

A conference on "Hybrid Rice and Innovative Technology for Enhancing Rice Productivity" was organized jointly by Dupont Pioneers, Hyderabad and National Rice Research Institute on 2 September 2014. Dr. PK Agrawal, ADG, NFBSFARA, ICAR chaired the workshop. Participants from IARI, BHU, DRR, IGKV, OUAT, Sambalpur University and NRRI participated actively in the event.

Launch-workshop of the New Plan Scheme on "Incentivizing Research in Agriculture"

A new XIIth Plan Scheme on "Incentivizing Research in

Prof. SK Datta addressing on the occasion

Agriculture" comprising of projects on rice yield under low light, C_3-C_4 intermediate pathway in *Poaceae*, genetic modifications to improve biological nitrogen fixation, molecular genetic analysis of resistance/tolerance to different stresses and semen sexing in cattle has been sanctioned by the ICAR. The scheme was launched in presence of Prof. SK Datta, Deputy Director General (Crop Sciences), ICAR, New Delhi on 13 January 2015 at National Rice Research Institute, Cuttack. The Launch-workshop was also attended by Dr. JS Chauhan, Additional Director General (Seeds), ICAR, New Delhi and PIs and Co-PIs of different component projects. Dr. T Mohapatra, Director, NRRI and the coordinator of the scheme gave a brief account of the scheme. There are 24 partner institutions and 142 scientific personnel as PI and Co-PIs involved in this scheme.

Workshop on Rice Seed Production: Constraints and Prospects

The Institute Technology Management Unit (ITMU) of NRRI, Cuttack organized a workshop on "Rice Seed Production: Constraints and Prospects" on 18 October 2014. The workshop was chaired by Dr. JS Chauhan, ADG (Seeds), ICAR, New Delhi and co-chaired by Sri RS Gopalan, IAS, Director (Agriculture and Food Production), Government of Odisha. More than 80 participants from State Agriculture Department, National Seeds Corporation, OSSOPCA, Odisha Agro-Industries Ltd., Private Seed Companies, Scientists from NRRI and OUAT, Farmer Seed Producing Agencies, progressive farmers and women farmers directly involved in seed production attended the meeting. The objective of the workshop was presented by Dr. T Mohapatra, Director, NRRI. Shri RS Gopalan, IAS, made a presentation on "Paddy Production in Odisha". He highlighted several issues related to regulating framework, seed quality assurance, trained man power needs etc. Shri BT Sheshadri, representative from Syngenta Foundation made a brief presentation and highlighted the thoughts of their involvement in developing Kalahandi district as a seed production hub by investing in infrastructural activity. Dr. JS Chauhan, in his chairman's remarks summarized the issues and challenges to rice seed system and suggested robust mechanism to strengthen public system, promote partnership with private and encourage efficient participatory seed production so that Odisha becomes a seed hub.

Farmers' Awareness Programme about Climate Resilient Rice Varieties

A farmers Training programme on 'General Awareness of Climate Resilient Rice varieties' was organized under NICRA Project, NRRI at Choto Sehera village, Sandeshkhali- 1 block (Sundarban), 24 Parganas (N), West Bengal on 27 June 2014. Around 100 farmers attended the meeting.

Dhan Diwas

Dhan Diwas was celebrated at RRLRRS, Gerua on 15 November 2014. Altogether 190 farmers from 4 districts, *viz.*, Kamrup, Nalbari, Darrang and Udalguri participated in the programme of Dhan Diwas. Dr. NK Sharma (Principal Scientist, AAU and Ex-Officer In-Charge, RRLRRS, Gerua) graced the occasion as the chief guest. Dr. Mridul Deka (Principal Scientist & Programme Coordinator, KVK, Nalbari) and Shri SS Ghosh (Agronomist, Bayer BioSience Pvt. Ltd.) graced the occasion as the guest of honour and the special guest, respectively. Mr. Moidul Haque, Project Coordinator of the NGO 'North East Centre for All Round Development, Mangaldoi and Mr. Dhiraj Das, Coordinator (Udalguri branch) of the NGO 'Green Life' also participated in the Dhan Diwas.

Field Day

Field days were organized at Gorakhat (Darrang district) on 27 May 14, Galdighala (Nalbari district) on 7 June 14 and at Hokradoba (Udalguri district) on 10 June 2014. More than 100 farmers participated in each field days. Dr. SG Sharma, Head, Division of CPB, NRRI, Dr. AK Gogoi, Zonal Project Director, KVKs, Zone III, Dr. NK Sharma, Principal Scientist, AAU & ex-Officer In-Charge, RRLRRS, Gerua graced the field day meetings at Gorakhat, Galdighala and Hokradoba as the chief guest, respectively.

Training Programmes

The following State and National level training programmes were organized during the year 2014-15.

- Trainers' training programmes on 'Improved Package of Practices for Increasing Rice Production' sponsored by OTELP, Government of Odisha from 19 to 22 May 2014 for 20 participants.
- Trainers' training programmes on 'Improved Package of Practices for Enhancing Rice Production and Productivity' sponsored by ATMA, Angul, Odisha from 7 to 11 July 2014 for 30 participants.
- Trainers' training programmes on 'Improved Package of Practices for Increasing Rice Production and Productivity' sponsored by ATMA, Valsad, Gujarat from 4 to 7 August 2014 for 23 participants.
- Trainers' training programmes on 'Production Technologies for System of Rice Intensification' sponsored by TSRDS, Kalinga Nagar, Jajpur, Odisha from 12 to 14 August 2014 for 25 participants.
- Trainers' training programmes on 'Package of Practices for Enhancing Rice Production Technology' sponsored by ATMA, Angul, Odisha from 19 to 23 August 2014 for 28 participants
- Trainers' training programmes on 'Package of Practices of Improved Rice Production Technology' sponsored by ATMA, Valsad, Gujarat from 4 to 8 September 2014 for 23 participants.

Paticipants of the training programme on "Package of practices of improved rice production technology" sponsored by ATMA Valsad with Director and Resource persons

- Trainers' Training Programme on 'Hybrid Rice Production Technology' sponsored by the State Institute for Management of Agriculture (SIMA), ATMA, Lucknow was organized from 16 to 20 March 2015 for 28 participants.
- One Exposure-cum-Training Programme on 'Rice Production Technology' sponsored by Centre for Agriculture and Rural Development (CARD), New Delhi was organized for 24 progressive farmers of Ahmadabad district of Gujarat from 23 to 24 March 2015. Drs. Lipi Das and SK Mishra coordinated the above training programmes.
- A workshop on NRRI-NCIPM Collaborative Project NRRI-NCIPM Collaborative project Development and Validation of IPM module for Rice at NRRI, Cuttack was organized on 22 November 2014. Dr. SD Mohapatra coordinated the programme.
- An onsite farmer's training programme on "Real Time Nitrogen Management through CLCC and General Awareness of Rice Cultivation in Climate Change Scenario" was conducted at village Sasan, Paattamundai Block, Kendrapara District on 21 October 2014. About 120 farmers participated in the programme.
- A one day Training -cum- Workshop on "Designing and Testing of Gender Sensitive Approaches in Rice Farming" was organized by NRRI, Cuttack on 11 August 2014 in Sankilo Village of Nischintakoili block, Cuttack district, Odisha under the chairmanship of Dr. T Mohapatra, Director NRRI, Cuttack as part of a project activity.

Exposure Visits

Four thousand five hundred seventy nine visitors including farmers, farmwomen, students, agriculture officers and scientists from Odisha, Nepal, Rajasthan, Meghalaya, Andhra Pradesh, Gujarat, Uttarakhand, Madhya Pradesh, Uttar Pradesh, Jharkhand, Chhatishgarh, West Bengal, Madhya Pradesh, Tamil Nadu and Goa 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

- Eminent agricultural scientist Padma Vibhushan Prof. MS Swaminathan paid a visit to NRRI on 16 November 2014 and enlightened the scientists of NRRI and other ICAR institutes on various issues related to agriculture in general and rice in particular.

Prof. MS Swaminathan addressing the scientists of NRRI

- Dr. JS Chauhan, ADG (Seeds & FFC), ICAR, New Delhi visited Sankilo village of Cuttack, Odisha on 14 January 2015 to see various research and developmental activities being undertaken by NRRI under the institute project. Hon'ble Shri Yaswant Sinha, Former Cabinet Finance Minister visited CRURRS, Hazaribag on 6 February 2015.
- Team of Economists (Dr. Allan Choppin, Dr. Kyte and Dr. Elizabeth) from Barkley University accompanied by Dr. Manzoor Dar (Sr. Project Consultant, STRASA; IRRI-India) visited the research station on their mission to assess spread of the variety 'IR 64-drought' under the MoU signed between IRRI and Barkley University on 7 April 2014.
- Professor K Pradhan, Ex-Vice Chancellor, OUAT, Professor DP Ray, Ex-Vice Chancellor, OUAT, Professor SP Adhikary, Vice Chancellor, Fakir Mohan University, Dr. P Das, Chairman and Director, The Science Foundation for Tribal and Rural Resource Development, Dr. RC Ray - CTCRI, BBSR, Professor A.T. Rao - Ex- Professor and Head, Department of Veterinary Pathology, OUAT, Dr. RC Srivastav - P.S, DWM, BBSR, Dr. G Kar - P.S, DWM, BBSR visited NRRI on 28 July 2014.
- Dr. PK Agrawal, ADG (NFBSFARA), ICAR, Dr. SR Bhatt, Principal Scientist, NRCPB, New Delhi and Dr. Dinesh Kumar, Principal Scientist, Directorate of Oil Seed Research, Hyderabad visited NRRI on 2 September 2014.
- Dr. S Ayyappan, Secretary, DARE and DG ICAR, visited CRURRS, Hazaribag on 26 August 2014. He saw the ongoing experiments in the fields and research facilities including Biotechnology Laboratory. Dr. SK Datta, DDG (Crop Science), Dr. AK Sikka, DDG, NRM & Agril Extension, Dr. JS Chauhan, ADG (Seed), Dr. R Ramani, Director IINRG, Ranchi, Dr. BP Bhatt, Director, ICAR Res. Complex for Eastern Region, Patna, Dr. AK Singh, Zonal PD, ICAR (Zone II) and Dr. RP Ratan, Director Extension & I/c VC, BAU, Ranchi accompanied the DG during this visit to CRURRS on 26 August 2014.

Dr. JS Chauhan, ADG (Seeds) with the women famers during the field visit

Foreign Deputation

- Dr. T Mohapatra, Director, NRRI visited Bangladesh as a member of Indian delegation as a part of MoU between IRRI and NFSM to observe the performance of high yielding and salt tolerant rice varieties and hybrids from 2 to 5 April 2014.
- Dr. Mukund Variar, OIC, CRURRS, Hazaribagh, Dr. DP Singh Principal Scientist, Division of Crop Physiology and Biochemistry, Dr. JN Reddy, Principal Scientist, Division of Crop Improvement, Dr. BC Patra, Principal Scientist, Division of Crop Improvement and Dr. SK Pradhan, Principal Scientist, Division of Crop Improvement, NRRI, Cuttack attended a workshop on "13th Review and Planning and Steering Committee of CURE" in Vietnam from 8 to 10 April 2014.
- Dr. L Behera, Principal Scientist, Division of Crop Improvement, NRRI, Cuttack attended a training course on "SNP Data Analysis" in Philippines from 5 to 9 May 2014.
- Dr. T Mohapatra, Director, NRRI attended the workshop on "Asian National Rice Development Strategic" in Malaysia from 6 to 7 May 2014.
- Dr. T Mohapatra, Director, NRRI to attended the workshop and presented a research paper on "SNPs in stress responsive genes and their relevance to abiotic stress tolerance in rice" in Singapore from 19 to 21 May 2014.
- Dr. Mohammed Shahid, Scientist, Division of Crop Production attended the "20th world Congress of Soil Science" jointly organized by Korean Society of Soil Science & Fertilizer, Rural Development Administration and International Union of Soil Science held at Jeju Island, South Korea from 8 to 13 June 2014.
- Dr. ON Singh, Principal Scientist and Head, Division of Crop Improvement visited Bangladesh as a focal point expert for country participation in the Expert Consultation Meeting for the Inception on Identification of rice varieties tolerant to abiotic stress" from 10 to 11 June 2014.
- Dr. T Mohapatra, Director, NRRI to attended Expert Consultation on 'Hybrid Rice Development in Asia: Assessment of Limitations and Potential' at Impact Forum Muang Thong Thani, Bangkok, Thailand from 2 to 3 July 2014.
- Dr. GAK Kumar, Principal Scientist, Social Science Division attended workshop on 'Rice Seed Management' at Taipei, Taiwan from 3 to 16 July 2014.
- Dr. Anantha MS, Scientist, NRRI Regional Station, Hazaribag attended IRRI collaborating programme on STRASA held from 28 July to 8 August 2014.
- Dr. T Mohapatra, Director, Dr. S Saha, Principal Scientist and Dr. RK Sarkar, Principal Scientist attended the 4th International Rice Congress (IRC 2014) at Bangkok, Thailand from 27 October to 1 November 2014.
- Dr. ON Singh, Head, Crop Improvement, NRRI and Dr. M Variar, Officer-in-Charge, CRURRS, Hazaribagh attended workshop on Rice Breeders Expert Elicitation at Caliraya Resort Club, Laguna, Philippines from 20 to 21 November 2014.
- Dr. ON Singh, Head, Crop Improvement and Dr. Amol Ghosh, Principal Scientist attended the inception meeting of the Asian Development Bank supported project "Development and Dissemination of Climate-Resilient Rice Varieties for Water-Short Areas of South Asia and Southeast Asia TA-8441" at Kathmandu, Nepal from 8 to 11 December 2014.

Seminar

- Dr. T Mohapatra, Director, NRRI delivered seminar on 'Use of mutants to understand genome function : experience with Nagina-22' on 23 June 2014.
- Dr. Vainathan, Director, Public Affairs, Syngenta, New Delhi delivered seminar on "Grow more rice journey" on 8 July 2014.
- Dr. Anand Prakash, Head, Crop Protection Division, NRRI delivered seminar on "Plant Protection in India: Challenges and Research priorities" on 28 July 2014.
- Dr. R Raja delivered a lecture on 'Structural genomic characterization of wheat quality loci: Glu B and Ha' on 24 January 2015.
- Dr. R Srinivasan, Professor, NRCPB, IARI, New Delhi delivered a special lecture on 'Relevance of transgenic crops' on 9 February 2015.
- Dr. J Ali, Sr. Scientist, IRRI, Phillipines delivered a lecture on 'Green super rice' on 25 February 2015.
- Dr. SD Mohapatra delivered a lecture on 'Rice Stem borer research: current status and future strategies' on 27 February 2015.

Awards/Recognition

- Dr. T Mohapatra, Director, NRRI received the prestigious NAAS Recognition Award for the Biennium 2013-14 in the 12th Agricultural Science Congress at NDRI, Karnal.
- Dr. T Mohapatra, Director, NRRI received Lifetime Achievement Award, Indian Genetics Congress 2015 in recognition of outstanding contribution in the field of Plant Genetics at SRM University, Kattankulattur, Tamil Nadu.
- Dr. T Mohapatra, Director, NRRI received the Bioved Agri-Innovation Award on the occasion of the 17th Indian Agricultural Scientists & Farmers' Congress at Bioved Krishi Prodyogiki Gram, Moharab, Allahabad.
- Dr. AK Nayak, Head and Principal Scientist, Crop Production, NRRI has been elected as Fellow of the National Academy of Agricultural Sciences (NAAS) - from 1st January 2015.
- Dr. Pratap Bhattacharyya, Senior Scientist, Crop Production has been awarded "Dr. K.G. Tejwani Award" for Management of Natural Resources by 'Indian Association of Soil and Water Conservationist' for the Biennium 2012-13.
- Dr. RK Mohanta received ANA- Mrs. Saroj Jakhmola Award for Best Ph.D. Thesis in Animal Nutrition for the biennium 2013-14 by Animal Nutrition Association, Izatnagar, Bareilly in the IX Biennial ANA Conference, 2015 organized at College of Veterinary Science, Guwahati, Assam on 22 January 2015.
- Dr. VK Singh presented research paper on 'Assessment of Suitable Variety for Direct Seeded Rice (DSR) in Rainfed Condition of Jharkhand', which was adjudged as the best paper and received award in 17th Indian Agricultural Scientists and Farmers' Congress on "Agri-Innovation for Enhancing Production and Rural Employment" at Bioved Research Institute of Agriculture & Technology, Allahabad from 21 to 22 February 2015.
- Dr. VK Singh, PC, Koderma awarded "Best KVK Scientist Award" 2014 in recognition of outstanding contributions in farm advisory services under Transfer of Technology and Participatory Research by Indian Society of Extension Education, IARI, New Delhi in the ISEE National Seminar at RVSKVV, Gwalior from 26 to 28 February 2015. Dr. VK Singh presented a oral paper entitled, "Weed Control in Direct Seeded Rice in Jharkhand", which received the best paper presentation award.
- Dr. Dipankar Maiti, Zonal Councillor (East zone) of the Indian Phytopathological Society(IPS) was honoured by the President, IPS by presenting "Scroll of honour" on 27 May 2014 during 66th annual general body meeting of the society held at IGKV, Raipur (Image 3) for successfully organizing zonal (east zone) chapter of National Symposium from 24 to 25 October 2013 at CRURRS, Hazaribagh.
- Dr. GAK Kumar received Best Country Presentation Award in International Workshop on Rice Seed Management organized by Taiwan ICDF, Taipei on 16 July 2014.
- Dr. SK Pradhan, Principal Scientist, Crop Improvement Division received Indo-Nepal Asia Gold Star Award, 2015 awarded by Global Society for Health & Educational Growth, Delhi.
- Dr. SK Pradhan, Principal Scientist, Crop Improvement Division received Bharat Shiksha Ratna Award-2014 awarded by Global Society for Health & Educational Growth, Delhi.
- Dr. SK Pradhan, Principal Scientist, Crop Improvement Division received Panchakhanda Samman, 2014 awarded by Kalaparisad, Rairakhol, Sambalpur.
- Dr. RK Mohanta was inducted into the editorial board of Indian Journal of Animal Nutrition, published by Animal Nutrition Society of India based at National Dairy Research Institute, Karnal, Haryana.
- Dr. RK Mohanta was elected into the national level executive body of Animal Nutrition Association based at Indian Veterinary Research Institute, Izatnagar, Uttar Pradesh for the period 2014-16.
- Dr. RK Sarkar, Principal Scientist received

prestigious rice plant physiology award "Yoshida Rice Plant Physiology Research Award 2014" at the International Rice Congress held at BITEC, Bangkok, Thailand.

- The Executive Committee of Society of Extension Education confers its 'Best Extension Professional Award' to Dr. VK Singh, PC, KVK, Koderma, Jharkhand during 7th National Extension Education Congress-2014 during 8-11 November 2014 for his outstanding contribution in the field of Extension Education.
- Dr. Mukund Variar was given a plaque of appreciation by STRASA for development and promotion of drought tolerant rice, New Delhi, April 2014.
- Dr. Mukund Variar was given a scroll of honor from Indian Phytopathological Society for services rendered as President (Eastern Zone) during 2014 in the National Symposium of IPS held at IGKV, Raipur.
- Dr. SK Lenka was felicitated as an emerging Scientist for the cause of the farming community by the Journal "Krushak Sambad", Cuttack, Odisha on 28 September 2014 on occasion of celebration of its Silver Jubilee Celebration at Odisha Journalists' Bhawan, Bhubaneswar.
- Dr. B Lal received Young Scientist Award of Bioved research Society, Allahabad in 17th Indian Agricultural Scientists and Farmers' Congress on "Agri-innovation for Enhancing Production & Rural Employment" from 21 to 22 February 2015 at Allahabad, U.P.
- Three SRFs of Microbiology section namely, Ms. Nilima Dash, Ms. Jayshree Rath and Mr. Avishek Banik were qualified for ARS-NET in Agricultural Microbiology.

ICAR Inter-Zonal Sports Tournament

The ICAR-NRRI Sports Contingent participated in the ICAR Inter-Zonal Sports Tournament held at ICAR-NDRI, Karnal from 11 to 14 March 2015. The ICAR-NRRI Kabaddi team maintained its winning streak and retained the championship. In individual events, NRRI won first and third position in 400 m race (men) and secured second position in 100 and 200 m race (men) and Javelin throw (women). The team also finished third in 800 m race (men) and 4 x 100 m relay race. Dr. R Raja was the Chief-de-Mission and Shri RK Behera was the Manager of NRRI contigent.

Best Workers of NRRI-2014

Best Worker	Category
Dr. (Mrs.) Padmini Swain	Principal Scientist
Dr. (Mrs.) Lipi Das Dr. Lotan Kumar Bose	Senior Scientist
Dr. Rahul Tripathi, Scientist	Scientist / Scientist (SS)
Mr. Prem Pal Kumar, T4	Technical (T4 - T9)
Mr. Nakul Barik, T3	Technical (T1 – T3)
Mr. Aswini Kumar Sethi, PS	Administrative-I (above UDCs including PS)
Mr. Ramesh Chandra Naik, UDC	Administrative-II (up to UDCs including Stenos)
Mr. Dambrudhar Das, SSS	SS Grade
Dr. Manish Chaurasia, SMS (Plant Protection)	KVKs
Mr. Prasanta Kumar Jena, Sr. Technical Assistant (Driver)	Best Sports Person

Dr. Pratap Bhattacharyya receives 'Dr. KG Tejwani Award'

Dr. T Mohapatra, Director, NRRI receives Lifetime Achievement Award

Commercialization of Hybrid Rice and other Technologies

MoUs signed

The ICAR- National Rice Research Institute, Cuttack has developed three rice hybrids namely, Rajalaxmi (CRHR 5), Ajay (CRHR 7) and CR Dhan 701(CRHR-32) of which Ajay and Rajalaxmi are for cultivation in irrigated ecology, whereas, CR Dhan 701 is for shallow lowland ecosystem. The maturity durations of these hybrids are 130, 135 and 142 days, respectively. These hybrids are becoming popular and private seed companies are coming forward to take up production and marketing of hybrid seeds under MoU on non-exclusive basis. NRRI has so far signed 26 MoUs with private seed companies for production and commercialization of hybrids under PPP mode for the benefit of the farmers.

During this year, five Memorandum of Understandings (MoUs) were signed for the institute technologies, of which hybrid rice Rajalaxmi (CRHR 5) and CR Dhan 701 (CRHR-32) were signed with G.V. Seeds, Hyderabad and Bioseed Research India, Hyderabad and public sector- University of Agricultural Sciences, Bangalore for licensing CRMS 32A for new hybrid development. One MoU was signed with Adarsh Engineers, Rajendra Nagar, Madhupatna, Cuttack for manufacturing and marketing of NRRI Agricultural Implements. The detailed list is mentioned below. Through commercialization of hybrids, revenue of more than Rs 15.0 lakhs was generated. 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 CRDhan-701 as part of the MoU signed with these companies.

Sl. No.	Name of Technology	Name of Party	Period of MoA
1	CRMS 32A for new hybrid development.	University of Agricultural Sciences, Bangalore	5 years (May 2014 to April 2019)
2	NRRI Agricultural Implements	Adarsh Engineers, Rajendra Nagar, Madhupatna, Cuttack	3 years (3rd June 2014 to 2nd June 2017)
3	CR Dhan 701 (CRHR 32)	G.V. Seeds, Hyderabad	3 years (4th August 2014 to 3rd August 2017)
4	Rajalaxmi (CRHR 5)	G.V. Seeds, Hyderabad	3 years (4th August 2014 to 3rd August 2017)
5	CR Dhan 701 (CRHR 32)	Bioseed Research India, Hyderabad	5 years (14th January 2015 to 13th January 2020)

MoU signed with Bioseed Research India, Hyderabad

Patents filed during 2014-15

During this year six patent applications were filed with the Intellectual Property (IP) office at Kolkata by ICAR-NRRI, Cuttack.

Sl. No.	Application/ Registration No.	Name of Innovation/ Technology/ Product/ Variety	Date of Filing/Registration	Application Gran ted/ Registered**
1.	265/KOL/2015	Formul ation of Fungal Entomopathogen *Metarhizum anisopliae* Tf19 to control Rice Leaf Folder	10.03.2015	Under verification
2.	264/KOL/2015	Formulation of Bacterial Entomopathogen *Bacillus thuringiensis* Tb160 to control Rice Leaf Folder	10.03.2015	Under verification
3.	263/KOL/2015	Formulation of Bacterial Entomopathogen *Bacillus thuringiensis* Tb161 to control Rice Leaf Folder	10.03.2015	Under verification
4.	262/KOL/2015	Formulation of Bacterial Entomopathogen *Bacillus thuringiensis* Tb263 to control Rice Leaf Folder	10.03.2015	Under verification
5.	261/KOL/2015	Formulation of Bacterial Entomopathogen *Bacillus thuringiensis* Tb261 to control Rice Leaf Folder	10.03.2015	Under verification
6.	260/KOL/2015	Formulation of Fungal Entomopathogen *Beauveria bassiana* Tf6 to control Rice Leaf Folder	10.03.2015	Under verification

Variety Registration with PPV&FRA

Ten proposals for registration as new varieties developed at ICAR-NRRI were submitted to the PPV&FR Authority in the year 2014-15. The required characterization data for filling up the proposals were collected from the field as well as from the laboratories. The proposal applications of new varieties sent to PPV&FRA are CR 2829-PLN-23, CR 2829-PLN-100, CR-2829-PLN-116, CR 2830-PLS-124, CR 2830-PLS-156, CR 2829-PLN-98, CR 2829-PLN-32, CR 2830-PLS-17, CR 2829-PLN-99 and CR 2829-PLN-37. They are now under examination for the suitability of registration by the PPV&FR authority, New Delhi.

During this year, 15 rice varieties have got registered and certificates have been issued by the PPV&FR Authority. They are as follows:

Sl. No.	Name of the variety	Registration No. & Date
1.	Ajay (CRHR 7) (IET 18166) (Hybrid)	162 of 2014/09.05.2014
2.	CRMS 31A	172 of 2014/13.05.2014
3.	Naveen	175 of 2014/13.05.2014
4.	Rajalaxmi (CRHR 5) (Hybrid)	206 of 2014/26.05.2014
5.	Varshadhan	471 of 2014/01.08.2014
6.	CR Boro Dhan 2	488 of 2014/05.08.2014
7.	Nua Kalajeera	493 of 2014/05.08.2014
8.	CR Dhan 70	495 of 2014/05.08.2014
9.	CR Sugandh Dhan 3	553 of 2014/14.08.2014
10.	CRMS 32A	590 of 2014/28.08.2014
11.	CR Dhan 10	612 of 2014/08.09.2014
12.	Nua Chinikamini	820 of 2014/26.12.2014
13.	Phalguni	821 of 2014/26.12.2014
14.	Luna Suvarna	822 of 2014/26.12.2014
15.	Luna Sampad	831 of 2014/30.12.2014

Germplasm Registration with ICAR-NBPGR

Two new rice germplasm proposals submitted from NRRI got registered for having Submergence tolerance namely, Bhundi and Kalaketaki out of a total 17 submitted for registration purpose to the Plant Germplasm Registration Committee of ICAR. However, three proposals have further been revised as per the suggestion of the PGRC and resubmitted for registration purpose.

Training and Capacity Building

Training is crucial for organizational development and success. It is fruitful to both employers and employees of an organization. An employee will become more efficient and productive if he/she is trained well. Training is the process of enhancing the skills, capabilities and knowledge of employees for doing a particular job. Training process moulds the thinking of employees and leads to quality performance of employees. Besides, workshops/ seminars/conferences congregate the practitioners, national and international experts on various contemporary subjects and issues which enhance the relevant knowledge, latest thinking and technological developments, national and international policies, best practices, cost effective and sustainable approaches. Looking to the importance of the training, workshops, seminars, conferences etc. the employees of the institute were deputed in different levels of training and exposed to various workshops/seminars/conferences as per the mandate of the institute. The details of the training and capacity building programme attended by the employees of the institute during 2014-15 are listed below.

Entry Level Training

S.N.	Title of the training	Period	Venue	Participants
1.	99th FOCARS training	1Jan to 29th Mar 2014	NAARM, Hyderabad	Aravindan S, M K Yadav and S K Gritlahre
2.	Professional Attachment training	8th July to 7th Oct 2014	CSKHPKV, Palampur	M K Yadav
		9th June to 8th Sep 2014	NRCPB, New Delhi	Aravindan S
		15th Oct 2014 to 14th Jan 2015	OUAT, Bhubaneswar	S K Gritlahre

Short Term Thematic Training

A. International

S.N.	Name of the training	Period	Venue	Participants
1.	SNP Data Analysis	5 to 9 May 2014	IRRI, Philippines	L Behera
2.	Molecular breeding course	21 Sept. to 4 Oct. 2014	IRRI, Philippines	SK Dash

B. National

S.N.	Title of the training	Period	Venue	Participant
1.	Participatory research for gender mainstreaming concern in agriculture	22 to 31 May 2014	DRWA, Bhubaneswar	TR Sahoo
2.	Refresher course on Agriculture Research Management	14-26 Aug 2014	NAARM, Hyderabad	Yogesh Kumar
3.	Pest Risk Analysis	1 to 5 Sep 2014	NIPHM, Hyderabad	KB Pun

4.	Next Generation Sequence Data Analysis	22 to 26 Sep 2014	KIIT University, Bhubaneswar	S Samantaray, L Behera and JL Katara
5.	Advanced techniques for assessment of soil health, GHG emissions and carbon sequestration in rice under changing climatic scenario and mitigation strategies (Winter School)	11 Nov to 1 Dec 2014	NRRI, Cuttack	BS Satapathy
6.	Recent Advances in Crop Management under Protected Cultivation (Winter School)	26 Dec 2014 to 15 Jan 2015	IARI, New Delhi	Bhoopendra Singh
7.	HRD programme for scientists of Home Science, Animal Science and Fisheries in KVKs of Odisha	6 to 8 Feb 2015	OUAT, Bhubaneswar	RK Mohanta
8.	Agrobiodiversity Conservation and Sustainable Livelihoods	24 to 28 Feb 2015	MSSRF, Jeypore Centre, Koraput	JL Katara and N Umakanta

Orientation Training

S.N.	Participant	Period	Venue
1.	M K Yadav and S K Gritlahre	8th April to 7th May 2014	NRRI, Cuttack
2.	Aravindan S	15th April to 14th May 2014	

In-Charge and members of different cells

Research Advisory Committee

Prof. VL Chopra, Ex-Secretary, DARE & Director Genreal, ICAR, 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, Internal Institute of Biotechnology & Toxicology, Chennai, Member
Dr. (Mrs) K Srinath, Emeritus Scientist, Chennai, Member
Dr. T Mohapatra, Director, NRRI, Cuttack, Member
Assistant Director General (FFC), ICAR, NewDelhi, Member
Shri K Rout, Ex-MLA, Kendrapara, Odisha, Member
Shri UK Parida, Kendrapara, Odisha, Member
Dr. JN Reddy, Principal Scientist, NRRI, Cuttack, Member Secretary

Institute Management Committee

Dr. T Mohapatra, Director, NRRI, Chairman
Director of Agrilculture & Food Production, Govt. of Odisha, Member
Director of Agriculture, Jharkhand, Ranchi, Member
Dr. PC Das, Dean of Research, OUAT, Bhubaneswar, Member
Dr. (Ms) N Sarala, Principal Scientist, Directorate of Rice Research, Hyderabad, Member
Dr. S Dixit, Principal Scientist, National Research Institute for Dryland Agriculture, Hyderabad, Member
Dr. SG Sharma, Head,NRRI,Cuttack, Member
Dr. RP Dua, ADG(FC), ICAR,New Delhi, Member
Finance & Accounts Officer, CIFA, Bhubaneswar, Member
SAO, NRRI, Cuttack, Member Secreatary
Shri K Rout, Ex-MLA, Kendrapara, Odisha, Member
Shri U K Parida, Kendrapara, Odisha, Member

Institute Technology Management Committee (ITMC)

Dr. T Mohapatra, Director, NRRI, 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)

Dr. T Mohapatra, Director, NRRI, Chairman
Dr. ON Singh, Member
Dr. AK Nayak, Member
Dr. (Mrs) A Poonam, Member
Shri BK Sinha, Member
Shri SR Khuntia, Member
Shri DK Mohanty, Secretary (Official side)
Shri N K Swain, Member
Shri S K Sahu, Member
Shri D R Sahoo, Member
Shri K C Bhoi, Member
Shri P Moharana, Member & Secretary (Staff Side)
Shri B K Behera, Member
Shri D Das, Member
Shri P Bhoi, Member

Central Public Information Officer

Shri B K Sahoo

PME Cell

Dr. (Mrs) M Jena
Dr. TK Dangar
Shri SSC Patnaik
Dr. JN Reddy
Dr. AK Nayak
Dr. GAK Kumar
Dr. (Mrs) M K Kar
Dr. NN Jambhulkar
Shri SK Sinha
Dr. R Chandra
Shri J Sethi
Shri M Nayak

Women Cell

Dr. (Mrs) M Jena
Dr. (Mrs) S Samantaray
Dr. (Mrs) M K Kar
Dr. (Mrs) S Mohanty
Ms. S Sahu
Mrs. N Biswal
Mrs. S Biswal
Dr. (Ms) J Pattanaik
Dr. (Mrs) A Poonam

Institute Grievance Cell

Dr. T Mohapatra, Director, NRRI, Chairman
Dr. ON Singh
Shri BK Sinha
Shri SR Khuntia
Dr. AK Mukherjee
Dr. PK Sahu
Shri RK Behera
Shri B Khatua
Shri NC Parija

Institutional Bio-Safety Committee

Dr. ON Singh
Dr. MJ Baig, Member, Secretary
Dr. R Srinivasan, Professor and Project Director, NRCPB, IARI, New Delhi
Dr. GR Raut, Head, Department of Agri-Biotechnology, OUAT, Bhubaneswar
Dr. J Dandapat, Head, Department of Biotechnology, Utkal University, Vanivihar, Bhubaneswar
Dr. PK Mohapatra, Head, Biotechnology, Ravenshaw University, Cuttack
Dr. SG Sharma
Dr. (Mrs) M Jena
Dr. L Behera
Dr. N Das

Personnel

Dr. Trilochan Mohapatra ....Director

Staff Strength of Scientists as on 31.03.2015

Crop Improvement Division

Dr. O.N. Singh..Pr. Scientist & Head
Dr. J.N. Reddy ....Pr. Scientist
Dr. B.C. Patra ....Pr. Scientist
Dr. Sarat Ku.Pradhan ....Pr. Scientist
Dr. (Mrs.) Meera Kumari Kar..........................Pr. Scientist
Dr. Lambodar Behera ....Pr. Scientist
Dr. (Mrs.) S. Samantaray.................................Pr. Scientist
Dr. Hatanath Subudhi ....Sr. Scientist
Dr. Lotan Kumar Bose......................................Sr. Scientist
Dr. K.Chattopadhyay ....Sr. Scientist
Dr. Sushant Kumar.Dash.................................Sr. Scientist
Dr. A. Anandan ....Sr. Scientist
Dr. R. Raja ....Sr. Scientist
Sri R.K. Sahu ....Scientist (S.G)
Sri S.S.C. Patanaik ....Scientist (S.G)
Sri B.C. Marndi ....Scientist (S.G.)
Shri J. Meher ....Scientist (SS)
Sri Jawahar Lal Katara ....Scientist
Dr. Ramlakhan Verma ....Scientist
Sri Soham Ray ....Scientist
Dr. (Mrs.) P. Sanghamitra ....Scientist
Sri N. Umakanta..Scientist
Sri Surendra Kumar Ghritlahre ....Scientist

Crop Production Division

Dr. A.K.Nayak ....Pr. Scientist & Head
Dr. P.C.Mohapatra..Pr.Scientist
Sri S.P.Patel ....Pr.Scientist
Dr. T.K.Dangar ....Pr.Scientist
Dr. P.K.Nayak ....Pr.Scientist
Dr. Maharani Din..Pr.Scientist
Dr. Amal Ghosh ....Pr.Scientist
Dr. Sanjoy Saha ....Pr.Scientist
Dr. P.Bhattacharyya..Sr.Scientist
Dr. (Mrs.)Annie Poonam ....Sr.Scientist
Dr. R.Raja ....Sr.Scientist
Dr. B.B.Panda ....Sr.Scientist
Dr. Rahul Tripathi...Scientist
Dr. (Mrs.)Sangita Mohanty ....Scientist
Dr. Mohammad Shahid ....Scientist
Sri Anjani Kumar ....Scientist
Sri Upendra Kumar ....Scientist
Sri Banwari Lal ....Scientist
Dr. (Mrs.)Sushmita Munda ....Scientist
Mrs. Priyanka Gautam ....Scientist

Crop Protection Division

Dr. (Mrs.) M.Jena......................................Pr. Scientist & Head
Dr. (Mrs) Urmila Dhua ....Pr.Scientist
Dr. P.C.Rath ....Pr.Scientist
Dr. S.D.Mohapatra ....Sr.Scientist
Dr. A.K.Mukherjee..Sr.Scientist
Dr. Srikanta Lenka ....Sr.Scientist
Dr. Manas Kumar Bag.....................................Sr.Scientist
Dr. Totan Adak..Scientist
Sri Berliner J ....Scientist
Sri Somnath Suresh Pokhare ....Scientist
Sri Manoj Kumar Yadav ....Scientist
Sri Aravindan S. ....Scientist

Crop Physiology and Biochemistry Division

Dr. S.G.Sharma ....Pr. Scientist & Head
Dr. R.K.Sarkar...Pr.Scientist
Dr. (Mrs) P.Swain...Pr.Scientist
Dr. M.J.Baig...Pr.Scientist
Dr. S.P.Singh ....Sr.Scientist
Sri Torit Baran Bagchi ....Scientist

Social Science

Dr. B.N.Sadangi.......................................Pr. Scientist & Head
Dr. P.Samal ....Pr.Scientist
Dr. N.C.Rath ....Pr.Scientist
Dr. G.A.K.Kumar ....Pr.Scientist
Dr. S.K.Mishra ....Sr.Scientist
Dr. (Mrs) Lipi Das ....Sr.Scientist
Dr. Biswajit Mondal...Sr.Scientist
Sri Nitiprasad Jambhulkar...............................Scientist

NRRI Regional Station, Hazaribag, Jharkhand

Dr. M.Variar ....Pr.Scientist & I/c O.I.C.
Dr. D.Maiti ....Pr.Scientist
Dr. N.P.Mandal ....Pr.Scientist
Dr. C.V.Singh..Sr. Scientist
Dr. Yogesh Kumar ....Sr.Scientist
Sri Anantha M.S. ....Scientist

NRRI Regional Station, Gerua, Assam

Dr.Khem Bahadur Pun........................Pr.Scientist & O.I.C.
Dr.Kanchan Saikia ....Sr.Scientist
Dr.Teekam Singh ....Sr.Scientist
Sri B.S.Satapathy ....Scientist

Krishi Vigyan Kendra, Santhapur, Cuttack

Dr. Shiv Mangal Prasad ....Sr.Scientist

Krishi Vigyan Kendra, Jainagar, Koderma, Jharkhand

Dr. V.K. Singh..............................Programme Coordinator

Staff Strength of Technical Staff as on 31.03.2015

Category-I

Sri Ajaya Kumar Naik...........Technician (Field Asst.)
Sri Alok Kumar Panda..........Technician (Extension Asst.)
Sri Keshab Chandra Das.......Technician (Machine Operator)
Sri A.C.Nayak ....Technician (Field Asst.)
Sri Bhagyadhar Pradhan ....Technician (Farm Mechanic)
Sri P. K. 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 Kumar Tripathy Sr.Technician (Field Asst.)
Sri Surendra Biswal ....Sr.Technician (Field Asst.)
Sri Pradeep Kumar Parida ...Sr.Technician (Driver)
Sri Debasis Parida.................Sr.Technician (Tractor Driver)
Sri Ajaya Kumar Nayak ....Sr.Technician (Pharmacist)
Sri Jogeswar Bhoi ....Technical Asst. (Field Asst.)
Sri A. C. Moharana.................Technical Asst. (Field Asst.)
Sri Brahmananda Swain ....Technical Asst. (Field Asst.)
Sri S.K. Mohapatra ....Technical Asst. (Field Asst.)
Sri Mansingh Soren ....Technical Asst. (Field Asst.)
Sri Srinibas Panda ....Technical Asst. (Electrician)
Sri Nakula Barik ....Technical Asst. (Field Asst.)
Sri Bhakta Charan Behera ......Technical Asst. (Field Asst.)
Sri Parimal Behera..................Technical Asst. (Field Asst.)
Sri Gauranga Charan Sahu....Technical Asst. (Mechanic)
Sri Kailash Ch. Mallick ....Technical Asst. (Field Asst.)
Sri Charan Naik ....Sr.Technical Asst. (Field Asst.)
Sri Meghanada Rout ....Sr.Technical Asst. (Mechanic)
Mrs. Chintamani Majhi.........Sr.Technical Asst. (Field Asst.)
Sri Bansidhar Ojha................Sr.Technical Asst. (Welder)
Sri Kshirod Chandra Bhoi ....Sr.Technical Asst. (Field Asst.)
Sri Prasanta Kumar Jena.......Sr.Technical Asst. (Driver)
Sri A. K. Moharana...............Sr.Technical Asst. (Field Asst.)
Sri D. R. Sahoo ....Sr.Technical Asst. (Projectionist)
Sri Prahallad Moharana ....Sr.Technical Asst. (Field Asst.)
Sri Arun Kumar Parida ....Sr.Technical Asst. (Painter)
Sri Ramrai Jamunda ....Sr.Technical Asst. (Fitter)
Mrs. Nibedita Biswal ....Sr.Technical Asst. (Lab. Technician)
Sri Santosh Kumar Ojha ......Sr.Technical Asst. (Electrician)
Sri J. P. Behura.......................Sr.Technical Asst. (Supervisor-Civil)
Sri K. C. Palaur......................Sr.Technical Asst.(Driver)
Sri Arun Panda ....Sr.Technical Asst. (Library Asst.)
Sri A. K. Mishra ....Technical Officer (Field Asst.)
Sri K. K. Suman.....................Technical Officer (Field Asst.)
Sri S. K. Behura ....Technical Officer (Field Asst.)
Sri H. C. Satapathy ....Technical Officer (Field Asst.)
Sri Aparti Sahoo....................Technical Officer (Field Asst.)
Sri J.C.Hansda ....Technical Officer (Field Asst.)
Sk. Abdul Samad ....Technical Officer (Field Asst.)
Sri R. S. Jamuda ....Technical Officer (Field Asst.)
Sri Srikrishna Pradhan..........Technical Officer (Field Asst.)
Sri M. N. Mallick...................Technical Officer (Field Asst.)
Sri K. C. Bhoi ....Technical Officer (Blacksmith)
Sri Bhagaban Behera ....Technical Officer (Photography)

Category-II

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 Asst. (Farm Asst.)
Sri Prempal Kumar................Sr.Technical Asst. (Farm Asst.)
Sri J. Sai Anand ....Sr.Technical Asst. (Farm Asst.)
Sri P. L. Dehury......................Sr.Technical Asst. (Farm Asst.)
Sri Manoj Kumar Nayak......Sr.Technical Asst. (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. Ramesh Chandra ....Sr.Technical Officer (Technical)
Dr. Pradeep Kumar Sahoo ...Asst. Chief Technical Officer (Fishery)
Sri A.V.G. Sharma ....Asst. Chief Technical Officer (Mechanic)
Sri Prakash Kar ....Asst. Chief Technical Officer (Photography)

Sri P. Jana ....Asst. Chief Technical Officer (Rice Production Training)

Category-III

Sri K. K. Swain ....Chief Technical Officer (Mechanical)

NRRI Regional Station, Hazaribag, Jharkhand

Category-I

Sri Ugan Saw ....Technical Asst. (Driver)
Sri Sawan Oran ....Sr.Technical Asst. (Field Asst.)
Sri A. N. Singh ....Technical Officer (Field Asst.)
Sri Ranjit Tirky ....Technical Officer (Field Asst.)
Sri Jitendra Prasad ....Technician (Extension Asst.)

Category-II

Sri R. P. Sah ....Technical Officer (Mechanic)
Sri D. Singh ....Technical Officer (Electrical)

NRRI Regional Station, Gerua, Assam

Category-I

Sri Haladhar Thakuria ....Technical Officer (Field Asst.)
Sri Bhupen Kalita..................Technician (Field Asst.)

Category-II

Sri Bibhash Medhi ....Sr.Technical Asst. (Farm Asst.)

KVK, Santhapur, Cuttack

Category-I

Sri Makardhar Behera...........T-3 (Tractor Driver)
Sri Arabinda Bisoi ....T-1 (Driver)

Category-II

Mrs. Sujata Sethy ....T (7-8), SMS (Home Sci.)
Sri Dillip Ranjan Sarangi ......T-6 SMS (Soil Science)
Sri Tusar Ranjan Sahoo ....T-6 SMS (Horticulture)
Dr.Manish Chourasia...........T-6 SMS (Plant Protection)
Dr.Ranjan Kumar Mahanta..T-6 SMS (Animal Science)

KVK, Jainagar, Koderma, Jharkhand

Category-I

Sri Sanjay Kumar ....T-2 (Driver Vehicle)

Category-II

Sri Rupesh Ranjan ....T-4, Trg. Asst. (A.F)
Sri Manish Kumar ....T-4, Trg. Asst. (Agril.)

Category-III

Mrs. Chanchila Kumari ....T (7-8), STA (H.S.)
Dr. Shudhanshu Sekhar........T (7-8), STA (V. Sc.)
Sri Bhoopendra Singh ....T-6, SMS (Horticulture)

Staff Strength of Administrative Staff as on 31.03.2015

Sri S.R.Khuntia ....Chief Finance & Accounts Officer
Sri B.K.Sinha ....Senior Administrative Officer
Sri K.C.Das ....Administrative Officer
Sri S.K.Mathur........................Administrative Officer
Sri Sunil Kumar Das.............Finance & Accounts Officer
Sri Basanta Kumar Sahoo .....Asst. Administrative Officer
Sri Bahudi Bhoi ....Asst. Administrative Officer
Sri B.K.Moharana ....Asst. Administrative Officer
Sri Sunil Kumar Sahoo..........Asst. Administrative Officer
Sri D.K.Mohanty ....Asst. Administrative Officer
Sri S.K.Jena ....Asst. Administrative Officer
Sri S.K.Ram.............................Asst. Administrative Officer
Sri Nabakishore Das.............Security Officer
Sri Narayan Mahavoi...........Private Secretary
Sri G.K.Sahoo ....Personal Assistant
Sri N.N.Mohanty ....Personal Assistant
Sri Janardan Nayak ....Personal Assistant
Sri Jagabandhu Sethi ....Personal Assistant
Sri Trilochan Ram.................Personal Assistant
Sri A.Kullu ....Personal Assistant
Smt. Belarani Mahana ....Personal Assistant
Sri Daniel Khuntia ....Personal Assistant
Smt. Nirmala Jena.................Personal Assistant
Sri Manas Ballav Swain ....Personal Assistant
Smt. Snehaprava Sahoo ....Personal Assistant
Miss Sabita Sahoo ....Personal Assistant
Sri B.C.Tudu ....Assistant
Sri Faguram Soren ....Assistant
Sri N.K.Swain ....Assistant
Sri C.P.Murmu ....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 Vishal Kumar ....Assistant
Sri Sharbadwip Sen ....Assistant
Smt. Gourimani Dei ....Assistant
Sri Manoranjan Swain...........Stenographer Gr.III
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.

NRRI Regional Station, Hazaribag, Jharkhand

Sri Sudhakar Das ....Asst. Administrative Officer
Sri R.Paswan..........................Personal Assistant
Sri Sanjeev Kumar ....Assistant
Sri C.R.Dangi.........................U.D.C.
Sri Arabinda Kumar Das......L.D.C.
Sri Satish Kumar Pandey......L.D.C.

NRRI Regional Station, Gerua, Assam

Sri N.C.Parija.........................Asst. Administrative Officer
Sri Rama Chandra Pradhan .Assistant
Smt. Jali Das ..........................U.D.C.

KVK, Santhapur, Cuttack

Sri Bibhuti Bhushan Polai ....Stenographer Grade III

Staff Strength of Skilled Support Staff as on 31.03.2015

NRRI, Cuttack

Sri Sahadev Naik ....Skilled Support Staff
Sri Sankhai Soren..................Skilled Support Staff
Sri Ratnakar Das ....Skilled Support Staff
Sri Sundara Marandi............Skilled Support Staff
Sri B.K.Behera ....Skilled Support Staff
Smt. Gurubari Dei ....Skilled Support Staff
Sri Pravakar Sahoo ....Skilled Support Staff
Sri Purna Chandra Sahu.......Skilled Support Staff
Sri Dambarudhar Das ....Skilled Support Staff
Sri Madan Mohan Nayak.....Skilled Support Staff
Sri Fakra Charan Sahu ....Skilled Support Staff
Sri Jogendra Biswal ....Skilled Support Staff
Smt. Snehalata Biswal ....Skilled Support Staff
Sri Sachitananda Das ....Skilled Support Staff
Smt. Namasi Singh ....Skilled Support Staff
Sri Lawa Murmu ....Skilled Support Staff
Sri Sudhakar Parida ....Skilled Support Staff
Sri S.C.Mohanty....................Skilled Support Staff
Sri Prafulla Bhoi....................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 Jagabandhu Bhoi.............Skilled Support Staff
Sri Pravakar Bhoi..................Skilled Support Staff
Sri Anand Naik ....Skilled Support Staff
Sri Nanda Sahoo ....Skilled Support Staff
Sri Pravakar Bhoi (Nemato.)Skilled Support Staff
Sri Duryodhan Naik.............Skilled Support Staff
Sri Ganesh Chandra Sahoo ..Skilled Support Staff
Sri Bichitrananda Khatua .....Skilled Support Staff
Sri Rabindra Dalai ....Skilled Support Staff

NRRI Regional Station, Hazaribag, Jharkhand

Sri Rameswar Ram ....Skilled Support Staff
Sri Liladhar Mahato ....Skilled Support Staff
Smt. Sita Devi ....Skilled Support Staff

NRRI Regional Station, Gerua, Assam

Sri Manoranjan Das..............Skilled Support Staff

KVK, Santhapur, Cuttack

Sri Rama Pradhan.................Skilled Support Staff

KVK, Jainagar, Koderma, Jharkhand

Sri Mukesh Ram ....Skilled Support Staff

Others (Canteen staff), NRRI, Cuttack

Sri Arabinda Jena..................Manager Grade II
Sri Meru Sahu ....Bearer
Sri Markanda Nayak............Bearer
Sri Madhaba Pradhan ....Bearer
Sri Nityananda Naik ....Wash Boy

Financial Statement for 2014-15

(As on 31 March 2015)

Plan 2014-15 *(Rs. in Lakh)*

Head of Account	RE	Expenditure
TA	25.00	25.00
HRD	4.69	4.69
Contingency	329.31	329.31
Capital	150.00	150.00
Total	**509.00**	**509.00**

Non-Plan 2014-15 *(Rs. in Lakh)*

Head of Account	RE	Expenditure
Establishment Charges	2230.00	2230.00
Wages	160.00	160.00
OTA	0.50	0.50
TA	10.00	10.00
Pension	3000.00	2818.56
Repair & Maintenance		
Equipment	18.00	18.00
Office Building	65.00	65.00
Residential Building	20.00	20.00
Minor Work	8.00	8.00
Contingency	402.25	402.25
Capital		
Equipment	3.00	3.00
Library Books	2.00	2.00
Furniture	6.00	6.00
Total	**5924.75**	**5743.31**

Work Plan 2014-15

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 and N Umakanta

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 and SK Ghritlahre

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 and Soham Ray

Hybrid rice for different ecologies

Principal Investigator: ON Singh

Co- Principal Investigator (Co-PI): RL Verma, JL Katara, S Samantaray, RK Sahu, BC Patra, MS Ananta, NP Mandal, D Maiti, SP Singh, TB Bagchi and AK Mukherjee

Development of high yielding genotypes for rainfed shallow lowlands

Principal Investigator : SK Pradhan

Co- Principal Investigator (Co-PI): ON Singh, SSC Patanaik, JN Reddy, SK Dash, MK Kar, L Behera, S Samantray, P Swain, J Meher, AK Mukherjee and A Anandan

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 and N Umakanta

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 and A Anandan

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 and Soham Ray

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 and NN Jambhulkar

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 and SK Ghritlahre

Improvement of rice through in vitro and transgenic approaches

Principal Investigator : S Samantaray

Co- Principal Investigator (Co-PI): LK Bose and RL Verma

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 and N Umakanta

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, M Shahid, P Bhattacharya, R Tripathi, A Kumar, R Raja, BB Panda, A Ghosh, Priyanka Gautam, Banwari Lal, S Munda and SS Pokhare

Agro-management for enhancing water productivity and rice productivity under water shortage condition

Principal Investigator : A Ghosh

Co- Principal Investigator (Co-PI): ON Singh, P Swain, CV Singh, BB Panda, A Poonam, R Tripathi, J Berliner and Priyanka Gautam

Crop weather relationship studies in rice for development of adaptation strategies under changing climatic scenario

Principal Investigator : R Raja

Co- Principal Investigator (Co-PI): BB Panda, AK Nayak, P Bhattacharyya, MJ Baig, R Tripathi, Priyanka Gautam, A Kumar and BS Satapathy

Development of sustainable production technologies for rice based cropping systems

Principal Investigator : BB Panda

Co- Principal Investigator (Co-PI): R Raja, AK Nayak, A Gosh, Teekam Singh, B Lal, R Tripathi, SD Mohapatra, M Shahid, A Kumar and SS Pokhare

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 : P Bhattacharyya

Co- Principal Investigator (Co-PI): AK Nayak, R Tripathi, BB Panda, R Raja, S Mohanty, M Shahid, A Kumar, S Saha, A Ghosh, S Munda and B Lal

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

Principal Investigator : A Poonam

Co- Principal Investigator (Co-PI): M Shahid, M Jena, PK Nayak, GAK Kumar, NN Jambhulkar, SM Prasad, SC Giri (RC of CARI), M Nedunchezhian (RC of CTCRI) and HS Singh (CHES of IIHR)

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 and S Munda

Management of problem soils for enhancing the productivity of rice

Principal Investigator : R Tripathi

Co- Principal Investigator (Co-PI): M Shahid, AK Nayak, A Kumar, S Mohanty and R Raja

Bio-prospecting and use of microbial resources for soil, pest and residue management

Principal Investigator : U Kumar

Co- Principal Investigator (Co-PI): TK Dangar

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 and MK Bag

Rice endophyte interaction with pathogens and pests in relation to environment

Principal Investigator : U Dhua

Co- Principal Investigator (Co-PI): M Jena, AK Mukherjee and MK Bag

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 and SK Pradhan

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 and T Adak

Formulation, validation and refinement of IPM modules in rice

Principal Investigator **:** PC Rath

Co- Principal Investigator (Co-PI): M Jena, SD Mohapatra, J Berliner, SS Pokhare, U Dhua, P Samal, S Saha, S Lenka, TK Dangar and T Adak

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 Marndi, A Ghosh, U Kumar, M Shahid, Totan Adak and P Sanghamitra

Phenomics of rice for tolerance to multiple abiotic stresses

Principal Investigator **:** RK Sarkar

Co- Principal Investigator (Co-PI): P Swain, MJ Baig, SP Singh and TB Bagchi

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 and JL Katara

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, AK Mukherjee, 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 and SK Mishra

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 and M Din

Ongoing Externally Aided Projects (EAPs)

Number	Title of the Project	Principal Investigator	Source of Funding
EAP 12	Multilocation evaluation of rice germplasm	HN Subudhi	NBPGR
EAP 15	Multilocation evaluation of rice germplasm	AK Mukherjee	NBPGR
EAP 27	Revolving fund scheme for seed production of upland rice varieties at CRURRS, Hazaribagh	NP Mandal	AP Cess Fund
EAP 36	National Seed Project (Crops)	RK Sahu U Dhua	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 99	Network Project on Transgenics in Crops	S Samantaray	ICAR
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 – Hazaribag Centre	M Variar N Mandal Y Kumar MS Anantha	ICAR - IRRI (BMGF)
EAP 126	Stress tolerant rice for poor farmers of Africa and South Asia-Drought prone rain-fed rice areas of South Asia-NRRI Centre	ON Singh P Swain	ICAR - IRRI (BMGF)
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 (BMGF)
EAP 128	Stress tolerant rice for poor farmers of Africa and South Asia – Salt affected areas (STRASA)	B Marndi A Nayak A Poonam SP Singh K Chattapadhayay	IRRI (BMZ) – ICAR
EAP 130	All India Network Project on Soil Biodiversity - Biofertilizers	D Maiti	ICAR
EAP 134	Development and maintenance of rice knowledge management Portal	GAK Kumar	NAIP
EAP 135	Bioprospecting of genes and allele mining for abiotic stress tolerance	GJN Rao	NAIP
EAP 137	Establishment of National Rice Resources Database	BC Patra	DBT
EAP139	AICRP on energy in agriculture and agro-based industries	SP Patel	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 145	Identification and functional analysis of genes related to yield and biotic stresses	M Jena L Behera RK Sahu	DBT
EAP 148	Strategies to enhance adaptive capacity to climate change in vulnerable regions	BB Panda S Mohanty R Raja	NAIP
EAP 154	Development of new plant type varieties with higher yield and resistance to major pest and diseases	SK Pradhan	AICRP
EAP 151	Hybrid Rice Research network	ON Singh RL Verma JL Katara	AICRP
EAP 153	Development of molecular markers linked to genes for resistance to Brown Plant hopper	RK Sahu M Jena L Behera	AICRP
EAP 154	Development of new plant type varieties with higher yield and resistance to major pest and diseases	SK Pradhan	AICRP
EAP 155	From QTL to Variety: Marker Assisted Breeding of Abiotic Stress Tolerant Rice Varieties with Major QTLs for Drought, Submergence and Salt Tolerance	T Mohapatra NP Mandal JN Reddy ON Singh DP Singh RK Sarkar P Swain BC Marndi	DBT, GOI
EAP 156	Marker–assisted backcrossing for transfer of durable bacterial blight resistance into elite deepwater rice varieties	SK Pradhan L Behera SK Das	DBT, GOI
EAP 158	National Initiative of Climate Resilient Agriculture (NICRA)	RK Sarkar ON Singh P Swain P Bhattacharya K Chattapadhyay S Mohanty	ICAR
EAP 159	Diversity of osmotolerant and biochemical strains of endophytic microorganisms of rice	Supriya Sahu (TK Dangar)	DST
EAP 161	Monitoring of the new initiative of "Bringing Green Revolution to Eastern India (BGREI) under the Rashtriya Krishi Vikas Yojana"	T Mohapatra A Ghosh	DAC, GOI
EAP 162	Stress tolerant rice for poor farmers of Africa and South Asia – Sub grant, Seed (CRURRS, Hazaribagh)	M Variar NP Mandal VK Singh Y kumar	IRRI -ICAR (STRASA)
EAP 163	Stress tolerant rice for poor farmers of Africa and South Asia – Sub grant, Seed (NRRI, Cuttack)	RK Sahu	IRRI -ICAR (STRASA)
EAP 164	Technology dissemination and adoption of water saving rice production (Aerobic rice and AWD system) to improve rice farming rural livelihood in water shortage regions	A Ghosh PC Mohapatra ON Singh P Samal	DST

EAP 165	Phenomics of moisture deficit and low temperature stress tolerance in rice	SK Dash ON Singh P Swain L Behera SK Pradhan LK Bose	ICAR-NFBSFARA
EAP 169	Genetic Diversity of farmers' rice varieties collected from different parts of the State of Odisha, India	L Behera U Dhua	PPV&FRA
EAP173	Crop Pest Surveillance and Advisory Project (CROPSAP-Paddy)	SS Pokhare	Govt. of Maharashtra
EAP 174	Ploidy regulated expression of genes involved in mega-gametophyte development, apomixis and its component traits	MJ Baig P Swain	DST
EAP 175	Improvement of locally adapted rice cultivars of North East Hill region against BLB through marker assisted backcrossing	JN Reddy MK Kar	DBT, GOI
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 179	Evaluation of the applicability of a dominant nuclear male sterility system in rice for hybrid seed production	ON Singh SK Sen (IIT, KGP)	NFBSFARA
EAP 181	Hastening the transfer of tolerance to drought from O. nivara into cultivated rice through anther culture approach	LK Bose	SERB (DST)
EAP 182	Cereal Systems Initiative for South Asia (CSISA) Phase II (Development of crop and nutrient management practices in rice for Odisha state)	AK Nayak	ICAR-IRRI
EAP 183	Functional genomics of osmotolerant microbes of coastal saline rice ecosystem	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	IRRI -ICAR (STRASA)
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	P Bhattacharya	ICAR
EAP 188	Cluster demonstration of stress tolerant rice varieties in eastern India with emphasis on rice-pulse cropping system in tribal belt	M Variar	ICAR
EAP 189	Front Line Demonstrations	NC Rath	DAC – DRR (NFSM)

EAP 190	Multi location evaluation of rice germplasm	M Variar	DRR
EAP 191	NRRI-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	NRRI/NCIPM
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 Goutam B Lal Md. Shahid R Raja	IRRI -ICAR (STRASA)
EAP 194	Simultaneous induction of growth promotion and induced resistance against foliar pathogens of rice using Trichoderma base biofungicide and studies on mexchanism of induction of resistance	Shanti Prava Behera (AK Mukherjee)	DST Inspire
EAP 195	Artificial induction of chlamydospore in Trichoderma sp.and identification of genes expressed during the process	HK Swain (AK Mukherjee)	DST Inspire
EAP 196	Development and dissemination of climate resilient rice varieties for water short areas of South Asia and Southeast Asia TA-8441	ON Singh A Ghosh P Samal A Anandan	ADB-IRRI
EAP 197	Consortia research platform (CRP) on bifortification	SG Sharma SK Pradhan S Samantray L Behera K Chattopadhyay SSC Patnaik TB Bagchi	ICAR Plan
EAP 198	Incentivizing Research in Agriculture: Study of rice yield under low light intensity using genomic approaches	L Behera 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	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	L Behera M Kar AK Mukherjee U Dhua NP Mandal	ICAR Plan


PROGRAMME : SOIL ORGANIC CARBON DYNAMICS VIS-A-VIS ANTICIPATORY CLIMATIC CHANGES AND CROP ADAPTATION STRATEGIES
PROJECT No : EAP 115. NAIP. COMPONENT - 4(2031)
TITLE : N-FERTILIZATION IMPACT ON SOIL-C DYNAMICS IN A RICE-RICE CROPPING SYSTEM
PI : P. BHATTACHARYYA
YEAR OF STUDY : 2nd YEAR
TREATMENTS
VARIETY : NAVEEN
DESIGN : RBD.
REPLICATION - 3
D/S 11 - 6 - 09
D/P 14-7-09

Results-Framework Document (RFD) 2013-14

Section 1
Vision, Mission, Objectives and Functions

Vision

Food and nutritional security through sustainable rice production.

Mission

To develop and disseminate eco-friendly rice production technologies for enhancing productivity and profitability of rice cultivation in all agro-climatic situations.

Objectives

1. Genetic enhancement and development of improved cultivars
2. Development and identification of appropriate crop production and protection technologies
3. Technology dissemination and capacity building

Mandate of the Institute

- 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, socioeconomic and institutional constraints to rice production under different agro-ecological conditions and in farmers' situations and develop remedial measures for their amelioration.
- Maintain database on rice ecology, ecosystems, farming situations and comprehensive rice statistics for the country as a whole in relation to their potential productivity and profitability.
- Impart training to rice research workers, trainers and subject matter/extension specialists on improved rice production and rice-based cropping and farming systems.
- Collect and maintain information on all aspects of rice and rice-based cropping and farming systems in the country.

Section 2: *Inter-se* priorities among key objectives, Success Indicators and Targets

Sl. No.	Objectives	Weight	Actions	Success Indicators	Unit	Weight	Target / Criteria Value				
							100%	90%	80%	70%	60%
1	[1] Genetic enhancement and development of improved cultivars	68	[1.1] Evaluation of genetic material	[1.1.1] Breeding and germplasm lines evaluated	Number	15	600	550	500	450	400
				[1.1.2] Entries tested in AICRIP trials for multi-location testing	Number	5		450	400	350	300
				[1.1.3] Lines identified for unique traits	Number	8	5	4	3	2	1
			[1.2] Development of improved cultivars	[1.2.1] Entries contributed for AICRIP multi-location trial	Number	10	100	90	80	70	60
				[1.2.2] Varieties identified for release	Number	10	3	2	1	0	0
			[1.3] Seed production programme	[1.3.1] Breeder seed produced	Weight MT	15	50#	45	40	35	30
				[1.3.2] Truthfully labeled seed produced	Weight MT	5	60	55	50	45	40
2	Development and identification of appropriate crop production & protection technologies	12	[2.1] Development and testing of new technologies	[2.1.1] New technologies identified & tested	Number	12	10	9	8	7	6
3	Technology dissemination and capacity building	9	[3.1] Demonstrations conducted	[3.1.1] Front line demonstrations conducted	Number	4	20	18	16	14	12
			[3.2] Farmers/ Extension officials training programmes organized	[3.2.1] Trainings organized	Number	5	10†	9	8	7	6

	Efficient functioning of RFD system	3	Timely submission of Draft RFD (2013-14) for approval	On-time submission	Date	2	May. 15 2013	May16 2013	May. 17 2013	May. 20 2013	May. 21 2013
			Timely submission of results for RFD (2012-13)	On-time submission	Date	1	May 1 2013	May 2 2013	May 5 2013	May 6 2013	May 7 2013
	Administrative Reforms	4	Implement ISO 9001 as per the approved action plan	% implementation	%	2	100	95	90	85	80
			Prepare an action plan for innovation	On time submission	Date	2	July 30 2013	Aug.10 2013	Aug.20 2013	Aug.30 2013	Sept. 10 2013
	Improving internal efficiency/ responsiveness/ service delivery of Ministry/ Department	4	Implementation of Sevottam	Independent audit of implementation of citizen's charter	%	2	100	95	90	85	80
				Independent audit of implementation of public grievance redressal system	%	2	100	95	90	85	80

*As per the materials received from AICRIP
As per the DAC indent received
†As per sponsorship received

Section 3: Trend values of the Success Indicators

Sl. No.	Objectives	Actions	Success indicators	Unit	Actual value for FY 2011-2012	Actual value for FY 2012-2013	Target value for FY2013-2014	Projected values for FY 2014-2015	Projected values for FY 2015-2016
1	Genetic enhancement and development of improved cultivars	[1.1]Evaluation of genetic material	[1.1.1]Breeding and germplasm lines evaluated	Number	498	2470*	550	560	570
			[1.1.2]Entries tested in AICRIP trials for multi-location testing	Number	740	758	450	455	460
			[1.1.3]Lines identified for unique traits	Number	4	5	4	5	6
		[1.2]Development of improved cultivars	[1. 2.1]Entries contributed for AICRIP multi-location trial	Number	153	225	90	92	94
			[1.2.2]Varieties identified for release	Number	13	7	2	3	4
		[1.3]Seed production programme	[1.3.1]Breeder seed produced	Weight MT	30	45	45	47	50
			[1.3.2]Truthfully labelled seed produced	Weight MT	68	42.8	55	57	59
2	Development and identification of appropriate crop production & protection technologies	[2.1]Development and testing of new technologies	[2.1.1]New technologies identified & tested	Number	10	8	9	10	11
3	Technology dissemination and capacity building	[3.1]Demonstrations conducted	[3.1.1]Front line demonstrations conducted	Number	10	19	18	19	20
		[3.2]Farmers/ Extension officials training programmes organized	[3.2.1]Trainings organized	Number	6	9	9	10	11

	Efficient functioning of RFD system	Timely submission of Draft RFD (2013-14) for approval	On-time submission	Date			16-05-2013		
		Timely submission of results for RFD (2012-13)	On-time submission	Date			02-05-2013		
	Administrative Reforms	Implement ISO 9001 as per the approved action plan	% implementation	%			95		
		Prepare an action plan for innovation	On time submission	Date			10-08-2013		
	Improving internal efficiency/ responsiveness/ service delivery of Ministry/ Department	Implementation of Sevottam	Independent audit of implementation of citizen's charter	%			95		
			Independent audit of implementation of public grievance redressal system	%			95		

* Higher achievement due to evaluation of more number of germplasm under the project EAP 172 in collaboration with NBPGR and NICRA project

Section 4: Acronyms

Sl. No.	Acronym	Description
1	AICRIP	All India Coordinated Rice Improvement Project
2	DAC	Department of Agriculture and Cooperation
3	MT	Metric Tonne

Section 4: Description and Definition of Success Indicators and Proposed Measurement Methodology

Sl. No.	Success indicators	Description	Definition	Measurement	General comments
1	Breeding and germplasm lines evaluated	Germplasm which is source for improved varieties and newly developed breeding lines to be evaluated	Germplasm is a collection of genetic resources for rice	Number of germplasm and breeding lines evaluated	
2	Entries tested in AICRIP trials for multi-location testing	Breeding lines received from AICRIP are tested at the Institute	Breeding lines developed all over the country are tested through AICRIP for identification of promising entries	Number	No. of entries depends on materials received from AICRIP
3	Lines identified for unique traits	Lines with unique traits to be identified from the germplasm	Germplasm lines with very specific characteristics to be identified	Number	This will help in identification of lines useful for improving specific economic traits
4	Entries contributed for AICRIP multi-location trial	Breeding lines developed through various projects are nominated for different trials of AICRIP to know their performance over locations	Breeding lines nominated by the Institute for multi-location trials of AICRIP	Number	No. of entries will depend on performance in on-station trial
5	Varieties identified for release	Breeding lines tested along with checks in multi-location trials through All India Coordinated Research Projects and the best performing entries compared to checks are identified as new improved varieties for release	Best performing entries identified as a new variety for release	Number of such varieties identified	Targets for varieties identified given in Section 2 and their respective trend values in Section 3 may vary as the identification of varieties depend upon the availability of superior material with respect to yield, biotic and abiotic resistance/tolerance over the existing varieties

6	Breeder seed produced	Produce from nucleus and breeder seed is the starting point in seed chain of producing quality seeds for farmers	Breeder seed is the starting point in seed chain which is multiplied/converted in to foundation /certified seed	Quantity produced (MT)	Quantity may vary as per indent from DAC
7	Truthfully labelled seed produced	Truthfully labelled seed is produced at the Institute for supplying quality seeds of popular varieties to farmers	Truthfully labelled seed is the progeny of foundation, certified or labeled seed	Quantity produced (MT)	Quantity will depend on famers' demand for quality seed
8	New technologies identified & tested	New crop production & protection technologies for rice to be identified and tested to achieve profitable and higher rice production	Production technologies help in increasing production of rice, improving soil health and reducing cost of cultivation. Protection technologies help in economic control of diseases and insect-pests of rice	Number	
9	Front line demonstrations conducted	Front line demonstrations are conducted for technology testing in the farmers conditions	Frontline demonstration is the field demonstration conducted farmers field under the close supervision of scientists	Number	
10	Trainings organized	Capacity building activities related to rice knowledge and skill improvement/development programmes conducted for extension personnel and progressive farmers	Training is a process of acquisition of new skills, attitude and knowledge in the context of preparing for entry into a vocation or improving productivity in an organization or enterprise	Number	Number of trainings depends on sponsorship received

Section 5: Specific Performance Requirements from other Departments

Location Type	State	Organisation Type	Organisation Name	Relevant Success Indicator	What is your requirement from this organisation	Justification for this requirement	Please quantify your requirement from this Organisation	What happens if your requirement is not met.
Central and State Governments	States with AICRIP centres	ICAR, State Department	AICRIP and State Agricultural Departments	[1.2.2] Varieties identified for release	Multi-location testing of breeding lines	Co-ordinating multi location testing	No. of breeding lines tested	Less nos. of varieties will be identified for release
Central and State Governments	States indenting for breeder seed	Departments	DAC, State Agricultural Departments	[1.3.1] Breeder seed produced	Indent for quantity of breeder seed	Variety wise indent for breeder seed	Quantity of breeder seed produced as per the indent	Less quantity of breeder seed will be produced
Central Government		Departments	DAC	[3.1.1] Front line demonstrations conducted	Funding and indent	For conducting demonstrations	Funding as per the indent	Less nos. of demonstrations will be conducted
Central and State Governments	All rice growing states	Departments	DAC and other funding agencies	[3.2.1]Trainings organized	Funding and indent	For organizing trainings	Funding as per the indent	Less nos. of trainings will be organized

Section 6: Outcome/Impact of Organization

Sl. No.	Outcome/impact of organization	Jointly responsible for influencing this outcome/impact with the following department(s)/ministry(ies)	Success indicators	Unit	2011-12	2012-13	2013-14	2014-15	2015-16
1	Enhanced rice productivity	DAC, Ministry of Rural Development, State Agriculture Departments and NGOs	Increase in productivity	Percent	1.6	1.8	2.0	2.25	2.5

NRRI RFD 2013-14 Approved Annual Achievement

Annual (April 1, 2013 to March 31, 2014) Performance Evaluation Report in respect of RFD 2013-2014 of NRRI, Cuttack

Name of the Division : Crop Science
Name of the Institution : National Rice Research Institute, Cuttack – 753006
RFD Nodal Officer : Dr. (Mrs.) M. K. Kar

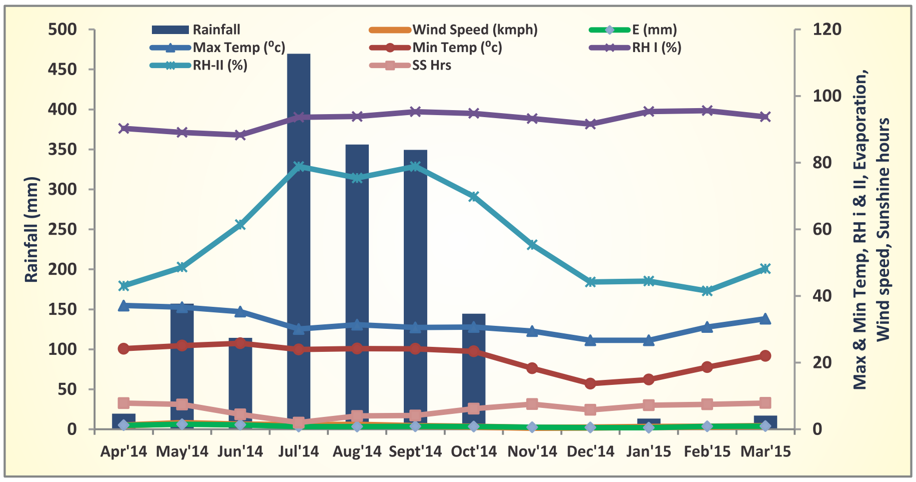
Sl. No.	Objective(s)	Weight	Action(s)	Success Indicator (s)	Unit	Weight	Target / Criteria Value					Achievements	Performance		Percent achievements against Target values of 90% Col.	Reasons for shortfalls or excessive achievements, if applicable
							Excellent 100%	Very Good 90%	Good80%	Fair 70%	Poor 60%		Raw Score	Weighted Score		
1	1] Genetic enhancement and development of improved cultivars	68	[1.1] Evaluation of genetic material	[1.1.1] Breeding and germplasm lines valuated	Number	15	600	550	500	450	400	873	100	15	158.7	
				[1.1.2] Entries tested in AICRIP trials for multi-location testing	Number	5	500	450	400	350	300	682	100	5	151.5	
				[1.1.3] Lines identified for unique traits	Number	8	5	4	3	2	1	6	100	8	150.0	
			[1.2] Development of improved cultivars	[1.2.1] Entries contributed for AICRIP multi-location trial	Number	10	100	90	80	70	60	118	100	10	131.1	
				[1.2.2] Varieties identified for release	Number	10	3	2	1	0	0	**7**	100	10	350.0	Due to identification of more no. of promising entries in AICRIP trials
			[1.3] Seed production programme	[1.3.1] Breeder seed produced	Wt MT	15	50	45	40	35	30	**60.3**	100	15	134.0	
				[1.3.2] Truthfully labeled seed produced	Wt MT	5	60	55	50	45	40	**70**	100	5	127.3	
2	Development and identification of appropriate crop production & protection techno logies	12	[2.1]Development and testing of new technologies	[2.1.1]New technologies identified & tested	Number	12	10	9	8	7	6	**10**	100	12	111.1	

3	Technology dissemination and capacity building	9	[3.1]Demonstrations conducted	[3.1.1]Front line demonstrations conducted	Number	4	20	18	16	14	12	30	100	4	166.7	
			[3.2]Farmers/ Extension officials training programmes organized	[3.2.1]Trainings organized	Number	5	10	9	8	7	6	18	100	5	200.0	Due to more no. of sponsorship received
	Efficient functioning of RFD system	3	Timely submission of Draft RFD (2013-14) for approval	On-time submission	Date	2	May 15 2013	May1 6 2013	May 17 2013	May 20 2013	May 21 2013	May 20 2013	70	1.4		
			Timely submission of results for RFD (2012-13)	On-time submission	Date	1	May 1 2013	May 2 2013	May 5 2013	May 6 2013	May 7 2013	May 6 2013	70	0.7		
	Administrative Reforms	4	Implement ISO 9001 as per the approved action plan	% implementation	%	2	100	95	90	85	80	**0**	0	**0**		
			Prepare an action plan for innovation	On time submission	Date	2	July 30 2013	Aug. 10 2013	Aug. 20 2013	Aug3 0 2013	Sept. 10 2013	July 26 2013	100	**2**		
	Improving internal efficiency/ responsiveness/ service delivery of Ministry/ Department	4	Implementation of Sevottam	Independent audit of implementation of citizen's charter	%	2	100	95	90	85	80	100	100	**2**		
				Independent audit of implementation of public grievance redressal system	%	2	100	95	90	85	80	100	100	**2**		

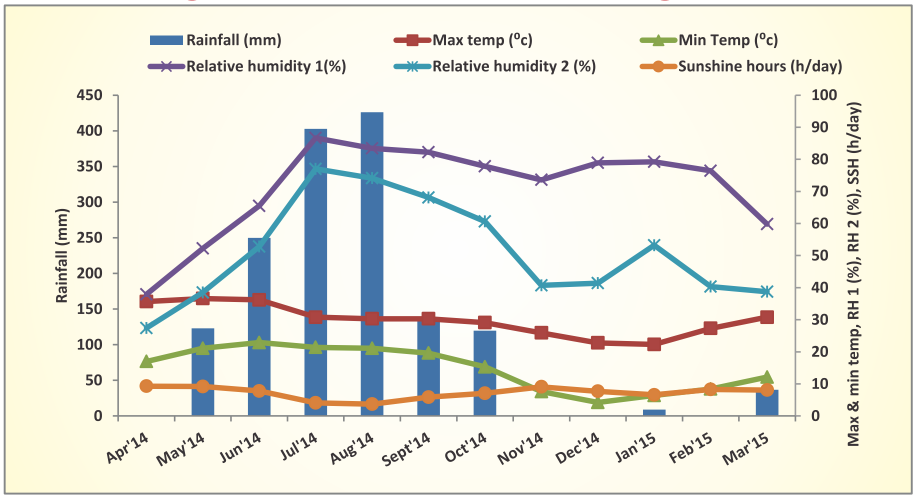
Total Composite Score: 97.1
Rating: Excellent

Weather

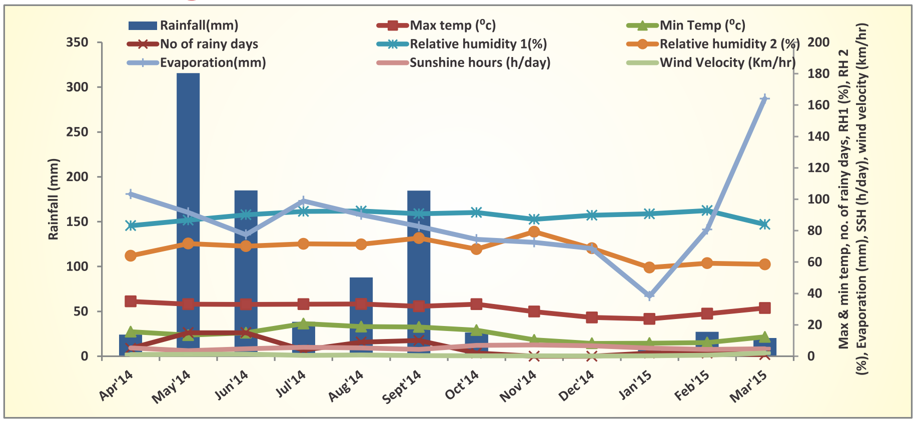
NRRI, Cuttack



NRRI Regional Station, Hazaribag



NRRI Regional Station, Gerua



Acronyms

AICRIP : All India Coordinated Rice Improvement Project
AMAAS : Application of Microorganisms in Agriculture and Allied Sectors
ASG : Aromatic-Short Grain
ASGON : Aromatic Short Grain Observation Nursery
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
BPH : Brown Planthopper
Bt : *Bacillus thuringiensis*
CMS : Cytoplasmic Male Sterile/Sterility
CRIDA : Central Research Institute for Dryland Agriculture, Hyderabad
CRIJAF : Central Research Institute for Jute and Allied Fibres, Barrackpore
NRRI : National Rice Research Institute, Cuttack
CRURRS : 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 Agricultural 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, Bhubaneswar
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
GWUE : Grain Water Use Efficiency
h : Hour
ha : Hectare
HI : Harvest Index
HRR : Head Rice Recovery
HYV : High-yielding variety
ICAR : Indian Council of Agricultural Research
IET : Initial Evaluation Trial
IFAD : International Fund for Agricultural Development
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
IRRI : International Rice Research Institute, Philippines
IVT : Initial Varietal Trial
Kg : Kilogram
KVK : Krishi Vigyan Kendra

L/l/ltr	:	Litre
LB	:	Long-bold
LCC	:	Leaf Colour Chart
LF	:	Leaf Folder
LS	:	Long-slender
LSI	:	Location Severity Index
MB	:	Medium Bold
MLT	:	Multilocation Trial
MS	:	Medium-Slender
NAAS	:	National Academy of Agricultural Sciences
NAIP	:	National Agricultural Innovation Project
NARES	:	National Agricultural Research and Ex-tension Research
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
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
WBPH	:	White-backed Plant Hopper
WCE	:	Weed Control Efficiency
WEH	:	White Ear Heads
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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